OUR IRON-CLAD SHIPS;

THEIR QUALITIES, PERFORMANCES, AND COST.

WITH CHAPTERS ON

TURRET SHIPS, IRON-CLAD RAMS, &c.

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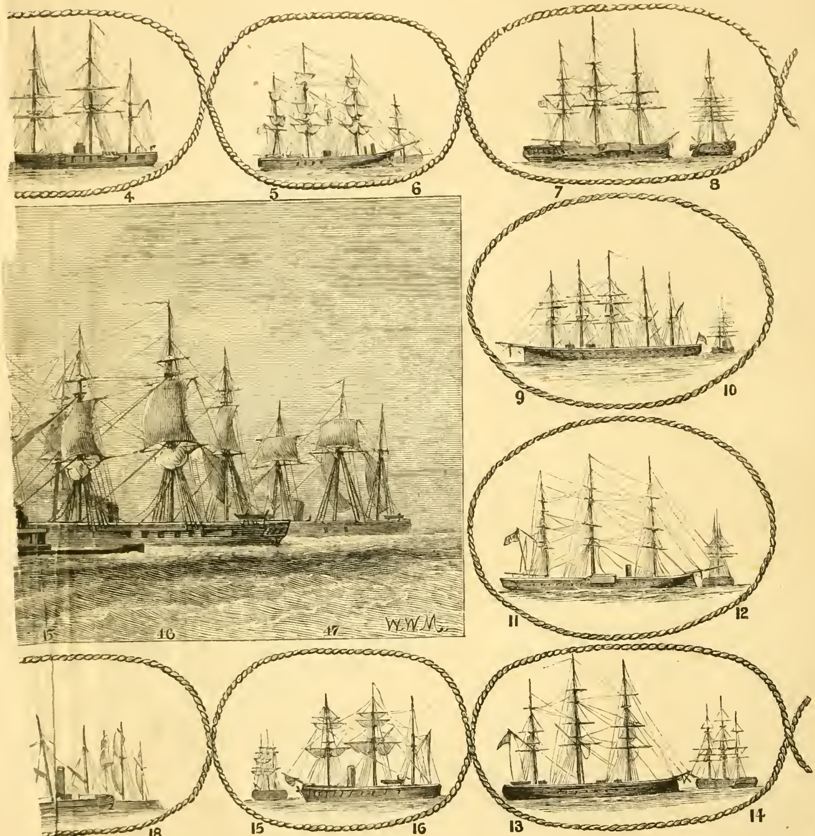

Alfred.	5. Viper.	7. Audacious.
rch.	6. Favorite.	8. Vanguard.
Clyde.	46. Penelope.	9. Agincourt.
on.	47. Enterprise.	10. Ocean.
l Sovereign.	15. Caledonia.	11. Triumph.
ervitch.	16. Prince Consort.	12. Scorpion.
		13. Achilles.
		14. Black Prince.

TO THE

RIGHT HONOURABLE HUGH C. E. CHILDERS, M.P.,

FIRST LORD OF THE ADMIRALTY,

This Volume

IS RESPECTFULLY INSCRIBED BY

THE AUTHOR.

INTRODUCTION.

The iron-clad ship question is so continually under discussion in the public press, and is justly deemed of so much importance to the country, that the publication of further information respecting it appears to be in many ways desirable. It is a question which cannot be thoroughly discussed in popular language—which alone I propose to employ in the present work—for it embraces many profound scientific problems; but there is a large mass of information relating to it which is perfectly susceptible of familiar exposition, and which there is no good reason for withholding from the reading public.

The only sources of such information at present open are undoubtedly insufficient. The annual speeches of the Parliamentary representatives of the Admiralty—able and copious as they often are—necessarily leave numerous facts and considerations concerning iron-clad ships untouched; and although the newspapers abound with intelligence upon the subject, they do not attempt to supply the place of connected and comprehensive statements embracing the subject as a whole, still less do they seek to set it before the public from the same point of view as those who daily regard it, so to speak, from a nearer stand-point. In fact, a candid and general survey of the iron-clad ship question will, I am sure, be welcomed by none more cordially than by gentlemen of the press, whose duty and privilege it is, to a large extent, to shape and direct the national opinion.

I know of no question which better deserves, or which is more likely to receive, impartial representation and advocacy than this iron-clad ship question, provided only that it be understood. The efficiency of its iron-clad fleet is of foremost importance to a small, isolated, maritime country like this, anchored on the edge of a continent like Europe, entrusted with the care of world-wide interests, and charged to maintain its power upon the sea at a time when the spirit of invention is setting at naught all past systems of ocean warfare, and mocking at every trace and tradition of the times when we won our naval renown. In proportion as the past is prolonged into the present we are weakened and endangered; in proportion as the novel capabilities of iron and steam are developed we are strengthened and made safe. This is no time, then, for clinging to any type of ship, or any feature of naval construction, merely because it is old and accustomed—no time for rejecting things because they are new and unaccustomed. But, on the other hand, this being pre-eminently a time of risk because of the transitions we are passing through, it is pre-eminently a time for making our great experiments with scrupulous care, and for wasting nothing on methods which *cannot* succeed.

There are special circumstances which render a broad and clear review of the question peculiarly desirable at present. Some of these arise out of the essentially transitional character of the period, owing to the continual improvement of guns and armour. In a time of transition, for example, public criticism becomes loosed from its usual restraints, and runs into error and extravagance. Under ordinary circumstances, the construction and behaviour of a war ship would admittedly be an abstruse and scientific question; but now, when so many changes are in progress, there is scarcely a journal, in town or country, which does not undertake to prescribe the proper forms, dimensions, and fighting features of war ships. Hence it happens that great diversity of feeling and opinion prevails on this subject, and it is not to be expected that any Board of Admiralty, or Admiralty designer, will give universal satisfaction. And, further, a time of transition is also a time of opportunity for all kinds of interested persons—inventors, patentees, contractors, and many others. A radical, or even a very considerable change in the type of our war ships, carries with it large orders to private firms, and minor advantages to a much larger number of persons; so that, for this cause also, it is to the interest of many to complain of, and even to denounce, the ships built by the responsible authorities. Besides these considerations there is the fact, that the change from very long iron-clads to shorter and handier ships of the first class was brought about by the substitution of a young and comparatively untried Chief Constructor for a much older and more experienced officer—a change which naturally furnished a new occasion for hostility to the powers that were. All these things have tended to obscure the true state of the subject, and to suggest the necessity for such a record and statement as I now propose to offer. I cannot hope that I have discussed every branch of the subject with perfect impartiality, for it is not possible to maintain absolute composure amid the din and worry of battle, and most of my work during the last seven years has been done under fire, and under the fire, too, of noisy and distracting, if not always powerful, ordnance. Nevertheless I have written, as I have worked, with the feeling that the only object worth consideration in this matter is the production of what are really the best ships for the Navy, and therefore I am not without confidence in the general fairness of the following pages.

One of the results of the publication of this work will, I trust, be to induce persons to look a little more closely than heretofore to the true causes of the different *performances* of the ships, both under steam and under canvas. It is not only idle, it is contrary to common sense and common experience, to visit upon the designer all those short-comings which are obviously the consequences of imperfect management. I appeal to the experience of the best seamen in our Navy when I ask if ships do not perform very differently in different hands. The sailing of a ship is by no means an art in which all persons are equally skilful. On the contrary, it is only those who have combined great ability with great devotion and professional love of their work, who have been eminently successful in establishing that delicate and beautiful relationship between the ship, the sails, the helm, and the wind, which is essential to great success in this branch of the sailor's art. The trim of the ship has to be watched and studied, the numerous detached sail-surfaces have to be brought into careful co-operation, so that each may take the utmost propulsive effort out of the wind; the helm has to be so used that the ship may be humoured to the sea, and find its way through it with as little obstruction as possible. These things cannot be accomplished with a new ship in a day: some little experience, at least, of a new craft is indispensable to the sailor's success in managing her; and, above all, he must possess the art of adapting his measures to the qualities and circumstances of the ship he is called upon to handle. The sailing of an iron-clad, with an extremely powerful rudder, and an enormous screw-propeller dragging in front of it—the best position for which screw, when not revolving, can only be ascertained by experience—is obviously a more difficult operation than the sailing of an old-fashioned frigate, and therefore requires greater skill and attention than was demanded of old, the more so as the pitches of the screws of the various ships differ greatly. How vain it is, then, to ignore all these considerations, and to take it for granted that a new ship, of new type, will exhibit her best sailing powers under all circumstances. Yet this has been done over and over again with our iron-clad ships; and even ships which have proved the best sailers in the fleet one year, on repeated trials and under various conditions, have been pronounced a year later as the worst sailers in the same fleet, and the consequent discredit has fallen upon the design—a circumstance of but little moment in itself, but of very great moment when it diverts attention from the true causes of the failure, and from the remedies which should be applied. It really ought to be borne in mind that ships which have sailed remarkably well one season, and have undergone no considerable change, would sail well the next under similar handling. In like manner the performances of the ships under steam are, as I have shown in the text, subject to the greatest possible variations by differences of management, especially at the present time when but few of the engineer or other officers of the Navy have had much experience of the contrivances now introduced into all our ships with the view of economising fuel—superheaters, surface-condensers, &c. The enormous modern steam-engines, furnished with those appliances, present an entirely new field for the experience of our officers and men, and a field which it is absolutely necessary to cultivate with the greatest assiduity and care, as it is by such engines that the great Channel Fleets of England will be propelled for many years to come. This is, to my mind, a very important point, for I foresee in it the certain reversal of the past practice of bringing our large war ships together for squadron evolutions almost as soon as they are out of the builders' hands. Until this year it has rarely happened that the captain and engineer have had even a week at sea in their ship, with freedom to vary their steaming operations as they found necessary for the full development of all those specialities of performance which every engine more or less exhibits. The new ship has been placed almost at once under the orders of the Admiral of the Channel Squadron for the time being, and whatever steaming has thenceforward been done has been done to order, or rather to orders, for a single signal from the Admiral often results in twenty signals from the deck to the engine-room. I have heard on good authority, and from more than one ship, that when the squadron has been ascertaining, each ship for itself, the number of revolutions per minute corresponding to a given speed of ship, nearly fifty orders for altering speed have been received in the engine-room in a single hour. If allowed a month or two at sea under steam, with the necessary coal for the purpose, and with freedom from external control, a good captain and engineer would ascertain the number of engine-revolutions required for every grade of speed with the greatest ease and nicety, and would add to this knowledge all those nice adjustments and minor modifications of the engines which would not only prevent those derangements which sometimes result in large repairs, but would also lead to great economy of fuel, of lubrication, and of labour. Another month or two of cruising alone, under canvas, would enable officers to bring out the best qualities of their ships, and would avoid those strange anomalies and discrepancies which abound in some reports of the squadron sailings of our iron-clads. Nor can it be doubted that with proper care the rolling of the ships might, where desirable, be materially modified, by altered stowage of weights, by consuming the coal first out of certain bunkers, and the stores out of certain store-rooms, and by other like contrivances. From the foregoing considerations it will at least be perfectly evident that while the designer is bound to do his utmost to give good qualities to his ship, her *performances* by no means rest in his hands alone. I would also observe that the peace performances of such ships as the 'Bellerophon,' 'Hercules,' and 'Monarch,' offer absolutely no indication whatever of what their fighting performances would be, seeing that their massive armour and mighty armaments take no part in peace trials. It is not a little absurd sometimes to observe even "grave and reverend signiors" solemnly discussing some wholly secondary performances—say the mere sailing—of these ponderous steam fighting engines, in total disregard of their armour, guns, rams, and steaming qualities; but it ceases to be absurd, and becomes distressing, when one hears, as he sometimes does, persons who influence public opinion and action, committing the same error. It would have been a great misfortune to the country if the Administrators of its Navy had in these days aimed primarily at producing floating bodies which the wind could blow about easily and rapidly, to the sacrifice of armour, guns, rams, and steaming powers; and I, for one, while feeling the full importance of giving good sailing qualities to ships that are to cruise in foreign and remote seas, am well content to see our floating Channel and Mediterranean Fortresses well armoured, well armed, and well supplied with steam propellers, even although they may be, and must be, a little less compliant to the breeze than were the frigates and liners of the past. It is nevertheless satisfactory to know that our armoured frigates have not only sail enough to be useful to them near home, but enough to take them abroad, perform good service there, and bring them back again. The 'Ocean' has gone so well through one commission in the China seas that she is about to be re-commissioned there for another; the same is true of the 'Royal Alfred,' in North America, and of the 'Zealous,' in the Pacific—the last news of the latter ship being that in performing a service under sail she outstripped one of our latest wooden sloops of war; and the 'Favorite,' while on the American station, raced with and beat under canvas one of our latest and best wooden corvettes, and has since returned from America to England, and cast anchor at Spithead, under sail alone.

The chapter on "Armour" will, I hope, clear away much of the misapprehension that has hitherto existed respecting the relative strength of the armour of the English and other ships. We have ships at sea more securely armoured than any French vessel, and several in course of construction which are very much stronger still. The surprising strength of the American Monitors has been much urged in this country, and has been extolled in the House of Lords as well as in the House of Commons : if the reader will examine the section of the 'Kalamazoo,' on page 35, he will see that even the strongest of all the American Monitors bears no real comparison with our own later vessels, even as regards the uniform thickness of its armour; while a reference to page 44 will convince him that the 'Dictator,' which has been exhibited to us *in terrorem* so very often, is, after all, a feeble construction, its armour diappearing almost immediately beneath the water's surface, so that every passage of a wave must expose its unarmoured part to shot and shell. It will be seen from this chapter, and especially from my remarks on page 31, that I consider that Sir William Fairbairn and Sir William Armstrong have been premature (to say the least) in their advocacy—if I have not misunderstood them—of the abandonment of armour for the future. This result may ultimately be brought about, but all the time this country can maintain, with a nor armour will be abandoned, and our clear duty for some time to come will be to avoid alike false analogies and speculative forecasts, and to develop as steadily and as rapidly as heretofore the power both of the gun with which we assail the enemy, and of the armour with which we repel his assaults upon us. As an encouragement to this course it may perhaps be not amiss to mention that I have myself devised plans for carrying extremely heavy armour which it has not yet been necessary to divulge, but which will come into active play when we have attained to the use of such thicknesses of armour as are now deemed too great for even a moment's consideration by those who think superficially upon this subject.

The chapter on the Armament of the Iron-clads sets forth the remarkable progress which the guns of the navy have made in the last few years. It is but five years ago that Parliament was discussing the practicability of carrying 6½-ton guns at sea, especially in broadside ships; we have now 12-ton guns, fought at sea with perfect ease, in many of the broadside ships of the Mediterranean and Channel squadrons, and the 'Hercules' has long been cruising about, both at home and abroad, with 18-ton guns worked most satisfactorily at the broadside in ports 11 feet above the sea, and with a horizontal range of fire which no unarmoured ship's broadside guns possess. The 'Monarch' has cruised successfully in heavy weather with 25-ton guns mounted in turrets. None but those who are hopelessly prejudiced can now doubt that, whether they be placed in turrets or out of turrets, the largest guns can be worked successfully and with terrible effect at sea, and in heavier weather than the small guns of old could be fought. For my part I look with lively expectation to the production of much more powerful guns than we have yet seen; I believe that the wonderfully strong and beautifully uniform metal, the manufacture of which Sir Joseph Whitworth has worked out with so much skill and perseverance, is opening up new possibilities in this direction, which may yet be coupled with the superior range, aim, low trajectory, and prolonged velocity which his ordnance system promises, and I have no doubt whatever that even the largest and best gun with which either this or any other system may provide us, will be effectually carried, and, if need be, gallantly fought at sea beneath our flag.

I beg leave to recommend to the thoughtful attention of the reader the chapter on the "Structure" of our ships. The subject is not one that strikes the attention, but there is no part of the iron-clad ship question more fraught with practical and economical considerations, nor is there any other feature which has had so much to do with the present superiority of our ships as compared with those of other Powers. If much anxious thought, attention, and inventive labour had not been devoted to this branch of the subject, the nation could not have had such ships as the 'Hercules,' 'Monarch,' and 'Audacious' in its navy; to carry their substance of armour and their calibre and number of guns, with unimproved structural arrangements, ships must have been built of far larger proportions, and have cost very much more; while the 'Thunderer' class, which is being built under the auspices of the present Board of Admiralty, must have been almost double their present size and cost. I repeat, this branch of the subject is not one which ordinarily engages notice, but it is second to none in its economical importance, or in its relation to the offensive and defensive powers of the navy.

It is unnecessary to refer at much length to the chapter on the Steaming properties of the ships. The recent cruise of the combined squadrons has signally and conclusively shown how utterly unfounded were those statements which represented that I had sacrificed the steaming capabilities of the 'Hercules' and other recent ships by improperly curtailing the coal supply. I have shown in the text that, owing to their moderate consumption of fuel, consequent upon their possessing engines of the new type, they are not only not inferior, but are much superior in this respect to most of the former ships. Now, in the 'Times' of October 4, 1869, is printed the consumption of the ships during the recent squadron trials, and what are the facts there given? These: that the consumption of the 'Hercules,' as compared with that of the 'Minotaur,' 'Northumberland,' and 'Agincourt' (three sister ships of former designers), was as follows—all the ships being employed, be it remembered, upon the same service, viz., proceeding together from Plymouth to Gibraltar, from Gibraltar to Lisbon, and from Lisbon to Queenstown :—

	Tons.	Cwt.
Minotaur	605	4
Northumberland	579	10
Agincourt	545	19
Hercules	297	9

As the 'Hercules' carries as much coal as each of the other three ships within fifty tons, it is perfectly obvious that I have even underrated in the text her advantage in this respect over former ships. The 'Monarch' did not exhibit nearly such good results as the 'Hercules,' owing chiefly to the packing of her piston-rods blowing out, and to some leakage of steam past the pistons into the vacuum; but even with her consumption very largely increased from these causes, she burnt 107 tons less coal than the 'Minotaur,' 81¼ tons less than the 'Northumberland,' and 47¾ tons less than the 'Agincourt.' The 'Bellerophon'—another of the recent ships which has been complained of for an alleged deficiency of coal-carrying power—is shown by the figures quoted in the 'Times' to have burnt much less than the ships of former design, the consumption of which has been given. The figures for her are not completely given, but her consumption from Plymouth to Gibraltar, and from Gibraltar to Lisbon, are shown, and, compared with those of the other three long and fine-lined ships, and with the 'Hercules,' are as follows:—

	Tons.	Cwt.
Minotaur	356	8
Northumberland	338	6
Agincourt	320	3
Bellerophon	235	17
Hercules	184	9

These figures, although they show that the 'Bellerophon' was less economical in her coal consumption than her successor, the 'Hercules,' also show that she burns much less than the other three ships, and that her supply of 560 tons is capable of steaming her for a greater distance than they can steam with their somewhat larger quantities. I hope these facts, taken with those given in the text, will completely dispel the error of those who question the capability of the new ships to make passages under steam as effectually as other ships. I have but little doubt that the calculations by which I have been led in the text to place the 'Monarch' very high in this respect, will be fully vindicated in future trials with the engines in an efficient state.

In previous observations upon the performances of the ships I have remarked at some length upon their sailing qualities. The recent cruise of the squadron, in so far as it has been publicly reported, has not added materially to our knowledge as regards this part of the subject. In the letter of the correspondent of the 'Times,' published in that journal of September 18th, certain trials are recorded in which the 'Hercules' and 'Monarch' appear to have sailed but indifferently; but as these ponderous and powerful ships raced under canvas only on the special trial with two unarmoured and one very lightly armoured ship, I am unable to feel surprise at their defeat; although it is worth remembering that in a former letter, published on the 7th of September, the same gentleman, with the greatest fairness, stated that these same two ships, heavily-armoured and armed as they are, each "appeared to "feel and spring to the pressure of her sails, although "there was but a pleasant and, indeed, a light summer's "breeze." There can be but little doubt that these recent ships, although so heavily burdened with thick armour and immense guns, have combined therewith sail power enough to enable them to greatly economise their fuel, which is the great object of their sails, and I feel certain that it will be highly satisfactory to many readers of this work to learn that the 'Hercules' went through all the service performed during the five weeks that the Admiralty flag floated over the Channel Squadron, and returned to England with but one-half of her coal consumed.

The question of the "rolling" of the ships received very useful illustration during the late cruise. The doctrine that a low freeboard is indispensable to steadiness was then finally overthrown. The lofty-sided armoured broadside ship 'Hercules,' the lofty-sided unarmoured broadside ship 'Inconstant,' and the lofty-sided armoured turret ship 'Monarch,' were all signally steady even in a heavy sea-way, and formed gun-platforms superior in steadiness to any previous ships. It is stated, possibly with truth, that on one occasion the 'Monarch,' from the superior elevation of her guns, could have fought them with greater ease and efficiency than any other ship; but I cannot for a moment infer from this, as some have done, either that she possessed the power to destroy all the other ships, or that her superiority as a fighting ship was thus established. I cannot imagine why, even on this one extremely boisterous day, a squadron of ships carrying more or less upper-deck guns, and still less a squadron of steam-rams like the 'Bellerophon' and 'Hercules,' should lie idle under the attack of the 'Monarch;' and, on the other hand, I am quite certain that the 'Monarch' was less capable, on all the other days of the five weeks, of withstanding the fire of the 'Hercules' than the 'Hercules' was of withstanding the 'Monarch's,' for every shot fired at short range from the central battery of the 'Hercules' would penetrate the 'Monarch's' water-line and boilers, while the water-line and boilers of the

'Hercules' are protected from the 'Monarch's' fire by a deep and impregnable armour-belt. The weakness of the 'Monarch' in this respect is due mainly to the turret system itself, which demands so much armour for the protection of the turrets as to leave comparatively little for the sides of the ship. It is on paper, and in the imaginations of men only, that these miraculous exploits of turret-ships take place: in an actual engagement their omnipotence would be qualified, and the impotence of other ships would be less easily secured. It is very satisfactory indeed to find that the Admiralty turret-ship 'Monarch,' of which everything bad was originally predicted—and which Captain Coles energetically disclaimed, as not representing his views of a turret ship, nor giving the principle a satisfactory trial—has proved a fast, steady, and formidable ship, and assuredly I shall not decry those real merits which I have laboured hard to secure to her; but on a great and critical question of this nature we must not pass by hasty inferences to false and perilous conclusions, but must enlarge our experience, weigh opposing considerations, and accept only well-established and well-matured results. I have, however, dwelt so fully upon the various aspects of this part of the subject in the chapter on Turret-Ships, that I need not enlarge upon it here.

An impression has gone abroad to the effect that the balanced rudder has failed; but this is not the case. The balanced rudder has accomplished most fully the great object which it was introduced to aid, viz. the endowment of our iron-clad steam-frigates and rams with that necessary handiness which the 'Warrior' and some other early iron-clads did not possess. The handiness of the 'Bellerophon,' 'Hercules,' and 'Monarch' under steam is most remarkable, and all that could be desired. When under canvas, the balanced rudder requires careful handling, but a little practice appears to remove all difficulties in that respect. With twin-screws in light-draught armoured vessels, this form of rudder does not appear to answer well, and it will probably not be repeated in such vessels, although it is common enough in the American monitors. But in the large steam frigates it has answered its prime object thoroughly well, and is without any such drawbacks as would for a moment justify its condemnation.

The chapters on the Cost of our iron-clad fleet, and upon the deeply important question of "Rams," shall speak for themselves. The former I respectfully commend to those gentlemen who study naval economy, and who will learn in it the real facts of that expenditure upon new iron-clads respecting which so much misapprehension has existed; the latter I no less respectfully commend to the earnest study of our naval officers. I trust that by means of their consideration of, and suggestions upon, the branch of naval construction and warfare there treated, I may be enabled to add to the interest and value of this chapter in future editions. The final chapter, on the Conversion of wooden Line-of-battle Ships into Iron-clads, will correct, I believe, some misapprehensions on this subject, and will serve to show that the devotion of large sums of money to such conversions would have been the means of spending such sums upon weak, decaying, and wasteful vessels.

If in this Introduction, or in the work itself, I seem to write with praise or complacency of my own works, I would ask the reader to believe that I have not written this book with that or any other personal end in view, but with the object of stating publicly facts which deeply concern the public, and respecting which many Members of Parliament and other gentlemen of weight and authority in the State, together with several of the reviewers of my former work on 'Shipbuilding in Iron and Steel,' have expressed a strong wish to learn more than has hitherto been published. Having entered upon the task of writing such a book, I have felt bound to write it freely and frankly, without staying to nicely balance my phrases, trusting to the generosity of critics and readers to put a kindly interpretation upon anything that may seem to require it.

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CHAPTER I.

VARIETIES OF IRON-CLADS.

It has often been remarked, as a matter of reproach to the administrators and architects of the British iron-clad navy, that the vessels composing it are extremely various in size, power, speed, and other qualities. It is no doubt true—whether it be a fair ground of complaint or not—that their variety is great, and is yearly becoming greater still. But if the reader could glance with me over a French photograph which is lying before me, in which *La Marine Moderne Cuirassée* is exhibited, he would discover that our portion of the exhibition is characterised by quite a tiresome appearance of sameness in comparison with the iron-clads of other countries. Our neighbours, the French, have particularly signalised themselves for variety of design. They have not, it is true, built any ships of such great length as some of ours; but they have built them of very different sizes, speeds, and strengths, and have equipped them with rigs and sails even more diversified than those of British ships. They have not done so much in the way of building turret-ships as we have; but they have arranged their guns in batteries as novel in form and character as turrets, and in such matters as "ram bows," "pink sterns," "internal shrouds," "crane catheads," and other devices (the names of which must sound oddly in the ears of non-nautical readers), the French have gone to lengths which our designers have never thought of approaching. The Russians have built iron-clads even more various than those of France; the Prussians have already obtained a very mixed fleet of such ships; the Italians have ships that differ almost as much as it is possible for ships to differ; neither the Austrian, the Turkish, nor the Spanish ships are severely uniform in character; the Dutch are building ships of very opposite descriptions; and the Americans have not only given to the world a new type in the monitor, but have secured a specific renown for broadside iron-clads in the performances of the 'New Ironsides,' and have displayed the fertility of their invention in the construction of the Stevens' battery and the 'Dunderberg,' the latter ship (which now belongs to the French, and has been re-named the 'Rochambeau') being perhaps the most singular sea-going iron-clad yet built.

The earliest European iron-clads—the French and English floating batteries built during the Crimean war—were without pretensions as ships, having, in fact, nothing "ship-shape" about them, and being mere floating forts designed for the attack of land batteries, and not for sea service; I shall therefore disregard them in noticing the various types of iron-clad vessels. The first examples of real iron-clad ships were 'La Gloire,' in France, and the 'Warrior,' in England, neither of which presented any great departures from the forms and appearances of ordinary ships—unless the sullen, low-browed, graceless aspect of 'La Gloire' entitles her to some distinction in this respect. Nor was the 'Warrior' in any marked degree a ship of singular appearance except in point of size. She was a long, fine, handsome-looking frigate, masted and rigged as usual, and formed with a bow and stern in no way differing from the bows and sterns of the most recent and beautiful wooden frigates. The 'Warrior' and her sister ship, the 'Black Prince,' were, however, destined to be the only English iron-clads embodying those forms and appearances which had come to be regarded as the most favoured traits of beauty in a ship. The 'Bellerophon,' the 'Penelope,' and the 'Lord Warden,' have their stem-lines relieved by short curved knees; but these diminished adornments are rather the last examples of the vanishing type of naval architecture than indications of a return to it. All British iron-clads are now built with stems approaching the upright above water, and this style, which was so much decried at first, is rapidly winning for itself æsthetic sanctions. It is already not an uncommon thing to hear a modern bow, like that of the 'Hercules,' for example, preferred even in point of appearance to the 'Warrior's.' Like changes of style and preference have materially affected the sterns of our iron-clads, and for very good reasons. The bow has been modified in order to dispense with overhanging weight, to increase its fitness to cleave and surmount waves, and to adapt it for ramming purposes. The stern has been modified in order to give protection to the rudder-head, to deflect raking shot, and to render it more fit to receive easily the blows of following waves. It is not to be doubted, however, that both bows and sterns are far from having attained ultimate and settled forms.

In discussing the varieties of our iron-clads, it is just and necessary that an honest discrimination between radical and minor changes should be exercised. It has been too much the habit to cast discredit upon our ship-construction on account of minor modifications, which, instead of being, as has been represented, evidences of change of plan and purpose, have, in fact, been proofs of a proper persistency in these respects. For example, it has of late been a steadily observed object in the construction of broadside iron-clad ships to extend as much as possible the horizontal range of the guns, both by increasing the training of individual guns and by placing guns in ports so situated as to facilitate bow and stern fire. Even in the days of wooden ships this was always deemed an important object, and often led to the over-burdening of fine bows and sterns with chase guns that seriously strained and weakened the ships. In the 'Warrior' and 'Defence' classes no attempt whatever was made to get any bow or stern fire from guns placed behind the armour; but of late years great efforts, and, I am glad to say, very successful efforts, have been made in this direction. If this had not been done, and the Constructors had been content with broadside fire only, they might have escaped a very large part of the extravagant censure by which the first trial of the 'Research's' guns was followed. On that occasion a lantern or two and a few cups were shaken off their hooks and broken by the simultaneous firing of all the heavy guns in ports cut for forward and stern fire only; and this slight incident, which argued no defect whatever in the ship, was at once so represented and exaggerated in one or two newspapers that the ship was said to be a perfect wreck. Complaints scarcely less extravagant have been made at various times respecting other vessels; but in spite of all opposition the broadside system has been extended and improved, until in the ships of the 'Invincible' class, a perfectly all-round fire, commanding every point of the horizon, has been attained from within an elevated armour-plated battery at the middle of the ship. Of course it has been found desirable to progress by small and careful steps towards this result, the light of experience being continually directed upon the path by which the advance has been made. To the ordinary eye these successive modifications have, no doubt, appeared to indicate an absence of settled purpose; but the simple truth is, that in all these changes one course has been steadily pursued, and those progressive trials and improvements have been made which in a few short years have brought about the complete fulfilment of the wishes of our sailors in this respect. From this example it will be seen how unfair it is for people to loosely accuse the Admiralty of undue variety in their plans; and examples of a like kind, enforcing the same caution, might be largely multiplied.

There have, however, undoubtedly been a few decided changes of plan and purpose since the 'Warrior' was built. The chief of these—neglecting in this place the new ships of the monitor type, such as the 'Glatton,' 'Thunderer,' and 'Devastation,' which will be considered hereafter—are the following:—

The 'Warrior' was armoured at the middle only, both bow and stern, and consequently the rudder-head and steering-gear were exposed to shot within thin iron sides; in later ships—in all which have been recently designed—this central or "box" battery has been associated with a continuous belt of armour extending from stem to stern, and protecting the region of the water-line and the steering-gear, the counter of the ship being carried down below the water in order to further screen the rudder-head. This last improvement, like many others, is wholly due to the Controller of the Navy, now Sir Spencer Robinson:

The 'Warrior's' armour was of uniform thickness over the whole of the protected broadside; in recent ships, over the most vital parts—such as the region of the water-line and in wake of the fighting decks—the armour is thicker than on the less important parts, and in some ships increased protection has been given to the region of the water-line by additional teak backing, and iron bulkheads fitted inside:

The 'Warrior' possessed only broadside fire from her battery guns; all the later vessels have had their broadside fire supplemented by bow fire and stern fire of greater or less extent, as already explained:

The 'Warrior' had only a main-deck battery armour-plated; recent ships have had a protected upper-deck battery given to them:

The 'Warrior' was designed to carry a considerable number of guns in an outspread battery; later ships have been built to carry a concentrated battery of very much heavier guns:

The 'Warrior' and 'Minotaur' classes were made extremely long, with a view to speed; recent ships have been made very much shorter in proportion :

The 'Warrior' was designed with V-formed transverse sections for a great length at the bow; later ships have been formed with sections of a U-shape :

The form of stem given to the 'Warrior' has been departed from in recent ships, as previously explained.

The above changes have undoubtedly resulted for the most part from radical differences of view between the constructors of the 'Warrior' and those of recent ships; but they are also due in part to the progress made in the armour and guns carried by war ships. This progress has been rapid and great. The armour of the 'Warrior' is everywhere 4½ inches thick; the 'Bellerophon's' is 6 inches, and the water-line strake of the 'Hercules' is 9 inches; the armour of the 'Hotspur' will be 11 inches thick, that on the sides of the monitor 'Glatton' 12 inches, and that on the turret of the latter vessel 14 inches; the monitors 'Thunderer' and 'Devastation,' now building at Portsmouth and Pembroke Dock, will also have 12 and 14-inch armour, and the new ram 'Rupert,' which may be regarded as a companion ship to the 'Hotspur,' will carry 11 and 12-inch armour. Presuming, as we may roughly do for this purpose, that the resistance offered by single armour plates to penetration varies as the square of the thickness,* we shall have—

* In their last Report the Iron Plate Committee observe that they "arrived "at the inference that with plates of equally good quality the resisting power "might be approximately considered proportional to the squares of their "thicknesses." No doubt this law is subject to some important limitations; but it is sufficiently accurate for the purpose to which I have applied it in the text.

For the strength of the Warrior's armour		about	20
,,	,, Bellerophon's	,,	36
,,	,, Hercules' (belt)	,,	81
,,	,, Hotspur's	,,	121
,,	,, Glatton's and Thunderer's 12-inch	,,	144
,,	,, Glatton's and Thunderer's 14-inch (turret)	,,	196

In other words—

The Bellerophon's armour is nearly *twice* the strength of the Warrior's					
The Hercules'	,,	about	4 times	,,	,,
The Hotspur's	,,	,,	6 ,,	,,	,,
The Glatton's and Thunderer's	,,	,,	7 ,,	,,	,,
The Glatton's and Thunderer's	turrets	nearly	10 ,,	,,	,,

As regards guns, we have advanced from the original $4\frac{3}{4}$-ton guns of the 'Warrior' to the 9-ton guns of the 'Lord Warden,' the 12-ton guns of the 'Bellerophon,' the 18-ton guns of the 'Hercules,' and the 25-ton guns of the 'Monarch,' 'Captain,' and 'Glatton,' while the turret-ships since designed, the 'Thunderer' and 'Devastation,' will have 30-ton guns—an advance which in about ten years has far exceeded all the progress previously made since the invention of gunpowder and guns.

It must be obvious even to the most non-nautical reader that the necessity of carrying such armour and such guns, and of firing them ahead and astern instead of on the broadside only, has rendered essential many modifications of the forms and arrangements of the sides and decks of recent ships as successive new designs have been required, and to this cause must be assigned part of the variety which our ships present. There are, however, other causes. There is, for instance, the necessity for building ships of different sizes—a very important point. The first of our sea-going iron-clads, the 'Warrior,' was a very large ship, far larger than the war-ships previously built. The 'Minotaur' class, which followed the 'Warrior,' was still larger. The 'Defence' class and the 'Hector' class were built on much smaller dimensions, but in both classes great sacrifices were made in consequence, and notwithstanding these sacrifices neither of these ships fell much below 4000 tons. The design of the 'Enterprise' opened the way to the production of much smaller sea-going iron-clads. This vessel was of less than 1000 tons burden, and yet was armoured all round at the water-line, carried heavier guns than any other vessel of her date, and was of moderate draught of water. This combination of qualities in a vessel so small was obtained by means of various novel arrangements—such, for instance, as a battery standing up above the upper deck—and these novelties added, of course, to the variety of our ships. It cannot be doubted, however, by any intelligent person that the novelties so introduced, while adding to the variety, added also in a most important degree to the efficiency of a navy upon which demands for small ships as well as large are continually and properly made from every quarter of the globe.

The introduction of twin-screws, and the desirability of adding to the Navy a few ships of comparatively light draught, have also led to further differences. So likewise has the desire—a very proper and praiseworthy one—to abandon the use of wood in iron-clad ships. Causes like these, taken in conjunction with those previously named, have justifiably and advisedly introduced considerable variety into our iron-clad fleet. It cannot be doubted, however, that the greatest cause of variety was the resort, some years ago, to the enormous lengths of 380 and 400 feet in the ships of the 'Warrior' and 'Minotaur' classes respectively. It has been found necessary to abandon these extreme lengths of hull for reasons which will be discussed so fully hereafter that it is unnecessary to dilate upon them here; and it is consequently sufficient to direct the reader's attention to the facts of the case.

It is most necessary to observe next that variety in the ships of a fleet is not attended by unfitness to act together to any such extent as is often supposed and represented. The primary object to be attained in this respect is that of grouping a navy into squadrons of about equal speed under full steam. If a moderate speed only, say 12 knots, had been aimed at in our first sea-going iron-clad, the 'Warrior,' it would have been quite easy to have secured an equal speed for all subsequent iron-clad frigates; and by giving a uniform speed of 10 knots to all smaller iron-clads, the entire iron-clad fleet would have comprised but two classes of vessels, as regards steaming capability. But the enormous speed of 14 knots was aimed at and secured in the 'Warrior' by means of her large dimensions and very fine lines, and the tendency ever since has been to approach this speed as nearly as possible in most of our armoured frigates. It is to this circumstance, perhaps more than to any other, that the differences of the speeds of our iron-clads are to be attributed. I shall hereafter refer more fully to the subject of the steaming capabilities of these vessels; but it may be proper to state here that, with a few exceptions, our iron-clad frigates have attained speeds of 13 knots and upwards, and that the smaller armoured vessels have in most cases exceeded 10 knots. Hence it appears that notwithstanding the differences of speed which do undoubtedly exist in our iron-clad navy, it is still quite possible to group the ships in squadrons, the larger of which, under judicious management, could proceed at a comparatively high speed even when the speed of the squadron was determined by that of the slowest ships in it.

But the fact which should be clearly pointed out is that, great as the differences in point of speed may be when the engines of all our iron-clads are exerting their maximum power, and all their bottoms are clean, these differences are not greater than—in truth, they are not so great as—those differences of speed which result from secondary causes, such as differences in the quality of coal, in the stoking, in the management of the engines, and in the degree of foulness of the bottom. Of course it is not for a moment suggested that these latter differences, of however common occurrence they may be, justify a disregard of uniformity in the design of ships; but it is, nevertheless, the fact that the differences of performance in our iron-clads at sea, which have hitherto resulted from these secondary causes, have proved abundantly sufficient to neutralise the inherent differences in the qualities of the ships themselves. Many illustrations of this fact might be taken from the various trials of the Channel Squadron; but a few cases will suffice for our present purpose. On the 1st of November, 1866, a full-speed trial of the six following frigates (with two or three smaller ships which I need not notice) was ordered, viz., the

'Achilles,' 'Bellerophon,' 'Caledonia,' 'Hector,' 'Lord Clyde,' and 'Ocean.' The sea was smooth, with only a slight swell, and the wind light, so that there was nothing in the external circumstances to prevent the several ships from doing their best, and obtaining results proportionate to, if somewhat less than, the results of their measured-mile trials. On the measured mile they had performed as follows:—

	Indicated Horse-Power.	Speed in Knots.
Achilles	5722	$14\frac{3}{10}$
Bellerophon	6521	$14\frac{1}{10}$
Caledonia	4552	$12\frac{8}{10}$
Hector	3256	$12\frac{3}{10}$
Lord Clyde	6064	$13\frac{4}{10}$
Ocean	4244	$12\frac{8}{10}$

On a full-speed trial, under similar external circumstances, if their bottoms were equally clean, and the performances of their boilers and engines equally good, they should have stood in the same order; but their bottoms were not in a similar condition, and the performances of their boilers and engines were so extremely different that the results of the squadron trial differed excessively from the other results, and were as follows:—

	Indicated Horse-Power.	Speed in Knots.
Achilles	5786	$13\frac{4}{10}$
Bellerophon	4156	11
Caledonia	4597	$11\frac{2}{10}$
Hector	2102	10
Lord Clyde	4852	13
Ocean	3997	11

In order that the reader may readily compare the performances of these six vessels on the two occasions above referred to, I have arranged the results of the trials in the following order:—

	Indicated Horse-Power.		Speed in Knots.	
	On Measured-Mile Trial.	On Trial of 1st Nov. 1866.	On Measured-Mile Trial.	On Trial of 1st Nov. 1866.
Achilles	5722	5786	$14\frac{3}{10}$	$13\frac{4}{10}$
Bellerophon	6521	4156	$14\frac{1}{10}$	11
Caledonia	4552	4597	$12\frac{8}{10}$	$11\frac{2}{10}$
Hector	3256	2102	$12\frac{3}{10}$	10
Lord Clyde	6064	4852	$13\frac{4}{10}$	13
Ocean	4244	3997	$12\frac{8}{10}$	11

From this it will be seen that the order in which the ships steamed on their sea trial was very different indeed from the order given by their respective best performances on the measured mile. That these great differences in performance resulted from secondary causes is obvious enough on the very face of the figures, presuming the observations and records forwarded by the Admirals in command to be tolerably accurate. In the case of the 'Achilles,' the boilers and engines (which are of the old type, and well understood) were so successfully worked that they produced slightly more power even than on the measured mile; but the speed of the ship fell short of her measured-mile speed by $\frac{9}{10}$ of a knot, a loss which must be principally attributed to foulness of bottom. In the 'Bellerophon,' the boilers and engines (which are of a new type, working at a very high speed of piston, and not at the time well understood) were less successfully worked, in fact, developed only 4156 H.-P., instead of 6521 H.-P.; and the speed of the ship was small in proportion, amounting to only 11 knots. It is interesting to remark that about 1 knot of this loss of speed is due to foulness of bottom; for at the measured mile, on a half-power trial, she went 12 knots with about the same power as the boilers and engines developed at this squadron trial. The 'Caledonia's' engines developed about the same power on both the measured-mile and sea trials; but the speed obtained on the measured mile exceeded that obtained at sea by more than a knot and a half; and as she is a copper-bottomed vessel, this can be accounted for in part only by foulness of bottom. The 'Hector' developed but two-thirds of her power, and fell short of her full speed by nearly $2\frac{1}{2}$ knots. On the measured mile she obtained, with reduced power, $10\frac{1}{4}$ knots, with but 1790 H.-P.; so that with 2102 H.-P. she ought to have approached 11 knots on the squadron trial; and the deficiency of a knot from this speed was probably due, for the most part, to foulness. The 'Lord Clyde' developed but four-fifths of her full power, and yet attained nearly to her full speed, losing nothing from foulness. The 'Ocean's' power on the sea trial also closely approached the amount developed on the measured mile, and yet her speed, like the 'Caledonia's,' fell much more below her full speed than was to be expected in the case of a copper-bottomed ship.

The foregoing facts show clearly enough that foulness of bottom and deficient development of steam-power introduced into the performances of the frigates engaged in this trial far greater differences than existed in the inherent qualities of the ships. Looking at the maximum (or measured-mile) performances of the vessels, we find that the difference in speed of the fastest and slowest of these six ships is 2 knots; whereas on the sea trial the 'Hector' was nearly $3\frac{1}{2}$ knots slower than the 'Achilles.' When each ship did its best, the 'Achilles' and 'Bellerophon' differed by less than a quarter of a knot; but on the squadron trial a difference of nearly $2\frac{1}{2}$ knots existed. At their greatest speeds the 'Caledonia' and 'Lord Clyde' differed by but little more than half a knot; but on the sea trial the 'Lord Clyde' beat the 'Caledonia' by 2 knots an hour. The performance of the 'Ocean' was so similar to that of the 'Caledonia' on both trials as to require no special remark.

Now let us turn to another sea trial, also made in smooth water, on the 26th November, 1867. The seven large frigates tried on this occasion were the 'Achilles,' 'Bellerophon,' 'Lord Clyde,' 'Lord Warden,' 'Minotaur' (flag-ship), 'Prince Consort,' and 'Warrior.' The flag-ship averaged $11\frac{4}{10}$ knots per hour for the eight hours of the trial, and her engines gave an average of 5629 H.-P. The results of the trial for the seven ships were as follows :—

	Indicated Horse-Power.	Speed in Knots.
Achilles	5688	$12\frac{7}{10}$*
Bellerophon	5092	$11\frac{7}{10}$
Lord Clyde	3822	$10\frac{8}{10}$
Lord Warden	4472	12*
Minotaur	5629	$11\frac{4}{10}$
Prince Consort	3721	$11\frac{6}{10}$*
Warrior	4752	12

The full-speed performances of the 'Achilles,' 'Bellerophon,' and 'Lord Clyde,' on their measured-mile trials have been given above, and those of the remaining four vessels are given in the following statement, the results

* These speeds differ materially from those given by the common log, and recorded at page 8 of the Parliamentary Return, No. 128, "Navy (Channel Fleet)," dated March 6, 1868, which are obviously a little in error in several cases; but it has only been thought desirable to correct them in the three cases where the errors were considerable. It will be seen by the diagrams between pages 8 and 9 of the Return that the 'Achilles' steamed about 20,686 yards, the 'Lord Warden' 11,125 yards, and the 'Prince Consort' 3349 yards, more than the flag-ship, in the 8 hours; so that their average speed must have exceeded hers ($11\frac{4}{10}$ knots) by $1\frac{3}{10}$, $\frac{6}{10}$, and $\frac{2}{10}$ of a knot respectively.

of the latest measured-mile trials (made at Stokes Bay in 1868) being taken in the cases of the 'Minotaur' and 'Warrior':—

	Indicated Horse-Power.	Speed in Knots.
Lord Warden	6706	$13\frac{5}{10}$
Minotaur	6702	$14\frac{4}{10}$
Prince Consort	3953	$12\frac{7}{10}$
Warrior	5267	14

To facilitate the comparison of the results obtained on the measured-mile and sea trials, I have in this case also arranged a statement that will enable the reader to see at a glance the differences which exist. Here also it appears that through foulness of bottom, and deficient development of steam-power, the order of merit of the ships, in point of speed, was very different on the sea trial from that given by the measured-mile trials.

	Indicated Horse-Power.		Speed in Knots.	
	On Measured-Mile Trial.	On Trial of 26th Nov. 1867.	On Measured-Mile Trial.	On Trial of 26th Nov. 1867.
Achilles	5722	5688	$14\frac{3}{10}$	$12\frac{7}{10}$
Bellerophon	6521	5092	$14\frac{1}{10}$	$11\frac{7}{10}$
Lord Clyde	6064	3822	$13\frac{4}{10}$	$10\frac{8}{10}$
Lord Warden	6706	4472	$13\frac{5}{10}$	12
Minotaur	6702	5629	$14\frac{4}{10}$	$11\frac{4}{10}$
Prince Consort	3953	3721	$12\frac{7}{10}$	$11\frac{6}{10}$
Warrior	5267	4752	14	12

Perhaps the difference between the results of the two trials will appear even more striking if put in the following form:—

Order of Merit.

According to Capability.	According to Trial of 26th Nov. 1867.
No. 1. Minotaur.	No. 1. Achilles.
,, 2. Achilles.	,, 2. { Lord Warden. Warrior. }
,, 3. Bellerophon.	,, 3. Bellerophon.
,, 4. Warrior.	,, 4. Prince Consort.
,, 5. Lord Warden.	,, 5. Minotaur.
,, 6. Lord Clyde.	,, 6. Lord Clyde.
,, 7. Prince Consort.	

So great were the differences of performance introduced by different degrees of foulness, differences of coal, different developments of power, and other secondary causes, that the fastest ship of all, the 'Minotaur,' was reduced almost down to the slowest; and the 'Lord Warden,' which should have been beaten by four ships, was beaten by one only, she herself greatly beating the 'Minotaur,' which ought to have beaten her by nearly a knot an hour.

I have dwelt upon this point, and illustrated it at some length, because it is very important that it should be thoroughly understood that even the most perfect uniformity in the steaming qualities of our iron-clad frigates at their maximum powers, would fail altogether to result in uniform performance at sea with only ordinary management as regards the engines and boilers, fuel, state of ship's bottom, and so forth; and that, after all that has been said about want of uniformity in the designs of our armoured ships, it will obviously be futile to look in that direction only for a guarantee of uniformity of performance and of steaming qualities.

If I were to discuss, in like manner, the extent to which uniformity of sailing performance is disturbed by secondary influences, it would be quite easy to show that the same facts and principles hold. It will only be necessary to illustrate this by a single example, that of the 'Pallas.' After witnessing the performances of this ship under canvas (in 1866) for a long period, Rear-Admiral Yelverton reported of her to the Board of Admiralty as follows:—"On all occasions of trial-"sailing, whether on a wind or going free, the 'Pallas'

" proved herself far superior to the rest of the squadron. " Her power of going to windward is extraordinary. . . " I may safely class her, in point of sailing, with some " of our good 36-gun frigates of other days." Rear-Admiral Warden, then second in command of the squadron, also placed her first in order of sailing capability. In 1867, however, although the ship had undergone no change in herself (beyond having some of her running gear strengthened), her performance under canvas was extremely bad, and Rear-Admiral Warden reported that "the 'Pallas' was 'nowhere,' " from *inability to do more*." * It is obvious, notwithstanding this falling off in performance, that, as the "ability" of the ship could not have changed, her bad performance must have been due to secondary causes, having nothing whatever to do with her design. The sailing trials made by the Channel squadron in 1868, of which the particulars are given in Admiral Warden's Report, show that the 'Pallas' again took a high place, and prove the accuracy of the opinion here expressed.

It is unnecessary to dwell longer on this aspect of the subject. It is plain that, whatever may be the variety of design embodied in our iron-clad fleet, the principal differences in the performances of the ships at sea are due to other causes; and that uniformity of steaming and sailing performances cannot be secured by the designer alone. The 'Lord Warden' and 'Lord Clyde' are just alike—built from the same drawings, supplied with boilers and engines of the same power, armoured to the same extent, and yet we

* The italics are mine.

have seen how differently they have steamed at sea under the same circumstances. It may be certainly concluded, therefore, that the practical differences between our ships, as regards steaming and sailing, are of much less importance than has been represented, and that great inducements exist for us to do all we can to secure uniformity in our fuel, our stoking, and our use of steam ; and also to keep the bottoms of our ships as clean as possible. This is unquestionably a very important subject, and points to the necessity of a more careful training of all our officers, but more especially of the engineer officers of the fleet.

I have already intimated, in an earlier part of this chapter, that variety of design resulting from progressive improvements is, in my view, to be preferred to a non-progressive uniformity. Before closing this chapter, it will be well to revert to this aspect of the subject. Let us take as an illustration the very important quality of power to ram an enemy. The first sea-going iron-clad, the 'Warrior,' possessed this quality in a very minor degree. She is not, it should be understood, wholly unfit to act as a ram. Any strong and well-built iron ship would deliver a formidable blow in striking an enemy at even a moderate speed ; but the 'Warrior' is much more than an ordinary ship in this respect, having a massive solid forged ram-stem, well supported by bulkheads and frames, worked within her elegant knee-of-the-head, expressly to adapt her for delivering a destructive blow upon an enemy. Still, more recent bows have varied largely and advantageously from the 'Warrior's,' in order to adapt them to ram more efficiently, as will be shown further on ;

and, what is even more important to my present argument, the proportions of the 'Warrior' have been wholly departed from in order to secure that quality of handiness in which the 'Warrior' is so deficient, and which is indispensable to the effective use of a ship as a ram. Whether the proportions of such ships as the 'Bellerophon' and 'Hercules' are, or are not, superior to those of the 'Warrior' and 'Minotaur' for steaming purposes will be fully considered in a later chapter; but that they are superior for ramming purposes does not admit of a doubt. The variation introduced in this respect, and the further variation of giving ram-ships the advantage of a balanced rudder are causes of difference between early and recent iron-clads, no doubt; but it would have been an evil thing for England if in the next naval action her iron-clad fleet had consisted of Warriors and Minotaurs only, and had comprised none of those stout and handy vessels which are, I believe, capable of playing a most destructive part among a hostile squadron. The actual introduction of this improvement is due much more to Sir Spencer Robinson, the Controller of the Navy, than to any other person; and the foresight and persistency with which he carried this change through will never be more fully appreciated than in the hour of action, should that unhappily arrive. Uniformity in our fleet would have been dearly purchased at the expense of this great improvement.

The modifications which the structure of the hulls of our iron-clads has undergone constitute another cause of variety, which, if mere variety be objectionable, are open to censure, but which bear to my mind a very different aspect. This remark applies both to the materials of which the hulls have been composed and to the disposition and distribution of those materials. There never has been a doubt in the minds of the Constructors of the Navy respecting the superior value of iron as the material of construction for such ships, and the present Controller of the Navy has adopted iron to the utmost extent compatible with other circumstances, and long since abandoned wood altogether as the framework of new constructions. The only reason for building iron-clads in wood has been found in the readiness and economy with which they could be produced either out of existing wood ships or out of stocks of timber provided in the days of wood ships. But it has been alleged that the iron upper-works of the 'Enterprise,' the combined wood and iron upper works of the 'Pallas,' and the compound or double armour of the 'Lord Warden' and 'Lord Clyde,' are examples of want of uniformity and consistency of purpose on the part of the Admiralty and its officers. This view is not, however, accurate. The 'Enterprise' (a small vessel of less than 1000 tons) was the first partially armoured wooden vessel, and it was deemed very desirable to render the construction of so small a vessel available as an experimental trial of the practicability of combining fire-proof iron upper works with the wooden bottom of such vessels. This experiment has succeeded remarkably well—so well that all the largest wood-built iron-clads of the French navy are now built with iron upper works. But it was precisely one of those experiments which it was very undesirable to repeat until its practical success or failure had been tested by a prolonged trial at sea, and consequently the plan could not with security be adopted, and therefore was not adopted, in the 'Pallas,' except in the immediate vicinity of the battery guns, where an iron side was indispensable. The plan was not applicable to the converted ships 'Zealous,' 'Royal Alfred,' and 'Repulse,' without too large an outlay for cutting down the wooden upper works; and the necessity for repeating the 'Enterprise' system in still later vessels has fortunately disappeared altogether from our Navy by the general adoption of iron in the construction of iron-clads. The adoption of an inner thickness of armour in the 'Lord Warden' and 'Lord Clyde' was the most obvious and common-sense method of increasing the defensive powers of those ships, after their 4½-inch armour had been provided, and when the progress of other navies rendered some increase necessary. In all these respects, therefore, the variety of system adopted has been the result not of fluctuating purposes, but of steady and determined progress where progress was all-important. The chapter which will follow upon the structure of iron-clads will show, I believe, that the same thing is true of the successive modifications which the iron hull has undergone in successive ships.

There is one other consideration connected with the variety of our armoured ships which appears to me well worth the attention of the officers of the Navy—the way in which that variety may be turned to account in time of war. In the old days, when actions had to be fought under sail, and when ships of a class were in the main alike, the limits within which the arts, the resources, and the audacities of the Navy were restricted were really very narrow; and yet how brilliant were its achievements! I cannot but believe that, if the English iron-clad fleet were now to be engaged in a general action with an enemy's fleet, the very variety of our ships—those very improvements which have occasioned that variety—would be at once the cause of the greatest possible embarrassment to the enemy, and the means of the most vigorous and diversified attack upon the hostile fleet. This is peculiarly true of all those varieties which result from increase in handiness, in bow fire, in height of port, and so forth; and unless I have mis-read our naval history, and mis-appreciate the character of our naval officers of the present day, the nation will, in the day of trial, obtain the full benefit of these advantages.

CHAPTER II.

ARMOUR OF THE IRON-CLADS.

I HAVE already briefly alluded to the different modes of distributing or disposing the armour upon the hulls of our iron-clad ships; in this chapter I propose to deal more fully with this subject, and to trace the additions that have been gradually made to the thickness of the armour carried by various ships. In order to add to the interest of the division, I shall also give similar information respecting some armoured ships of other countries.

When the first iron-clads were constructed, the most powerful guns carried by our ships of war consisted of the old smooth-bore 95-cwt. 68-pounders, and the $4\frac{1}{2}$-inch armour-plating which was employed was, when properly backed and supported, capable of withstanding the fire of these guns. This thickness of armour, backed in various ways, forms the protection of a large number of our iron-clads, having been adopted in all the iron-built ships first constructed, except those of the 'Minotaur' class; in all the converted ships of the 'Caledonia' class (except the 'Royal Alfred'), which were altered from line-of-battle ships; and in all the armoured corvettes and smaller vessels yet completed. In the first iron ships—the 'Warrior,' 'Black Prince,' 'Achilles,' 'Defence,' 'Resistance,' 'Hector,' and 'Valiant'—the $4\frac{1}{2}$-inch armour was backed by 18 inches of teak fitted outside the iron hull; and in the wood ships the armour was bolted on outside the planking of an ordinary line-of-battle ship, being consequently backed by about 30 inches of timbering and planking. In the ships of the 'Minotaur' class, the armour was increased in thickness to $5\frac{1}{2}$ inches; but instead of having 18 inches of teak backing, as in the 'Warrior,' and the other ships enumerated above, there was only a thickness of 9 inches; so that practically the sides of this class of vessel are of the same strength as the armoured portions of the 'Warrior' and 'Defence.' It was long supposed, in consequence of certain experiments at Shoeburyness, that the increase of armour and decrease of wood backing in the 'Minotaur' class, as compared with the 'Warrior' class, had resulted in a considerable reduction in shot-resisting strength. This, however, ultimately proved to be incorrect, the error having arisen from a change in the strength of the powder employed.* In

* "The 'Minotaur' target differed from the 'Warrior' mainly in the "reduction of its wood backing, and in an increase of equivalent weight in "the armour. A single layer of 9-inch teak and armour-plates $5\frac{1}{2}$ inches "thick were used in this, the frames and skin-plating remaining about the "same. For a long time it was supposed that this target had proved much "inferior to that of the 'Warrior,' and there were not wanting persons to "publicly, and strongly and repeatedly, censure the departure that had been "made from the 'Warrior' system. I must confess that I was never able to "join in that censure myself, and when it became my duty to consider, with "the Controller of the Navy and his officers, how the 'Bellerophon' might "best be built in this respect, we ventured to adhere to the reduced thickness "of wood backing and the increased thickness of armour, notwithstanding the "outcry against them. I am happy to be able to state what, perhaps, many "gentlemen present may not yet have heard (for it is ill news that flies apace, "and not good news), viz., that all the gloomy and disparaging comparisons "which were drawn between the 'Warrior' and 'Minotaur' targets have "recently proved to be in error, it having been discovered that what is known "as '2 A' powder was used with two out of the three rounds of 150 lbs. "cast-iron spherical shot which were fired from the $10\frac{1}{2}$-inch gun, at the

the 'Lord Clyde' and 'Lord Warden,' the armour is in some places $4\frac{1}{2}$-inch and in others $5\frac{1}{2}$-inch, worked outside a wooden hull of about the same thickness as the converted ships of the 'Caledonia' class; but in order to increase the resisting power of the ship's side, and especially to prevent the entrance of shells (which are so destructive to wood-built ships), a skin of $1\frac{1}{2}$-inch iron is worked behind a large part of the $4\frac{1}{2}$-inch armour, between the outside planking and the timbers. By this means the total thickness of iron to be penetrated is made to equal 6 inches over a considerable part of the area of the armoured side. The frames of these two vessels, although no thicker than those of the ships of the 'Caledonia' class, are made solid throughout, and are consequently much stronger.

In the 'Bellerophon,' the armour-plating is 6 inches, and the teak backing 10 inches thick, while the efficiency of the target presented by the ship's side is greatly increased by having the skin-plating $1\frac{1}{2}$ inch thick, or nearly 1 inch thicker than in the iron-built vessels which preceded her. Another important feature of the construction is that outside the skin-plating, and

" 'Minotaur' target, the effect of using this powder having been to raise the " striking velocity of the shot from 1,620 feet to 1,744 feet per second. The " change in the powder was made (I know not how or why) immediately " after the first round, and invalidated all the comparisons that were made " in and after the report of the trial. The 'Minotaur,' 'Agincourt,' and " 'Northumberland,' are now known to possess much greater strength than " has been supposed, and are in all probability at least equal to the 'Warrior' " in that respect. When the great cost of these large ships and the time " which has been required for building them are considered, it must be highly " satisfactory to the country to learn that no mistake was made in designing " their armour, and that they are really as stout and strong as their designers " proposed."—From a Paper *On the 'Bellerophon,' 'Lord Warden,' and 'Hercules' Targets*, read by the Author at the Institution of Naval Architects, and reprinted *in extenso* in the Author's 'Shipbuilding in Iron and Steel,' p. 483.

between the planks of the wood backing, longitudinal girders are worked at intervals of about 2 feet, thus forming a network of framing in conjunction with the strong vertical frames inside the skin-plating, which are about the same distance apart. This arrangement has been proved most satisfactory as regards the efficient support it gives to the armoured side, and has been adopted in all our armour-clad ships built since the 'Bellerophon.'* The 'Penelope' has her hull protected

* Although the contrary has often been freely asserted, this arrangement differs altogether from that proposed by the late Mr. Chalmers, the essential feature of which consisted of a series of loose edge plates interposed between the strakes of wood backing to the outer armour-plate, and cut off from any connection with the hull proper by means of a thin inner armour-plate backed by a few inches of wood, so that no structural strength whatever was obtained by their use. The following extract is taken from the Paper *On the 'Warrior,' 'Bellerophon,' and 'Lord Warden' Targets*, referred to in the foot-note on p. 25:—

"I have now to describe to you the 'Bellerophon' target; and in order to "make the principles of its construction clear, I must mention the two points "in reference to which the 'Warrior' and 'Minotaur' targets appeared to "me susceptible of improvement. It seemed, first, that a great addition to "the general stability and strength of the structure might be secured if the "strong vertical iron frames of the ship were crossed horizontally by other "frames of approximately equal strength, and spaced like the vertical frames; "and, secondly, that the risk of shot or shell passing through the structure, "between the frames, would be greatly reduced, and the resistance of the "frames much more effectually elicited, wherever a shot or shell might strike, "if the skin of the ship were considerably thickened. In other words, it "appeared highly desirable to extend, throughout the entire structure, that "double skin-plating, and those external frames or stringers, which had already "been introduced, as we saw a minute ago, in the weakened portions of the "'Warrior' target. These features constitute the characteristic merits—for "they proved on trial to be merits—of the 'Bellerophon' target; and it is a "pleasure to me, and not by any means a subject of regret, to know that the "germs of these improvements may be traced in the structure designed by "my predecessors. By virtue of these we secure many important objects. "The combined horizontal and vertical 10-inch frames, connected by the "double skin of ¾-inch iron, constitute an enormously strong and rigid "structure, eminently well adapted to sustain the armour under all circum-"stances, while both the doubled skin and the external stringers (to which "we fitted butt-straps in the 'Bellerophon' herself), increase the longitudinal in the most vital parts—near the water-line, and in wake of the fighting deck—by 6-inch armour, and in

" strength of the ship to a most unusual extent. It will complete the general " description of the 'Bellerophon' target when I state that the armour was " 6 inches thick, and the teak 10 inches; and that, instead of forming the " external frames or stringers of a plate and two angle irons, as was done in " the 'Warrior,' we formed them of one large angle iron 10 by 3½ inches.

" You are now in a position to understand the true reasons that existed for " riveting external stringers to the outside of the 'Bellerophon's' skin-plating, " and you cannot fail to see how little the adoption of that arrangement had " to do with the notion of giving direct support to the armour-plates. I " mention this because it has been supposed, and stated publicly on many " occasions, that these edge plates were adopted in imitation of a quite " different system, and with the view of rigidly backing up the armour. " This, however, is wholly a mistake; for much as I, for one, should like " to banish the teak from our iron-clads, and to make their hulls of iron " throughout, I am of opinion that a rigid iron backing has many disadvan- " tages. In fact, so far were we from valuing these edge plates as direct " armour supports that we caused them to be reduced in depth behind one " of the plates of the target, and to a large extent in the ship also, expressly " in order to keep them from too immediate contact with the armour; and " we did so because it appeared undesirable to bring the force of a blow so " directly and fully upon that portion of the hull proper of the ship which is " immediately in front of the shot, as these plates would otherwise tend to " bring it, especially if placed closer together. We put armour upon a ship to " protect the hull, which we require to preserve from the blow as effectually " as possible. A very rigid backing, in direct contact with the skin of the " ship, must obviously transfer much of the shock of a shot to that skin; " whereas a moderately yielding backing allows the force to expend itself upon " the armour which is put there to receive it, and thus protects the skin from " its violence. This is a very important point, and one upon which too " hasty opinions may easily be formed. I have given the most careful con- " sideration to the matter, and have seen many corroborations of the sound- " ness of the views here expressed. There is one test which is easily applied, " but which is usually applied in a manner the very reverse of what it should " be. It is this: wherever you see an armour-plate that is supported by close " rigid edge plates struck upon a line of support, you will find that the " armour-plate is comparatively but little injured, and on removing it from its " backing, you will find that the edge plate has scored more or less deeply into " the back of the armour-plate. Now what does this point to? To the fact " that the edge plate has been driven back with violence upon that which " supports it, viz., that very skin of the ship which you desire to preserve " intact. If the external frames or stringers of the 'Bellerophon' had been " situated within a few inches of each other, I should have considered this " circumstance so serious as to destroy all prospect of success in carrying out " the plan; but with the frames 2 feet apart, it is not so, as the isolated edge the remaining portions by 5-inch, worked upon 10 and 11 inches of teak backing respectively. This was one of the first of our ships in which the device of thickening the armour on portions of the broadside was adopted, a device which has since been extensively employed. The longitudinal girders behind the armour in the 'Penelope' are similar in their arrangement to those of the 'Bellerophon,' but there is not as great a thickness of skin-plating. The turret-ship 'Monarch' has 7-inch armour on the most important parts of the hull, and 6-inch on the other parts, the armour being supported by 12-inch teak backing, with a thickness of skin-plating ($1\frac{1}{2}$-inch) and an arrangement of longitudinal girders similar to those of the 'Bellerophon.' The 'Captain's' protection resembles the 'Monarch's,' except in wake of the turrets, where there is 8-inch armour; the thickness of the backing and skin-plating and the arrangement of the girders are the same in both ships. The ships of the 'Invincible' class have 8-inch and 6-inch armour on the broadside, backed by 8 and 10 inches of teak respectively, and by $1\frac{1}{4}$-inch skin-plating, with the usual arrangement of girders.

The thickness of armour carried has, however, for the present, reached its maximum for sea-going broadside ships in the 'Hercules,' which has 9-inch armour at the water-line, 8-inch on the most important parts of the

" plate of $\frac{1}{2}$-inch iron buckles up under the blow before it can injure the skin. " I will only add on this head that in expressing the foregoing views I am " not neglecting the consideration that closely situated edge plates must tend " greatly to distribute the blow: I am well aware of that fact; but the answer " to it is that the time allowed for distributing the force is very short, and " that so far as they distribute it at all, they distribute the blow upon and " over the skin of the ship, which we wish to preserve, and take it for that " purpose from the armour, which is employed expressly to receive it."

broadside, and 6-inch on the remainder. Outside the $1\frac{1}{2}$-inch skin-plating of this vessel, teak backing 12 and 10 inches thick is fitted, together with longitudinal girders of the usual character. This does not, however, constitute the whole of her protection, for from below the lower deck down to the lower edge of the armour the spaces known as the "wing passages" are filled in solid with additional teak backing, and inside this there is an iron skin $\frac{3}{4}$ inch thick, supported by a set of vertical frames 7 inches deep. The total protection, therefore, of the most vital part of the ship, in the region of the water-line, consists of the following thicknesses of iron and wood:—Outside armour 9 inches; then 10-inch teak backing with longitudinal girders at intervals of about 2 feet, worked upon $1\frac{1}{2}$-inch skin-plating supported by 10-inch vertical frames spaced 2 feet apart; the spaces between these frames are filled in solid with teak, and inside the frames there is a further thickness of about 19 or 20 inches of teak; the whole being bounded on the inside by $\frac{3}{4}$-inch iron plating, stiffened with 7-inch frames. The total thickness of iron (neglecting the girders and frames) is thus $11\frac{1}{4}$ inches, and of this 9 inches are in one thickness; the teak backing has a total thickness of about 40 inches. The trial at Shoeburyness of a target constructed to represent this part of the ship's side proved that it was virtually impenetrable to the 600-pounder gun; and perhaps no better idea of the increase of the resisting power of the sides of our iron-clads can be obtained than that derived from a comparison of the 68-pounder gun which the 'Warrior's' side was capable of resisting with the 600-pounder tried against the 'Hercules' target!

But the limit of the thickness of armour carried must not be considered to have been yet attained. Coast defence vessels and rams are, as I have previously stated, being built to carry 11 and 12-inch armour; the new turret-ships 'Thunderer' and 'Devastation,' lately designed, will carry quite as great thicknesses, and ships have been designed for sea-going purposes, and may yet be constructed, which are to carry even 15 inches of armour. There can be little doubt that, as improvements are made in the manufacture and working of heavy guns, corresponding additions will be made to the resisting powers of the iron-clads built. It is hardly possible to foresee in what way the competition between guns and ships will terminate; but having the experience we possess of the successful accomplishment of what, only a few years ago, were regarded as impossibilities in the construction of iron-clads, it would be folly to attempt to set a limit to the results that will be attained in the future. The Admiralty have long been in possession of a design for a turret-ship with sides plated with 15-inch armour, and turrets with 18-inch armour. I have also prepared outline designs, not on extravagant dimensions, to carry 20-inch armour, both on broadsides and on turrets.

The preceding facts and figures may be briefly summarised as follows, if the ships are grouped according to the thicknesses of their armour and backing, *without regard to the greater or less extent of the surface protected.* For convenience I shall divide them into iron-built and wood-built. In the turret-ships the turret armour is generally a little stronger than the side armour.

	Armour.	Backing.	Skin-Plating.	
	Inches.	Inches.	Inches.	
Iron-built:—				
Scorpion, Wivern	$4\frac{1}{2}$	9	$\frac{1}{2}$	The weakest of our armour-clads.
Viper, Vixen, Waterwitch	$4\frac{1}{2}$	10	$\frac{1}{2}$	But very slightly stronger than the above.
Warrior, Black Prince, Achilles, Defence, Resistance, Hector, Valiant, Prince Albert	$4\frac{1}{2}$	18	$\frac{5}{8}$	All of equal strength to resist shot.
Agincourt, Minotaur, Northumberland	$5\frac{1}{2}$	9	$\frac{5}{8}$	
Bellerophon	6	10	$1\frac{1}{2}$	The greater thickness of skin-plating in this and most of the following ships is obviously equivalent to an increase in the thickness of armour.
Penelope	6	10	$\frac{3}{4}$	
Invincible, Audacious, Vanguard, Iron Duke, Swiftsure, Triumph	6	10	$1\frac{1}{4}$	

NOTE.—The 'Penelope's' armour is only 5 inches thick on some parts of the broadside. The 'Invincible' and her consorts have 8-inch armour on the water-line belt.

	Armour.	Backing.	Skin-Plating.
Monarch, Captain	7	12	$1\frac{1}{2}$

NOTE.—The 'Captain' has 8-inch armour in wake of the turrets.

	Armour.	Backing.	Skin-Plating.
Hercules, Sultan — On belt	9	10	$1\frac{1}{2}$
Hercules, Sultan — Over gun-slides	8	10	$1\frac{1}{2}$
Hercules, Sultan — On sides generally	6	12	$1\frac{1}{2}$

NOTE.—In the 'Hercules,' in the neighbourhood of the water-line, there is an additional protection of about 30 inches of teak backed by a $\frac{3}{4}$-inch iron skin, besides the belt protection named above.

	Armour.	Backing.	Skin-Plating.
Hotspur — On sides	11	12	$1\frac{1}{4}$
Hotspur — On breastwork	8	12	$1\frac{1}{4}$
Rupert — On sides	11	12	$1\frac{1}{4}$
Rupert — On breastwork	12	12	$1\frac{1}{4}$
Glatton, Thunderer, Devastation	12	18	$1\frac{1}{2}$

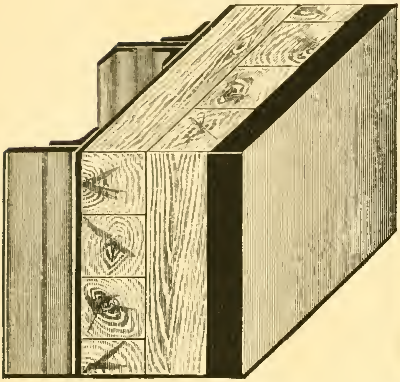
	Armour.	Thickness of Side.	
Wood-built:—	Inches.	Inches.	
Caledonia			
Ocean	4½	29½	
Prince Consort			
Royal Oak			
Zealous		30½	
Pallas		22	
Favourite	4½	26	
Research		19½	
Enterprise		19½	
Royal Sovereign	5½	36	
Royal Alfred	6	29½	
Repulse	6	31	
Lord Clyde	4½	31½	1½-inch inner skin of iron.
Lord Warden			

NOTE.—In these two ships there is a strake of 5½-inch armour at the water-line, and the frame is filled in solid behind the armour, so that in addition to the outer and inner armour the whole thickness of the side is available to resist penetration; in all the other wood ships water can enter when the outside planking, which is only 8 or 10 inches thick, is penetrated.

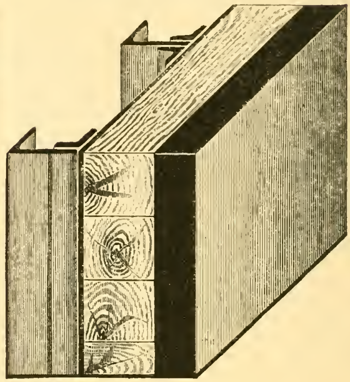
The information conveyed in the preceding summary of the strengths of the respective iron-clads to resist shot is illustrated in the accompanying woodcuts, which show specimen blocks cut out of the sides of a number of the ships that may be taken as types of the various classes. The 'Kalamazoo' may be taken as a specimen of the latest and strongest class of American monitors.

After the above brief statement of the thickness of armour carried by our own ships, it may not be uninteresting if I give a few facts of a similar character with respect to the armoured vessels of the French and American navies. The 'Gloire' class, and the 'Magenta' and 'Solferino,' have armour a little over 4½ inches thick, worked upon ordinary wooden hulls. The same thickness of armour as the 'Warrior's' is carried by the iron-built frigate 'Couronne,' and by the small wooden floating batteries of the 'Palestro' class; all the other floating batteries are iron-built, and have 5½-inch

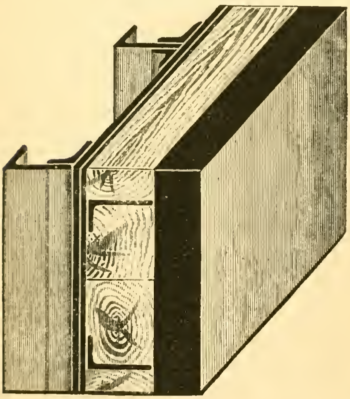
WARRIOR



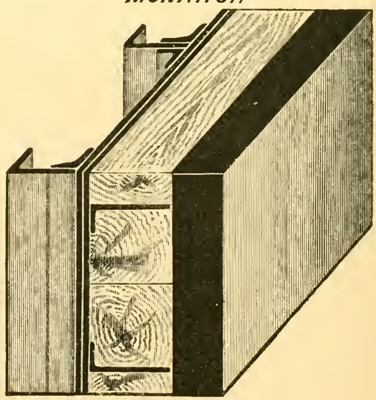
NORTHUMBERLAND



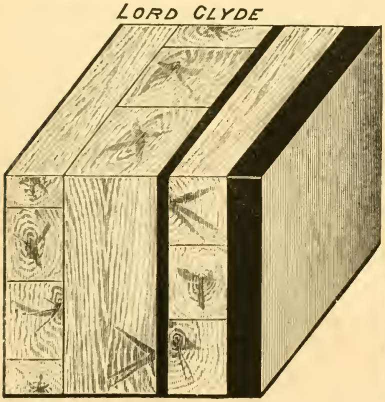
BELLEROPHON



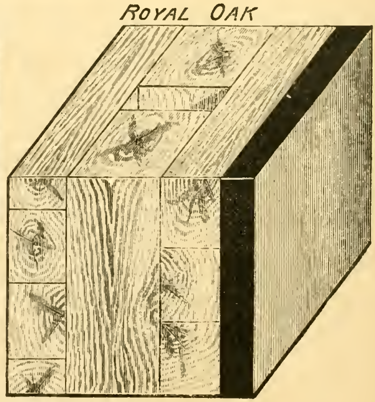
MONARCH



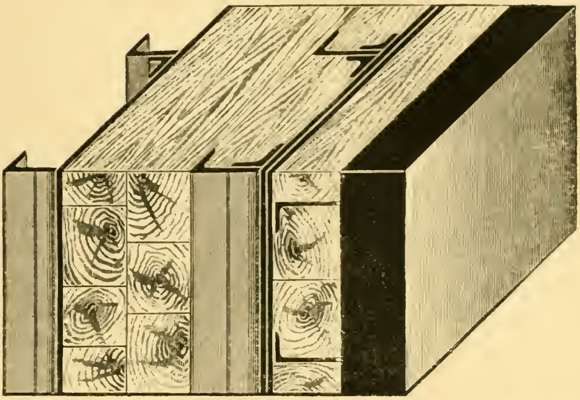
LORD CLYDE



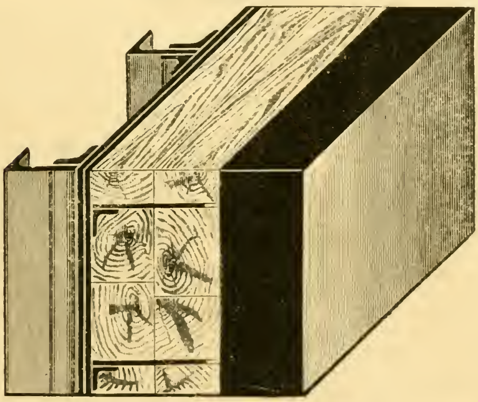
ROYAL OAK



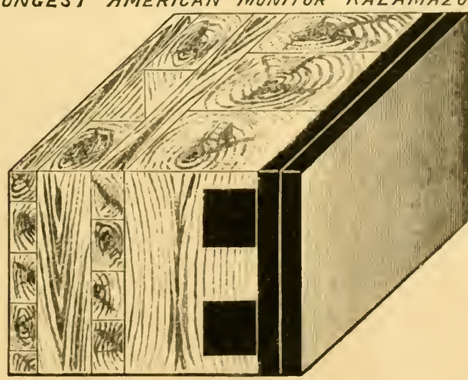
HERCULES



THUNDERER



STRONGEST AMERICAN MONITOR "KALAMAZOO"



armour. The frigates of the 'Flandre' class, and the ram 'Taureau,' have armour a little less than 6 inches thick outside wooden hulls; while the armoured corvettes or second-rate frigates of the 'Alma' class have $5\frac{8}{10}$-inch armour at the water-line, and $4\frac{8}{10}$ and 4-inch on other parts of the hull. The vessels of the 'Marengo' class (corresponding nearly to the 'Invincible' class of our own Navy) have $7\frac{8}{10}$-inch armour at the water-line, and $6\frac{1}{5}$-inch and 4-inch on other parts; while the rams of the 'Bélier' class have $8\frac{2}{10}$-inch and 7-inch armour, the strongest carried by any French vessel yet built. It may be proper to add that by far the greater number of French iron-clads are wood-built, and that the armour is simply secured outside the planking of the wooden hulls, no inner skin-plating or longitudinal girders, similar to those of the English ships, being worked. This fact renders the French ships weaker than our vessels, even when the thicknesses of the external armour and of the backing are equal; and to bring this difference more clearly before the reader, I cannot do better than quote from Captain Noble's 'Report on Various Experiments carried out under the direction of the Ordnance Select Committee, &c.' He says*:—
"It might appear at first sight that wood backing "would have the effect of strengthening an iron plate "the results, however, of a very large number of cases "go to prove the opposite, namely, that the backing "affords little, if any, support to the plate unless it be "of the rigid form, such as the 'Chalmer,' 'Hercules,' "and 'Bellerophon.' In other words, if a shot is

* See page 36 of the Report 'On the Effect of Backing to Iron Plates.'

"capable of penetrating an unbacked $4\frac{1}{2}$-inch plate, it "will perforate it or break it away equally if it be "backed by wood alone . . . . . We have evidence, "however, that a rigid backing is a great advantage. "This was particularly apparent in the case of the "'Hercules,' where the plates were not perforated by "some shot which struck with sufficient 'work' to "penetrate them completely if unbacked. We have "also evidence of the great superiority of packed "backing of teak, such as in the 'Warrior,' 'Minotaur,' "&c., over the ordinary side of a line-of-battle ship, "and of the great support which an inner skin affords. "Thus it required 33 foot-tons per inch of shot's cir-"cumference to penetrate the backing and skin of the "'Warrior,' viz. 18 inches of compact teak, and a "$\frac{5}{8}$-inch iron plate strengthened and supported by iron "ribs; and we see that 16 foot-tons per inch were "sufficient to penetrate the side of an ordinary line-of-"battle ship, viz. 25 inches of oak. We also find that "the backing of the 'Lord Warden' required 58 tons "per inch, and of the small plate target about 16 tons "per inch. This shows the vast superiority of com-"pact backing supported by internal iron plates." It need only be added that the "small plate" target here referred to was constructed in such a manner as to fairly represent the armoured side of a French frigate of the 'Flandre' class, although the chief interest of the trial consisted in the use of small plates and wood-screw fastenings, instead of the larger plates and through fastenings employed in our ships.

In the American navy what is known as "laminated" armour has been almost universally adopted, the protecting material being made up of several thicknesses. This plan was at first necessitated by the fact that thick armour-plates could not be produced in anything like the required quantity by the ironworks in the country. A few ships have been constructed with solid armour, the greatest thickness being carried by the 'Roanoke,' which has 5½-inch plates; and the other vessels having, for the most part, 4½-inch armour. With the exception of these three or four vessels, the American iron-clads have laminated armour, which the trials made at Shoeburyness prove most conclusively to be far inferior in its powers of resistance to solid armour of the same thickness. Nearly all the monitors have their armour made up of several thicknesses of 1-inch plate, backed in some cases by what are termed "armour stringers," or plank armour of very small breadth and of moderate thickness. Even when thus strengthened, however, laminated armour is not to be compared with solid plates. In January, 1862, the Iron Plate Committee carried out some experiments against targets constructed on the laminated principle by Mr. Hawkshaw, and the results will be found in Captain Noble's very able Report.* Only a few experiments were made, so that no exact estimate of the relative strengths of solid and laminated armour can be based upon them; but, as Captain Noble observes, they show "that laminated "armour is considerably weaker than solid armour," and that "a 4-inch solid plate would have effectually "stopped all the projectiles, whereas they easily pene-"trated 6 inches of laminated plates." It is interesting

* See page 25 of the Report.

to observe that the law of the resistance of single armour-plates varying as the square of the thickness—which law has been established by direct experiment for thicknesses up to $5\frac{1}{2}$ inches, and is perhaps approximately true for greater thicknesses—is not conformed to in the comparison of solid and laminated armour. For example, a 4-inch solid plate would be sixteen times as strong against penetration as a 1-inch plate, but would not be four times as strong as four 1-inch plates riveted together and forming laminated armour of equal thickness with the solid plate, although it would undoubtedly be much stronger than the laminated arrangement. In short the multiplication of thin plates has a tendency to increase the amount of their proportionate resistance, and it would be most improper to apply the law of the resistance varying as the square of the thickness to the comparison of such an assemblage with a solid plate of equal thickness.* At the same time there is

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* The subject of laminated armour came into prominence also during the investigation respecting the "Gibraltar" shields which was conducted in 1867-68 by a Special Committee, whose Report has since been presented to Parliament. Captain Noble's evidence (at p. 35 of the Report) is especially interesting on this point, and he gives some valuable information respecting trials made at Shoeburyness on the relative resistances of 7-inch armour when made up of one plate, or of two or three thicknesses. He states that these resistances to penetration were in the proportions of 61, 57, and 52; the solid plate being about one-fourteenth stronger than the armour made up of two $3\frac{1}{2}$-inch plates, and one-sixth stronger than that made up of three $2\frac{1}{3}$-inch plates. After giving these figures, Captain Noble remarked that "these results show "that plates thus built up in thick layers, bolted together, afford a very large "amount of resistance to perforation, although they are not quite equal to a "solid plate;" but drew a marked distinction between this arrangement and the laminated structures, such as the American monitors' armour, in which a number of thin plates are used. There is, no doubt, great justice in these opinions, although Captain Noble's final conclusion respecting the most favourable application of the plate-upon-plate system still gave the advantage to the solid plate, and made a 13-inch plate equal to three 5-inch plates riveted together.

In a Paper (published in volume xvii. of the Royal Engineers' 'Professional and can be no question that armour-plating is much more effective in resisting projectiles when rolled in

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Papers') on 'Experiments on Iron Armour,' Colonel Inglis has given an interesting account of experiments made to determine the relative resistances of solid and built-up armour. I use the term "built-up" in contradistinction to "laminated," because the targets fired at were formed of two or three thicknesses of 5-inch plates, and such structures obviously are not at all comparable with the American laminated armour, in which plates only 1 inch thick are used. From these experiments Colonel Inglis concludes that a solid 10-inch plate is very little, if anything, stronger than 10-inch armour formed by fastening together two 5-inch plates; and that a solid 15-inch plate, while it proved better than three thicknesses of 5-inch plates against a single blow, is more liable to break up extensively under repeated blows than the built-up armour. There are several points in connection with these experiments which, in my opinion, render them far from conclusive on the question at issue, but to which I cannot refer at length. One fact, however, may be mentioned as an illustration of this remark, viz., that the 10-inch plate taken as the representative of solid armour had been previously fired at in testing it as a sample, and had also been used as a target for testing Palliser and other projectiles. Colonel Inglis himself says that "there was not clear space left on the plate for more "than three rounds, but where they were planted it was quite uninjured." The opinion here expressed with respect to the condition of the "clear space" left after the tremendous battering which the plate had undergone, is one which I cannot entertain in view of our experience with armour-plates that have been subjected to the fire of heavy guns. It must be stated also that the targets experimented upon were built and fastened in a manner that could not be adopted for the side-armour of ships; that the bolts connecting the three plates were not aimed at; and that the trials were made exclusively to determine the relative worth of the two systems of armour-plating as applied to land fortifications. A careful study of these trials, however, still leaves the impression that solid armour is stronger than built-up armour, even when such considerable thicknesses as 5-inch plates are used in the latter. Colonel Jervois, in a paper on 'Coast Defences,' says also that "experiments have shown "that the resistances to penetration of thick solid plates are not so much greater "than those of an equal thickness made up of several layers of comparatively "thick plates," thus indirectly confirming the opinion expressed above.

For land fortifications it is more important to economise in cost than in weight of armour: in ship construction this is not so; and it would obviously be better to apply the solid plates, which give greater protection in proportion to the weight. All this, be it observed, is independent of the consideration that the through fastenings of the layers of plates must be very liable to injury, and that the protection would therefore suffer by the breaking of the fastenings, as was found to be the case in the actual trials both on the Hawkshaw targets and on the "Gibraltar" shields. This liability has, it is true, been since reduced by means of various devices, but these do not entirely remove it, and they could not be so satisfactorily applied on a ship's side as they can in a shield for land fortifications.

solid plates than when made up of several comparatively thin plates; and besides this, it must be remembered that the connection of the various layers of thin plates requires the employment of numerous large rivets or bolts, and that the liability to injury from the impact of projectiles is thus greatly increased. The wood backing fitted in the monitors is, in many cases, of great thickness, but it is not nearly so efficient as the backing and girders of our ships; and the system of armour fastenings adopted is not to be compared with that of our Navy.*

Keeping these facts in view, I would now invite attention to a short statement of the thicknesses of armour carried by the principal American iron-clads, excluding from consideration the few ships which have solid armour (to which reference has been made above) and the light-draught vessels built for river service. The original 'Monitor' had her hull protected by five layers of 1-inch plate, diminishing first to 4 inches and then to 3 inches in thickness below the water. The wood backing was 27 inches thick, and was bolted to $\frac{5}{8}$-inch iron plating forming the skin of the ship. The next vessels built—the 'Passaic' class—have armour of the same thickness as the first 'Monitor,' but have 39 inches of wood backing. The 'Canonicus' class have the five layers of 1-inch plates supported by two "armour stringers" let into 27-inch wood backing, in the neighbourhood of the water-line, the intention being to increase the strength of this part of the side. How

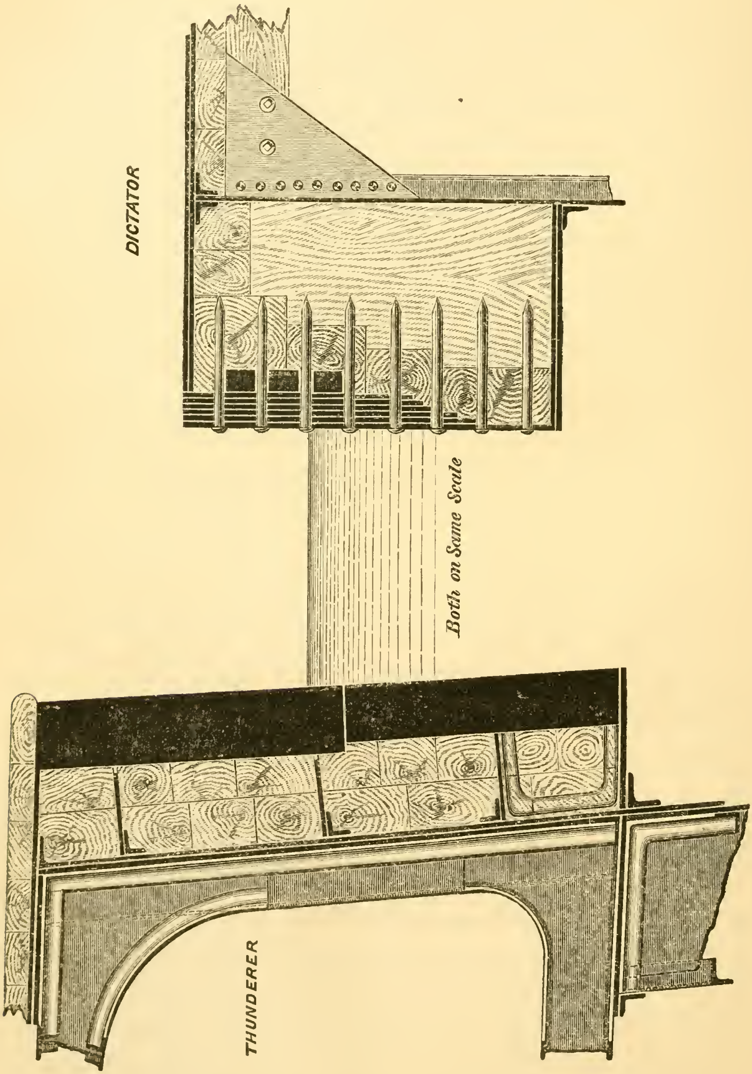
* Full particulars of the various systems of armour fastenings proposed and adopted, as well as detailed information concerning the practical processes of preparing and fixing armour-plates on the sides of ships, will be found in chap. xxi. of my work on 'Shipbuilding in Iron and Steel.'

small the increase must be will appear when it is stated that these stringers are only narrow planks of iron $6\frac{1}{2}$ inches broad, and, for the most part, 4 inches thick; that they are totally unconnected with each other, and that the additional protection thus afforded extends in all over a breadth of 15 inches only. The 'Minatonomoh' and the 'Monadnock,' which are the best-known vessels of this class, owing to their ocean voyages in the Atlantic and Pacific, appear from American authorities to be protected in nearly the same manner as the 'Canonicus,' but they are wood-built. The 'Puritan' and the 'Dictator' have six layers of 1-inch plates on their sides, with wood backing 42 inches thick, into which three "armour stringers" 5 inches thick are fitted near the water-line, this additional protection extending over a depth of 25 inches only. In the 'Kalamazoo' class the total thickness of armour (6 inches) is made up of two layers of 3-inch plates, backed by 30 inches of oak, the side in the neighbourhood of the water-line being strengthened by three armour stringers, 8 inches broad, and of equal thickness, which are let into the backing. These stringers are a few inches apart, and the additional protection, including the intervening spaces, extends over a depth of less than 4 feet near the water-line. This is by far the most formidable armour carried by American ships of the monitor type, and is sometimes referred to as representing a protection of 14 inches of iron; but while it is true that this is the total thickness of armour in some parts, it is also true that in other parts the protection is limited to the two thicknesses of 3-inch plates, and that in no part is the side nearly as strong as it would be when covered with 14 inches of *solid* iron.

The rapid diminution of the thickness of the armour of the American vessels is a point too frequently lost sight of, because the practical effect of it is to give even the largest and most powerful of the monitors next to no protection below water. If we take the case of the 'Dictator,' for example, we shall find that in this respect she literally bears no comparison with our own vessels. At a distance of $2\frac{1}{2}$ feet below the load water-line, she has but two 1-inch plates to protect her; and at a distance of 3 feet, but one such plate. In the engravings on the next page I have placed a section of her armour and of the armour of the new English turret-ships 'Thunderer' and 'Devastation' side by side. In the 'Kalamazoo' class, which are the most effectually plated of the American vessels, the lower edge of the lowest block of iron backing is but 18 inches below the water, and at 2 feet 9 inches below water the plating is but 3 inches thick.

To these remarks on the hull-armour of these vessels it may be proper to add a few on the turret-armour. The first 'Monitor' had the turret made up of eight thicknesses of 1-inch plates, and the vessels which succeeded her—the 'Passaic,' 'Canonicus,' and others—had eleven thicknesses. The later ships, such as the 'Dictator' and 'Kalamazoo,' have turrets 15 inches thick, made up of an inner drum of four or five layers of 1-inch plates, and an outer drum similarly constructed, and made up of five or six layers of plates, with segments of wrought-iron hoops, 5 inches thick, placed between the two drums. No wood backing or frames are used in the construction of these turrets.

I have thus thrown together in a brief space the principal facts connected with the thicknesses of armour carried by the ships of the American, French, and



British navies, and would now pass to an allied topic of great importance, viz., the disposition of the armour on the hulls. In our earlier iron-clads the protection is only partial, extending over a portion of the length of the broadside. No better example of this system can be chosen than the 'Warrior.' Her length is 380 feet, and the armoured portion is only 213 feet in length, the extremities of the ship being left entirely unprotected. At the ends of the armoured portion, both before and abaft, iron-plated bulkheads are built across the ship, and enclose a central or "box" battery, on the sides of which the armour extends from the upper deck down to a little more than 6 feet below water. By limiting the armour to the middle portion of the ship, the weight to be carried is, of course, considerably reduced, and very fine bow and stern lines can be obtained, thus rendering the vessel's speed very high in proportion to her engine-power. Outside the battery, the hold of the ship is divided into numerous watertight compartments, so that, even if the side should be pierced, the safety of the vessel might be ensured. The necessity for this precaution will appear from the consideration that for nearly 170 feet of the length, the side is as penetrable to projectiles as that of an ordinary iron ship; and even when all care has been taken to subdivide the extremities, the rudder head and steering apparatus are left entirely unprotected. This system of partial protection is also adopted in the 'Black Prince,' 'Defence,' and 'Resistance;' but the desire to increase the amount of protection led to the introduction into the 'Hector' and 'Valiant' of a modification of the 'Warrior's' disposition of armour. This modification consisted in adding a belt of plating, extending from the upper to the main decks, before and abaft the main portion of the broadside armour, which was arranged similarly to the 'Warrior's.' The main deck, on which the guns are fought, is thus protected throughout the entire length, but the extremities "between wind-and-water" are quite as unprotected as those of the 'Warrior,' and the hold is divided into numerous watertight spaces as previously described.

Both these plans of disposing the armour were afterwards considered unsatisfactory, and resort was had in the 'Minotaur' class, and in the converted ships of the 'Caledonia' class, to the system which had been introduced into the construction of the floating batteries built during the Crimean war, by means of which what is known as "complete protection" is secured. Throughout the length the armour extends from the upper deck down to about 6 feet below the water-line. The same system of protection is followed in all our turret-ships, except the 'Monarch,' and the breastwork monitors; but the upper decks of these vessels are at a considerably less height above water than those of the frigates. The principal advantages possessed by this disposition of the armour over that of the 'Warrior' are that the extremities of the ship, and especially the parts near the water-line, are iron-cased, and that the protected guns can be ranged along the length of the broadside instead of being concentrated in a central battery. There are, however, the accompanying disadvantages of having the bow and stern heavily burdened, and of requiring a great increase in the total weight of armour. For wood-built iron-clads this plan has the additional advantage of protecting the upper works throughout the length from the destructive effects of shells. The French ships are, for the most part, plated in this manner, the principal exceptions being found in vessels designed within the last four or five years.

The great development in the power of ordnance, made almost simultaneously with the introduction of armour-plating, led not only to increase in the thickness of armour carried, but to changes in the system of protection, or, in other words, to different modes of disposing or arranging the armour. As we have seen, the 'Warrior' has 4½-inch armour over a limited portion of the hull—a "patch" on each side, to use a phrase which the *Times* once applied with less fairness to more recent vessels. The 'Minotaur' on the contrary is completely armoured from stem to stern, and was made 20 feet longer than the 'Warrior' for the purpose of accomplishing this result, and retaining a fine form. The system introduced by myself, first in the small sloop 'Enterprise,' and subsequently in the 'Bellerophon,' 'Hercules,' and other large ships, consists in completing the ship's armour in the region of the water-line, but not in wake of the gun-deck. In fact, this system, as far as arrangement of armour is concerned, consists in taking a middle course between the 'Warrior' and 'Minotaur.' Add a deep water-line belt to the 'Warrior,' and you have the more recent arrangement; or take away the gun-deck armour of the 'Minotaur' at the ends of the ship, and you have the same thing. After the conversion of the 'Enterprise' was ordered, each of these measures was actually taken with ships of the classes named. The 'Achilles,' a ship of the 'Warrior' class, had the water-line belt added; and the 'Northumberland,' a ship of the 'Minotaur' class, had the gun-deck armour omitted from the ends. The new plan is known as the "central battery and armour belt system," the protected guns being placed in a battery, like the 'Warrior's,' of which the fore and after ends are shut in by armoured bulkheads built across the ship. By this arrangement the great weight of the armour and armament of the battery are in the middle of the length, and the extremities of the ship are not overloaded with an immense weight of iron as in the 'Minotaur.' The armour belt extends from a few feet below water up to a moderate height above, usually ending at a deck of which the beams are covered with stout iron plating, by means of which the parts of the vessel before and abaft the battery are protected against the effects of dropping or oblique fire. The belt serves not only as a protection to the most vital parts of the ship but also as a shield to the rudder-head and steering apparatus; and the plan is obviously extremely favourable to the use of larger guns and thicker armour than are usual, as it favours the contraction and concentration of the armour and armament without exposing the vital parts of the ship.

Compared with the 'Warrior's' or the 'Minotaur's' disposition of armour, the new plan has advantages that cannot fail to have struck the reader, but which it may not be amiss to briefly summarise:—At the bow and stern, the 'Warrior' is so readily penetrable as to render it certain that the water would find its way inboard; and though the ship's safety might be ensured, or at the least prolonged, by the watertight compartments, yet it will not be doubted that a very serious reduction in speed would ensue, and that it would be better, if possible, to prevent penetration altogether. The armour belt does this, and by also protecting the steering apparatus supplies an important feature which is entirely wanting in the 'Warrior.' If the new plan is compared with the system of complete protection, exemplified in the 'Minotaur,' it will appear that the former admits of a much greater thickness of armour being carried by ships of moderate dimensions than the latter. It must, of course, be obvious that completely armoured ships can carry a larger number of protected guns than ships with partial plating; but this is of comparatively little moment, as the tendency in modern war ships is to increase the size and diminish the number of the guns. No more striking example of this can be found than in the 'Minotaur,' which was intended to carry 20 guns a side on the main deck and carries 11 only, the weight of the guns carried having been increased from 100-pounders to $6\frac{1}{2}$-ton and 12-ton guns. With a central battery of moderate length it is, therefore, possible to carry as large a number of heavy guns as is thought desirable, or at least as many as would give far greater offensive power than numerous light guns; and the range of training of these large guns can be made as great as, or greater than, that of the guns in a completely protected ship. The manner in which this result is attained will be described in another chapter, but it may be stated here that in the 'Bellerophon,' 'Hercules,' and other ships, there are also protected batteries at the extremities in which bow and stern chasers are placed, the lengths of these batteries being comparatively small, and the weight of protecting armour not so considerable as to heavily burden the extremities.

An important alteration has been made in the disposition of the armour in the 'Invincible' class, the plating being continued up to such a height above the upper deck for a portion of the length amidships as to protect four heavy guns mounted at the angles of an octagonal battery, of which the ends are enclosed by transverse iron-plated bulkheads. These guns can be fired in the line of the keel as well as on the broadside, and as they are at such a considerable height above water, could be fought in weather when the ports of the main-deck battery could not be opened. Previously to the design of these vessels, the 'Lord Warden' and 'Lord Clyde' had been supplied with powerful armoured bow batteries on the upper deck, but the later arrangement has many advantages.

In their recent ships, the French have given up the system of complete protection, and have adopted the central battery and armour belt. They adopted the same arrangement, however, much earlier in the two-decked iron-clads, 'Magenta' and 'Solferino,' although their frigates are mostly armoured throughout the length. In their latest ships of the 'Marengo' class, the arrangements are of a very similar character to those of the 'Invincible' class in our own Navy, there being protected batteries amidships on both the main and upper decks, the latter commanding an enlarged horizontal range of fire.

But few remarks are needed with respect to the arrangement of the armour on American ships. Their broadside frigate, the 'New Ironsides,' was only partially protected, and the monitors are, of course, protected throughout the length from the upper deck down to a few feet (usually about 4 feet) below water. The small amount of free-board, or height out of water, in these vessels reduces the area of the armoured surface of the target presented by the ship's side, and lessens the weight of armour required. A further reduction in weight is effected, as before explained, by ending some of the layers of plating at a very small distance below water; but this obviously greatly reduces the resisting power of the side, as the example of the 'Dictator' clearly shows. This is a most important point in connection with the protection of the monitor class; and another feature deserving special notice is the necessity which exists of adding very greatly to the weight and thickness of the iron upper deck in order to prevent penetration by depressed fire, a danger to which these vessels are peculiarly liable on account of their small height out of water. This is a point much neglected by amateur advocates of turret-ships with extremely low free-board, but one which is really of vital importance, and which has been so recognised by Mr. Ericsson and other American constructors; while in our own Navy we have an example of the high estimation in which the Admiralty hold this matter in the monitors which they are now building, and which have iron upper decks 2, $2\frac{1}{2}$, and 3 inches thick. The area of this deck in the 'Glatton,' for example, is 11,348 square feet; the total weight of 3-inch plating for such an area of deck is about 608 tons, a weight sufficient to increase the free-board of such a ship by 7 feet, even if the whole additional height of side were plated, say, with 9-inch armour. These facts cannot fail to bring home to the reader's mind the importance attaching to the proper protection of the decks of ships of the monitor type, and to show that the total weight of armour required in these vessels is not so much less than that in broadside ships of the same principal dimensions, but having a greater height of free-board and thinner upper deck, as many persons suppose. The fact is that with a low free-board you are at liberty to apply to the protection of the deck the armour which, if applied on the broadside, would leave the deck still exposed, thus either rendering further armour necessary or exposing the ship to depressed and vertical fire. It is in this that the real economy of armour in ships of low free-board lies.

Before concluding this chapter, I desire to make a few remarks respecting the arrangement of the armour on the so-called "breastwork monitors," designed within the last two or three years at the Admiralty. These ships resemble American monitors in having their upper decks at a comparatively small height above water; but instead of having those decks flush, except where the turrets, the funnels, air-shafts, and casings to hatchways rise above the deck-height, they have a space amidships, enclosed by an armoured breastwork, which rises several feet above the deck, in which space the turrets, funnels, air-shafts, and principal hatchways are situated. By this means the actual height of free-board is increased considerably for a large portion of the length; the height of the turret ports above water is made much greater than is usual in the American monitors; the liability to serious injury, resulting from the perforation of the deck, funnels, &c., is much reduced; and other advantages are gained, to which I shall refer more particularly in the chapter on turret-ships. For the present I desire to deal only with the comparative powers of carrying armour possessed by ships built on the American and English systems, and for this purpose a brief statement will suffice.

Supposing two ships to be built having the same height of upper deck above water, and the same thickness and weight of side armour, the question arises whether it would be better to protect the lower parts of the turrets, the funnels, and the air-shafts, as well as all the openings in the deck, by separate patches of armour, or to have an enclosing breastwork, which would protect all those parts. It will be obvious that, if the former plan were adopted, the deck would have to be completely plated over with strong iron, while the latter plan would render it unnecessary for the large space enclosed by the breastwork to be so strongly protected. This gives a considerable advantage to the breastwork monitor, and one which would be little, if at all, diminished by the difference in weight between the armour on the breastwork and the armour required for protecting separately the various parts enumerated above. For instance, in a ship with two turrets, the weight of armour on the lower parts of the turrets, the funnel, and the air-shafts—all of which must be plated for a considerable height above the low deck, in order to prevent penetration and the consequent entry of water into the interior of the ship—together with that protecting the hatchways, would not fall below the weight of armour on a breastwork surrounding the bases of all these parts.

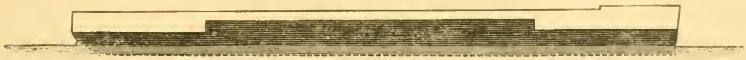
The breastwork system compares still more favourably with that employed in the 'Prince Albert,' 'Captain,' and other turret-ships, in which a height of free-board of 7 or 8 feet has been adopted, in order to raise the turret guns a considerable height out of water. In these vessels the hulls are armoured throughout the length up to the height of the upper-deck beams; but by adopting the breastwork and low free-board, the turret guns can be carried at as great a height above water as in ships with a greater height of upper deck above water, or even higher, and the total surface to be armoured is diminished. It is possible, therefore, either to carry a greater thickness of armour on certain dimensions on a breastwork turret-ship than can be carried by a turret-ship of the 'Captain' type, or to carry as thick armour on a breastwork ship of smaller dimensions.

In order to render the preceding descriptions still clearer, I have given in the accompanying engravings illustrations of the various methods of disposing the armour upon the hulls of our iron-clads. In each case the darkened part represents the armoured portion of the ship, and the lower dotted lines indicate the positions of the lower edge of armour. It is only necessary to add that the 'Cerberus' is taken as the type of breastwork monitors; and that it has been considered unnecessary to give a sketch of a completely protected ship, as by omitting the upper-deck bow battery of the 'Lord Clyde' the reader will have a representation of that arrangement.

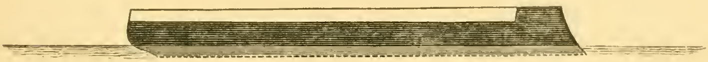
WARRIOR

HECTOR

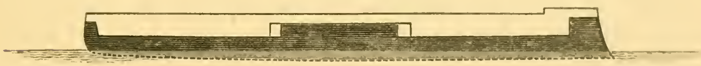
ACHILLES



LORD CLYDE



HERCULES



INVINCIBLE

CERBERUS

MONARCH

CAPTAIN

CHAPTER III.

ARMAMENT OF THE IRON-CLADS.

THE powers of offence of our iron-clad ships have grown simultaneously with their powers of defence, and in the preceding remarks on the thicknesses and arrangement of armour-plating I have of necessity alluded, more than once, to the progress made in naval ordnance within the last few years. A very few remarks on the armament of these vessels will, therefore, suffice to complete the reader's information on the subject.

The offensive powers of a war ship are principally measured by the number and power of her guns, and by the training which those guns command; while in iron-clad ships protected guns are those which must be chiefly considered. The wooden line-of-battle ships and frigates of which the strength of our navy consisted previously to the building of the 'Warrior' were armed with 68-pounders weighing 95 cwt., 8-inch guns weighing 65 cwt., and 32-pounders of which the heaviest weighed 58 cwt. and others only 42 cwt. The 68-pounders were usually mounted as pivot-guns, and the 65-cwt. guns were the heaviest mounted on the broadside, while the bulk of the armament was formed of 32-pounders. These guns, being distributed along the broadside and arranged as bow and stern chasers, commanded the whole sweep of the horizon;

and, as previously remarked, in some cases great sacrifices were made to accomplish this result. A great advance was made upon the weight of the broadside guns carried by the 'Warrior,' her armament consisting, at first, entirely of 68-pounders. The original intention was to have thirty-six of these guns, two being mounted as pivot-guns on the upper deck, and twenty of the remainder being placed in the protected battery on the main deck. These twenty guns constituted the real strength of the ship, considered as an iron-clad, as the sixteen carried outside the battery were even more liable to injury than they would have been in a wooden ship; but the arcs of training of the protected guns were extremely limited (only extending about 25 or 30 degrees before and abaft a transverse line), and there was, consequently, an entire want of command over by far the greater part of the circle of training, and of direct ahead or astern fire. Similar remarks apply to the protected guns of the 'Black Prince,' 'Defence,' and 'Resistance.' In the vessels of the 'Minotaur' class, provision was, however, made for bow and stern fire; a transverse armoured bulkhead was built across the ship at about 25 feet from the bow, and the chase guns were fought behind the bulkhead upon the upper deck.

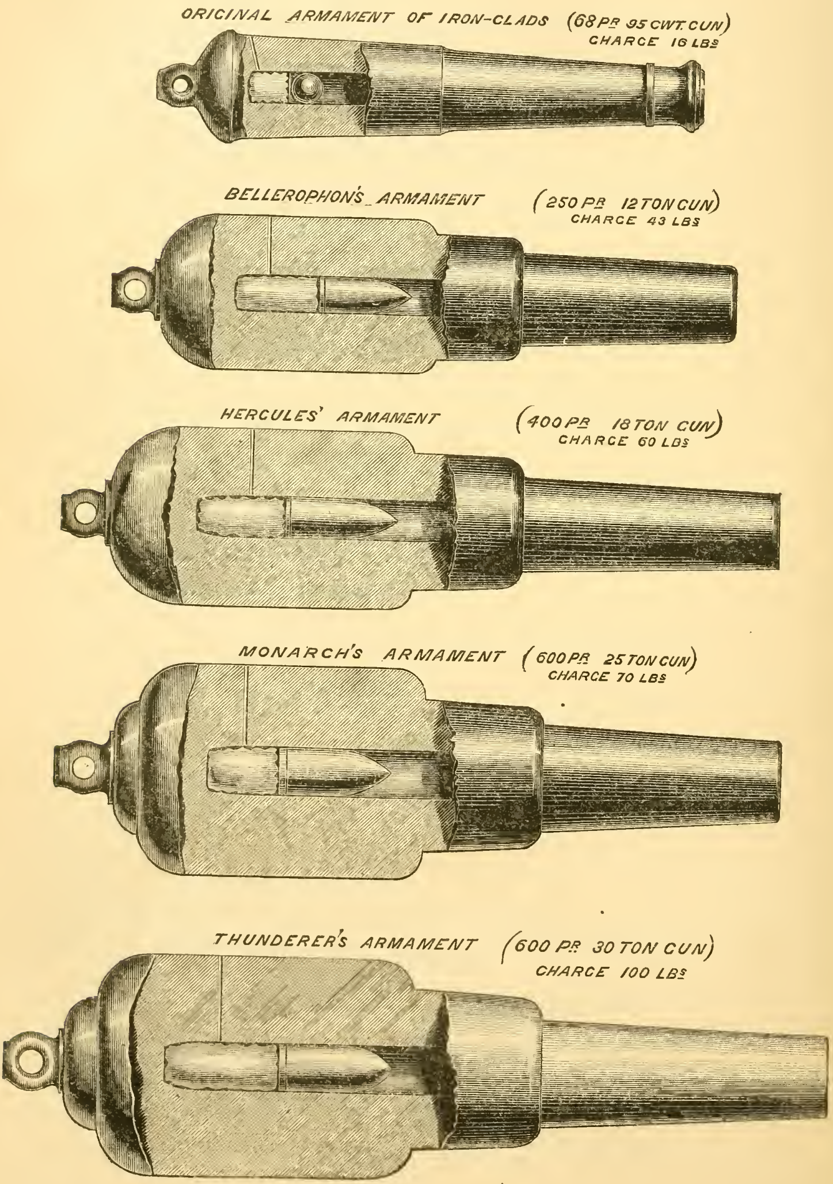
I need not trace the various steps by which the advance has been made in the power, weight, and training of our naval guns, or describe the many and ingenious contrivances that have been introduced by Captain Scott and others into the mounting and working of heavy guns. Suffice it to say that, instead of the 68-pounders of the 'Warrior's' original armament which failed to penetrate the 'Warrior' target at 200 yards' range, we now have 6½-ton guns that would pierce the 'Warrior's' side at 500 yards, 12-ton guns that would do the same at 2000 yards, and 25-ton guns that would probably penetrate any iron-clad afloat, before the construction of the 'Hercules,' at a range of 4000 yards, while 30-ton guns will be carried by the 'Thunderer' and 'Devastation.' The armaments of the earlier iron-clads have, of course, been changed as heavier guns have been introduced, and as a representative case we may take that of the 'Minotaur,' which has been previously alluded to. This vessel was designed to carry fifty comparatively light Armstrong guns, forty of which were to be placed in the main-deck battery, two to be used as protected bow-chasers, and eight to be unprotected on the upper deck. As now arranged, her armament consists of four 12-ton and eighteen 6½-ton guns in the battery, and of four 6½-ton guns on the upper deck, two of which are protected by an armoured bulkhead. The number of guns (exclusive of boat and field guns, &c.) now carried is, therefore, only one-half of that at first intended; but as their power is so much increased, the wisdom of the change is too apparent to need any comment.*

* In referring to this subject at the Royal United Service Institution in 1863, Captain Scott made the following interesting remarks:—"The size of "the gun is of vast importance, more than is generally assigned to it, and for "this reason—20 guns, each a 1-pounder, are fired at a target of iron 1½ in. "thick, and produce no effect; one gun, a 20-pounder, is fired and smashes it, "the velocity in both cases being equal; in both cases the same amount "of metal is used; and on this principle an official record of experiments at "Portsmouth states that one 68-pounder produced more destruction than five "32-pounders. Arguing from this, it appears that one 150-pounder is more "effective than ten 68-pounders, one 330-pounder is equal to seven 150-"pounders, and a broadside of three 330-pounders is more destructive than

While, in ships already built, the substitution has been made of a moderate number of heavy guns capable of piercing the sides of most iron-clads, for a considerable number of lighter guns which would be virtually powerless against the greater number of armoured vessels, it has naturally formed part of the design of later ships to make provision for fewer but much heavier guns. For example, the 'Bellerophon' carries ten 12-ton guns in her central battery, and three 6½-ton guns on other parts of the main deck (two of the latter being in an armoured bow battery), besides two more 6½-ton guns on the upper deck; and the 'Hercules' has eight 18-ton guns in the central battery, two 12-ton guns in protected batteries at the bow and stern, and four 6½-ton guns on the upper deck, the latter being unprotected. These 18-ton guns, throwing projectiles of 400 lbs. weight, are the most powerful yet mounted on the broadside, but the arrangements for working them were so complete as to leave no doubt of their successful management—an anticipation which has been fully realised in the trials since made at sea. The armaments of the turrets of the 'Monarch,' 'Captain,' and 'Glatton,' are to consist of 25-ton guns throwing 600-lb. shot, and the monitors 'Thunderer' and 'Devastation,' designed this year (1869), are, as I have said, to have 30-ton guns. Judged simply by the projectiles, the progress made in naval ordnance must seem enormous

"10½ Warriors." In this last statement the 'Warrior's' broadside is taken at twenty 68-pounders. Captain Scott also gives a table based on this principle, which will be found in the *Journal* of the Institution for 1863. Without considering these deductions to be exact, we may take them as the result of the attempts made by an experienced officer to infer from actual experiment what the comparative value of different guns would probably be.

when the 68-lb. cast-iron spherical shot of the 'Warrior's' guns is compared with the elongated,



steel or chilled-iron projectiles now used, which for the 'Bellerophon's' guns weigh 250 lbs., for those of the 'Hercules' 400 lbs., and for the turret-ships' guns 600 lbs.; and when we add to this the substitution of rifled ordnance for smooth-bore, the advancement made in the last few years seems still more striking. The effects produced by these enormous shot, propelled by heavy charges of powder, we should naturally expect, would be out of all comparison with those produced by the old ordnance; and in order to present the reader with the means of partially comparing the powers of our present guns and those of the guns carried by our wooden fleet and our earliest iron-clads, the accompanying engravings and table are given *:—

Description of Gun.	Weight of			Initial Velocity with Highest Charge.	"Energy" per inch of Shot's Circumference		Total "Energy" of Projectile at 1000 Yards
	Gun.	Projectile.	Highest Charge.		At Muzzle.	At 1000 Yards.	
Cast-iron, smooth-bore:—	Tons. Cwts.	lbs.	lbs.	Feet.	Foot-tons.	Foot-tons.	Foot-tons.
32-pounder	2 18	32	10	1690	..	..	..
8-inch (shell gun)	3 5	49½	10	1488	..	..	..
68-pounder	4 15	68	16	1579	46	18	452
Wrought-iron, muzzle-loading rifled:—							
7-inch	6 10	115	22	1430	75	52	1143
8-inch	9 0	180	30	1330	88	66	1659
9-inch	12 0	250	43	1340	111	85	2403
10-inch	18 0	400	60	1290	148	123	3863
12-inch	25 0	600	70	1212	163	137	5165
12-inch	30 19	600	100				

I would chiefly direct the reader's attention to the three columns on the right-hand side of the table, as they afford the best means of comparing the relative powers of the guns. Without entering into an expla-

* As the 30-ton gun has been only recently adopted, and has not yet been tried, I am unable to give the particulars of the initial velocity, &c.

nation of the dynamical expression "energy" here employed, it will be sufficient to state that the columns headed "'Energy' per inch of Shot's Circumference," represent what may be termed the "punching" powers of the guns, *i.e.*, their power to force their projectiles through an armour-plate and its backing; while the "total energy" tabulated represents the real amount of power stored in each shot, and which can be expended on a target. Before passing to the consideration of these figures, it is necessary to remark that I have only given them for the 68-pounder among the smooth-bore guns, as that is the only case in which the penetrating power is at all worth notice. Taking first the punching power of the shot when it leaves the muzzle, it appears that the 25-ton gun is about 3½ times, the 18-ton gun more than 3 times, the 9-ton gun nearly twice, and the 6½-ton gun more than 1½ time as powerful as the 68-pounder. These are noteworthy facts; but at the 1000 yards' range the proportionate powers of the rifled guns are greatly increased. For example, the 25-ton gun rises from 3½ times to more than 7½ times, and the 18-ton gun from 3 times to nearly 7 times the power of the 68-pounder; and similar remarks apply to the other rifled guns. The total energy of the largest rifled guns, of course, increases even more rapidly than the punching or penetrating power per inch of circumference; and at the 1000 yards' range we see from the last column that the 25-ton gun is more than 11 times, the 18-ton gun about 8½ times, and the 12-ton gun more than 5 times as powerful as the 68-pounder 8-inch gun. The maintenance, at long ranges, of the penetrating power of heavy projectiles from rifled ordnance is a matter of the highest interest and importance. I cannot, however, dwell upon it now, but leave the reader to study at his leisure the preceding table. The more fully he grasps the facts there stated the higher will become his appreciation of the immense advances made in the power of the armaments of our iron-clads.

Our neighbours, the French, have made considerable progress in the same direction, having to a great extent exchanged the 55-pounder smooth-bore guns that at first formed the bulk of their armaments for 5-ton and $7\frac{1}{2}$-ton rifled guns, while some of the larger and later vessels carry $13\frac{3}{4}$-ton and $21\frac{3}{4}$-ton rifled guns. It is of course difficult to compare these guns with those carried by our own ships, but according to the best information at present made public, the $21\frac{3}{4}$-ton French gun is about equal to our 18-ton gun, the $13\frac{3}{4}$-ton French to our 12-ton gun, and the $7\frac{1}{2}$-ton French to our $6\frac{1}{2}$-ton gun. The calibres of the three French guns are about $10\frac{3}{5}$, $9\frac{1}{2}$, and $7\frac{1}{2}$ inches respectively, and they are all breech-loaders. A writer in the *Revue Moderne* for December, 1868, who is evidently well informed, criticises these guns most unfavourably, stating that the breech arrangements are by no means satisfactory, and that under the most favourable circumstances the heaviest guns could not be fired at a greater rate than once in two minutes, while the English heavy guns can be fired three or four times during that interval. According to this authority our 9-inch 12-ton gun is more powerful than the heaviest French gun, and this he attributes to bad powder and to the improper construction of their guns, by which the initial velocities obtained do not much exceed three-fourths those obtained with our guns. His conclusion, with respect to the relative merits of the guns of the two navies is given in the sentence:—"It must then be confessed, "whatever it may cost us, that in an engagement "where the artillery would be called upon to play a "decisive part, a French squadron would be almost "powerless against an English squadron of similar "force." Without professing to regard this verdict as conclusive, I think there can be little doubt that our artillery is, at present, much superior to the French, and that the system of muzzle-loading for heavy guns has hitherto proved far better than that of breech-loading.*

The Americans, as is well known, have followed a different system in the development of their naval guns, preferring to have a heavy projectile of large size with a comparatively low velocity, instead of an elongated projectile of less weight moving at a high velocity. The American system has been well termed the "racking" or "battering" system, in opposition to our own method, which is known as the "punching" system. In carrying out their plan, the Americans have adopted guns of 9, 11, 13, 15, and even 20-inch calibre, and guns of 25-inch calibre and upwards are said to be

* The Ordnance Select Committee reported in 1863 that "the preponderance "of opinion seems to be against any breech-loading system for the larger "guns." In chapter vi. of Mr. Holley's work on 'Ordnance and Armour' (London: Trübner and Co., 1865) will be found full descriptions of the merits and demerits of the various systems of breech-loaders proposed, and accounts of the trials made with various guns. A study of these facts will, I think, convince the reader of the wisdom of the policy of having made our heavy guns muzzle-loaders, at any rate, up to the present time.

contemplated. These large guns are almost without exception of cast iron, and nearly all are smooth-bores throwing cast-iron spherical shot. The 15-inch gun has been adopted for the turret-armaments of most of the monitors, but a few ships have 20-inch guns. The 15-inch guns throw a shot of about 450 lbs., with a charge of 60 lbs. of their cannon powder;* the 20-inch guns throw a shot of about 1080 lbs., with a charge of from 120 to 200 lbs. of their powder. Great differences of opinion prevail with respect to the comparative merits of our own and American guns. This we should naturally anticipate, but a few facts drawn from the trials made at Shoeburyness will serve to give a more definite view of the subject. In his admirable Report "On the Penetration of Armour-Plates by Steel Shot," Captain Noble shows that the American 15-inch gun, charged with 50 lbs. of our powder, and throwing a spherical steel shot weighing 484 lbs., would fail to penetrate the 'Lord Warden's' side at any range; while our 9-inch 12-ton gun, with a 43-lb. charge, would send its 250-lb. shot through her at a range of 1000 yards. He also states that the 15-inch gun would not penetrate the 'Warrior' beyond a distance of 500 yards, while our 7-inch $6\frac{1}{2}$-ton guns (weighing about one-third as much as the 15-inch gun) would do the same with a charge of 22 lbs. of powder and a 115-lb. shot; and the 12-ton gun would penetrate up to 2000 yards. It must be remembered that, instead of the steel shot here supposed to be used with the 15-inch gun, cast-iron shot are really employed by the Americans; and this tends

* This is about equal to 50 lbs. of English powder.

to increased superiority in our guns as respects penetrating power. There can be little or no doubt that the American guns have greater battering power; the real question at issue is, as before stated, the relative merits of penetration, and racking or battering. We think, with the French, that the former is to be preferred; the Americans have preferred the latter. Experience can scarcely be summoned to settle this difference of opinion in favour of the latter plan, for even if the Americans could show that their system was most successful in the engagements of the Civil War (which I am by no means prepared to admit they can do), it would still remain a fact that no comparison could be drawn between the improvised, hastily constructed, and ill-armoured ships which the Confederates produced and the well-built and carefully armoured and fastened ships of European navies. It would not have been surprising to find the armour and backing torn away bodily from the sides of many Confederate ships by the impact of heavy shot; the wonder is rather that, instead of this taking place, these very weak ships in some cases withstood a heavy fire without receiving any serious injury to their hulls.

The advocates of the American system have laid more stress, perhaps, upon the result of the fight between the monitor 'Weehawken' and the Confederate casemated ship 'Atalanta' than upon any other event of the war; and I may, therefore, be pardoned a few additional remarks respecting it. On this occasion the 'Atalanta's' side was smashed in by a 15-inch shot from the 'Weehawken's' gun at a range of about 300 yards, and mainly in consequence of this the ship was surrendered, as she was aground and could not steam away. The protection on the side of this improvised iron-clad has been described as 4½-inch armour, inclined at an angle of 35 degrees to the horizon, and backed by more than 2 feet of wood; the facts, according to reports of American officers, seem to be that the armour consisted of two layers of iron bars, about 6 inches wide, and that the fastenings of these bars, as well as the other details of the construction, were exceptionally weak and imperfect in consequence of the urgency with which the preparation of the ship had been pushed forward, and of the want of suitable materials in the Confederate dockyards. In short, it is scarcely possible to conceive that the battering system could have been applied against a target better fitted to be shaken to pieces; and, from the results obtained under these circumstances, it is absurd to attempt to deduce any correct ideas respecting the effect which this gun would produce against European iron-clads. The results given in Captain Noble's Report are so conclusive as to the powers of the 15-inch gun that we are not likely to hear of the fate of the 'Atalanta' being again used as an indication of what would befall any French or English iron-clad that might be attacked by an American monitor.

It is not without interest to note that the latest expression of American opinion on this question decidedly inclines to the abandonment of their own battering system, and the adoption of rifled guns with a high speed of projectile. In their Report, issued on 15th February, 1869, the Ordnance Committee appointed by the Congress say:—"To return to smooth-bores "throwing huge spherical masses of iron at low velo-"cities is to disregard all modern progress in the

" science of gunnery, and to return to the arm in use " two hundred years ago." Such an admission as this, coming from such a body, cannot but be regarded as a proof that, after some years of experience with their own system, the Americans have become convinced of the superiority of the European system. This conclusion in no way detracts, however, from the credit due to the American people for the extraordinary skill and enterprise which they brought to bear upon the construction of both guns and ships when called upon to suppress the gigantic rebellion of the Southern States by land and sea.

In concluding these remarks on the armaments of iron-clad ships, I would again refer to the great importance of giving large arcs of training to protected guns. The 'Warrior' is very deficient in this respect; the 'Minotaur' is powerful, but this power is obtained in connection with complete protection. Our later ships with central batteries and armour belts have been gradually improved, by cutting ports in the armoured bulkheads at the ends of the batteries, and recessing the sides of some vessels so as to be able to fight guns at a small angle (usually about 15 degrees) with the line of the keel; while in other ships, as in the 'Bellerophon,' short protected batteries have been formed at the extremities in order to get fore-and-aft fire. In our most powerful broadside ship, the 'Hercules,' these two plans are combined, the foremost and aftermost 18-ton guns on each side of the central battery being capable of firing through recessed ports in the bulkhead, as well as at broadside ports, and a 12-ton gun being carried in each of the batteries at the bow and stern to obtain fore-and-aft fire. By these arrangements every point on the horizon can be commanded by powerful guns sheltered behind armour. The most complete arrangement yet made is, however, to be found in the 'Invincible' class, which commands an all-round fire from guns placed in a central protected battery. This is accomplished by means of the four upper-deck battery guns, which can be fought either in a fore-and-aft line or on the broadside, the main strength of the broadside consisting, however, of the six guns in the main-deck battery, which have the ordinary broadside training. As previously stated, the French have made similar arrangements, in order to increase the horizontal range of their protected guns; and the Americans have recognised the importance of this feature of construction by having the deck arrangements of their monitors of such a character as to permit the turret guns to be fired in all, or nearly all, directions. The English turret-ships constructed before the introduction of the breastwork system for monitors accomplish the same object in another way, but with many serious limitations, as I shall explain in another chapter; all the breastwork monitors, however, have a complete command of all points of the horizon with their turret guns.

CHAPTER IV.

STRUCTURE OF THE IRON-CLADS.

A PERUSAL of the preceding chapters will, I think, have convinced the reader that great progress has been made since the construction of the 'Warrior' in both the armour and the armament of iron-clads; I propose in this chapter to show that equally great and important progress has been made in the structure of those ships. I shall not deal with the subject from a technical point of view; my object will be rather to show, in as popular language as possible, that the great essentials of strength, combined with lightness, safety, and durability, have all been carefully kept in view in the changes made from time to time, and that those changes really constitute improvements — in other words, that our recent ships are much superior in their structural arrangements to those which preceded them.

It is well known that the adoption of armour-plating was accompanied in this country by the introduction of iron for the construction of the hulls of ships of war, and our iron-clad fleet is for the most part iron-built. There are, as I have previously stated, a considerable number of wood-built iron-clads in our Navy, but most of those vessels are converted ships — such as the 'Caledonia' class, the 'Royal Sovereign,' the 'Favorite,' 'Research,' and 'Enterprise'; while the remainder—

such as the 'Lord Warden,' 'Lord Clyde,' and 'Pallas' —were built of wood mainly for the purpose of utilising the large stores of timber that had been accumulated in the dockyards for use in wood shipbuilding. With these exceptions, our iron-clads are iron-built, and there is little, if any, reason to suppose that in the future the numbers of our wood-built iron-clads will be added to, unless it should become necessary, in order to meet the exigencies of a war, to build such ships of material already at hand, or to convert our line-of-battle ships into armoured vessels. The feasibility and propriety of converting these ships will be discussed in a future chapter; for the present I need only state that plans have been prepared for the purpose of carrying out such conversions should the necessity ever arise.

The non-professional reader may perhaps be surprised to find that, when wood ship building had, through long years of practice, become so well understood and perfected, it should suddenly have given place to iron; but I shall endeavour to show that there were good reasons for the change. It needs no argument to prove that in the construction of all ships, and particularly of iron-clads, one of the chief aims of the naval architect should be the choice of such structural arrangements as will best combine strength with lightness. The dimensions and outside form of a ship determine her displacement, and her capacity to carry weights of course depends largely upon the weight of her hull, as the difference between the total displacement and the weight of hull is the exact measure of her carrying capacity. Now in wood ships the hull weighs much more than in iron ships of equal size; in fact, while in well-built wood ships the weight of hull is quite one-half the displacement, in properly constructed iron ships it is now considerably less, and yet the structural strength is much greater. This fact, with others, has led to the rapid development of iron shipbuilding in the mercantile marine, where the saving in weight of hull can be turned into remunerative cargo carrying power. In iron-clad ships it is even more important that this saving in weight of hull should be made; for all weight thus saved can be applied either to increasing the thickness and weight of armour carried, or to decreasing the dimensions of the ship required to carry a certain weight of armour. For instance, an armoured ship having a total displacement of 6000 tons will, if she is wood-built, have a hull weighing about 3000 tons, and the weights she can carry will be of about equal amount, whereas, if built of iron, on the system of our recent iron-clads, the hull will only weigh about 2500 or 2600 tons. The difference, 400 or 500 tons, can of course be applied to thickening the armour and adding to the armament, if that is considered desirable; or, if the total weights carried remain the same in the two ships, it will allow of the tonnage of the ship being reduced by fully that number of tons. This illustration will, I think, convince the reader that under this aspect the change from wood to iron is highly beneficial, and I shall further on give some examples, taken from actual ships, which will further confirm this view.

Nor is this all. An almost equally important feature in the comparison of wood and iron hulls for iron-clads has just been alluded to, and now claims a brief notice, viz. the greater strength of iron-built ships. Even in a well-built wood ship-of-war it is found that more or less working takes place when the ship is severely strained by rolling and pitching at sea; and this working necessarily tends to reduce the structural strength, gradually it is true, but no less certainly. In ordinary iron ships working is practically impossible; and, when the structural arrangements are properly made, the only serious cause of loss of strength is to be found in the slow deterioration, in thickness especially, of the various parts. When we pass from unarmoured to armoured ships, the contrast is still more striking, since the causes of straining naturally become developed as the load becomes increased, and the armour, although it forms so large a part of the total weight, has not as yet been made fully available in giving additional structural strength. It is true that a very considerable amount of longitudinal strength is given by the armour; and that as far as our experience goes, the wood-built iron-clads have not displayed any serious signs of weakness, the reason doubtless being that the weights of armour they carry are not very great. Still the fact remains, that, in order to strengthen a wood ship sufficiently to carry even a moderate weight of armour, very large dimensions have to be adopted for the component parts of the hull; and if the weights of armour were made as great as they have been of late in iron ships, the strengthenings required in wood ships would undoubtedly become increased in weight to an extent which would make it still more desirable to use iron instead of wood.

The durability of our costly iron-clads is another most important feature, and in this respect also iron-built ships are undoubtedly superior to wood. In an iron-built armoured ship the hull proper is made up of a material which is subject only to deterioration by the action of the sea-water outside, and the bilge-water inside, or other causes producing more or less rapid oxidation. If proper precautions are taken to keep the plating well coated with paint, or some other protective material, the deterioration resulting from these causes is very slow indeed, as is proved by our experience during the last twenty-five or thirty years. We may conclude, therefore, that with proper care the hulls of our iron-built iron-clads will remain in an excellent condition for a long period; and it is worth notice also that the only part liable to decay not at once accessible—the wood backing to armour—is really outside the hull proper, and can, if it should become necessary, be got at and renewed by removing the armour only, the structure of the ship remaining untouched. As far as our experience goes, however (and it now reaches over ten or eleven years), it appears that there is not so much reason to dread the rapid decay of this backing as many persons have supposed. The wood used for the purpose is teak, and the conditions under which it is placed are such as to make it probable that it will remain efficient for a very considerable time; while its freedom from acids prevents any gradual wasting of the armour-plates and fastenings such as would most probably take place if a wood like oak were employed.* The wood decks,

* The part of the backing most liable to decay is obviously that near the water-line of the ship, and doubts might reasonably have been entertained respecting the durability of this part, even if the other portions continued

upper works (when of wood), and internal fittings of these ships, are, of course, as liable to decay as those of wood-built ships, but there is no difficulty in replacing them, and their decay but slightly, if at all, affects the strength of the structure. Now turn to a wood-built ship, and what a different state of affairs do we meet? The materials used in the hull are all liable to more or less rapid decay, and unless, as is very difficult to ensure, the timber used is thoroughly seasoned, the ship may soon be expected to require repairs. There is no occasion to do more than allude to the fact that within the period of service of many wood ships the cost of repairs has far exceeded the original outlay on the construction; nor should it be forgotten that in the best wood ships there must be some amount of working, and that this tends to increased rapidity in decay and loss of strength, while the parts most liable to decay are just those which can be with the greatest difficulty replaced. Instead of the continued efficiency which with a fair amount of attention can be ensured in an iron hull, we find, then, an unavoidable and certain falling-off in efficiency in a wood hull; and instead of the comparative ease with which the repairs in the subordinate portions of the former which are liable to decay can be made, we have the difficult and expensive repairs sure to be required in the essential parts of the wood hull; while even with those repairs, unless the sums expended upon them are very large indeed,

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sound. It has, however, been ascertained by a thorough examination of the backing of some of the floating batteries built during the Crimean war that no decay had taken place at any part after eleven years from the date of launching.

the wood-built iron-clad will not last nearly so long as the iron-built ship.

Taking next the question of safety, the popular impression is doubtless in favour of the superiority of wood ships. So much has been said of the dangers of iron ships foundering at sea, or being lost by driving ashore and having the thin bottom plating penetrated, that there was at first a very strong feeling expressed against the propriety of embarking our naval forces on ships which were liable to such dangers. It has also been urged that the great comparative thickness of a wood ship's bottom renders her much less liable to loss by striking the ground, and that the fact of wood being of so much less specific gravity than iron gives her a great advantage. There is undoubtedly some truth in these remarks, but nevertheless they do not fairly represent the facts of the case. An ordinary iron ship's bottom is without doubt very thin and liable to penetration by a rock or any other hard substance; but the danger resulting from penetration is very greatly reduced by the adoption of a proper number of watertight divisions or bulkheads in the ship's hold, while it may be almost got rid of by the cellular bottom, now given to all our iron-clads, which prevents the entrance of water into the hold even when the outer plating is penetrated. Then with respect to the losses of iron ships at sea by breaking down the side, it is only necessary to say that such accidents can only happen to badly built ships, and that all our iron-clads are well-built and specially strengthened. In iron-built iron-clads, also, the liability to loss by fire is practically reduced to a minimum, but this is not, and in fact cannot be, the case in wood-built ships; so that, while not inferior to our wood ships in freedom from danger of foundering, our recent iron ships are on the whole much safer vessels. I must add that, as shown in Chapter II., the structural arrangements of an iron ship lend themselves much more readily than those of a wood ship to the conversion of the side into an efficient target; so that in defensive power also the iron ship is superior.

In lightness combined with strength—and therefore in armour-carrying power—in durability, and in safety, our iron-built iron-clads may therefore be assumed to be superior to our wood-built ships. There were, however, very good reasons for the production of the latter vessels at the time they were built, for by their construction we were enabled to add rapidly in our dockyards to our armoured fleet ships of equal merit with those building by the French, while the resources of the private shipbuilders of the country were made available for the construction of iron-built ships such as the 'Warrior' and 'Minotaur.' When the urgent needs of the earlier periods of the reconstruction of our Navy had thus been met, the Admiralty wisely determined to develope our iron-clad fleet mainly by means of iron-built vessels, the only wood iron-clads constructed having, as I said above, been built for the purpose of utilising some part of the large store of timber in the dockyards. The French, as is well known, have clung to the construction of wood ships, only two or three large iron ships having yet been built. This course has not, however, been unopposed, many advocates of iron for the hulls having urged the adoption of a course similar to that followed in our own Navy. The explanation of the French policy is doubtless to be found in the facts that they have not the same facilities for iron shipbuilding that we have in this country, nor anything like the same resources in ironworks and factories; while they have an ample supply of timber for shipbuilding purposes, and are well accustomed to all the processes of wood construction. Most French shipbuilders do not deny the advantages possessed by iron, and in their most recent iron-clads some recognition of these advantages has been made, the unprotected parts of the upper works (above the armour belt and outside the central battery) being of iron, while the main portion of the hull is of wood. This is the system which was commenced in the 'Enterprise,' and it has the great advantage of making the unprotected upper works of an iron-clad with a wood hull practically incombustible—an advantage which is of the greatest importance in naval warfare, since incendiary shells are, perhaps, the most formidable weapons of destruction that can be employed against an entirely wood-built ship with only partial protection.

There is, however, one argument in favour of wood on which many French and some English writers have laid great stress, and which undoubtedly has some weight, viz., the superiority in point of anti-fouling possessed by copper-sheathed wood ships. This is at present an incontestable advantage, but it is not necessarily permanent, and various plans have been proposed for covering iron ships' bottoms with paints, compositions, and metallic sheathing, and doing away with the fouling now so common. Our experience goes to show that none of the paints or compositions yet tried at sea secure immunity from fouling for any considerable time, especially in tropical waters, and this fact has brought the schemes for sheathing iron ships' bottoms with metal into greater prominence. Two iron-clads for our own Navy, the 'Swiftsure' and 'Triumph,' are being constructed, in which the bottoms will be sheathed with wood, outside which will be fastened a copper sheathing like that commonly used in wood ships. I did not advise this experiment in the case of these iron-clads, but the late Board of Admiralty had sufficient confidence in the plan to authorise its adoption in them. Other schemes have been proposed, of a simpler and less expensive character, for using zinc sheathing on the bottoms of iron ships, concerning which valuable experience is being gradually gained. Even if we did not already possess these means of at least partially preventing fouling, however, there could not be much doubt that some means would be discovered; and it would surely be bad policy to sacrifice the important permanent advantages obtained by building iron hulls solely on account of the present disadvantage resulting from the fouling of iron bottoms. In the case of the French navy, it is true that this argument for wood is more weighty than with our Navy, because they have fewer dockyards and naval stations abroad where iron ships could be docked or have their bottoms cleaned. If we had not the advantage in this respect, however, I think it would still remain true that the numerous and important benefits resulting from the use of iron would far more than balance the disadvantages connected with foulness.

Having thus noticed the chief considerations connected with the relative merits of iron and wood for the structure of iron-clads, I next pass on to observe the improvements that have been made in the structure of our iron-built ships since the date of the 'Warrior's' construction. These improvements are mainly the result of the adoption of what is known as the "bracket-frame" system, first introduced into the 'Bellerophon.' A few particulars of the systems exemplified in the 'Warrior' and 'Bellerophon' must therefore be given, in order to make the improvements intelligible to the non-professional reader, and in giving them, I shall, as far as possible, use popular language.*

The 'Warrior' and the earlier iron-clads are constructed with deep frames, or girders, running in a longitudinal direction through the greater part of the length of the ship, combined with numerous strong transverse frames, formed of plates and angle-irons, crossing them at right angles. In fact, up to the height of the armour the ship's framing very closely resembles in its character that of the platform or roadway of a common girder bridge, in which the principal, or longitudinal, strength is contributed by the continuous girders that stretch from pier to pier, and the transverse framing consists of short girders fitted between and fastened to the continuous girders. If we conceive such a platform to be curved transversely to a ship-shape form, and the under side to be covered with iron plating, we have a very fair idea of the construction of the

* Full descriptions and detailed drawings of the structural arrangements of our iron-built iron-clads, from the 'Warrior' up to the 'Invincible' class, will be found in chapters vi. and vii. of my work on 'Shipbuilding in Iron and Steel.'

lower part of the 'Warrior.' If, instead of this arrangement, we conceive the continuous longitudinal girders to be considerably deepened, and the transverse girders to be replaced by so-called "bracket-frames," and then, after curving this to a ship-form, add iron-plating on both the upper and the under sides, we have a correspondingly good idea of the construction of the lower part of the 'Bellerophon.' The 'Bellerophon's' construction is, therefore, identical in character with the cellular system carried out in the Menai and other tubular bridges, which system has been proved by the most elaborate and careful experiments to be that which best combines lightness and strength in wrought-iron structures of tubular cross-section. The 'Warrior's' system, wanting, as it does, an inner skin of iron—except in a few places, such as under the engines and boilers—is not in accordance with the cellular system, and is inferior to it in strength. As regards safety, also, no comparison can be made between the system of the 'Warrior' and that of the 'Bellerophon.' If the bottom plating is penetrated, in most places, the water must enter the 'Warrior's' hold, and she must depend for safety entirely on the efficiency of her watertight bulkheads. If the 'Bellerophon's' bottom is broken through, no danger of the kind is run. The water cannot enter the hold until the inner bottom is also broken through, and this inner bottom is not likely to be damaged by an ordinary accident, seeing that it is two or three feet distant from the outer bottom. Should some exceptional accident occur by which the inner bottom is penetrated, the 'Bellerophon' would still have her watertight bulkheads to depend on, being, in fact, under these circumstances, in a position similar to that occupied by the 'Warrior,' whenever her bottom plating is broken through; while an accident which would prove fatal to the 'Warrior' might leave the 'Bellerophon' free from danger so long as the inner bottom remained intact. This is no mere fancy picture of possible danger in one case and safety in another; our experience amply confirms it. For example, the 'Great Eastern,' which is built on the cellular system, and has a double bottom, once ran upon the rocks on her way to America, and had her outer plating torn away to an extent which would have been fatal to a ship without an inner skin, but as her inner skin was not penetrated, the ship continued her voyage in safety. A practical demonstration such as this of the advantage in point of safety of the cellular system can surely meet with no answer; and the advantage in point of strength is also manifest when it is remembered that the 'Great Eastern,' notwithstanding her immense size, has shown few signs of weakness, even when burdened with the very heavy weights of telegraph cables she has had on board.

It may be proper in this connection to draw attention to the fact that the probable employment of torpedoes in a future naval war has not been lost sight of in carrying out these structural improvements. Up to the present time torpedoes have been used almost solely for coast and harbour defence, and have, under those circumstances, proved most destructive, as a glance through the reports of the operations of the Federal fleet at Charleston and other Confederate ports will show. It is still doubtful, however, whether these formidable engines of war can be applied with anything like the same efficiency at sea, under the vastly different conditions which they will there have to encounter. The Americans have, it is true, proposed to fit torpedo-booms to their unarmoured ocean-cruisers, such as the 'Wampanoag,' and a naval war would doubtless at once bring similar schemes into prominence. Nothing less than actual warfare can be expected to set the question at rest; but whatever the result of such a test may be, it is obviously a proper policy of construction to provide as much as possible against the dangers of torpedoes; and it must be freely admitted that the strongest iron-clad yet designed, although practically impenetrable by the heaviest guns yet constructed, would be very liable to damage from the explosion of a submerged torpedo. No ship's bottom can, in fact, be made strong enough to resist the shock of such an explosion; and the question consequently arises, How best can the structure be made to give safety against a mode of attack which cannot fail to cause a more or less extensive fracture of the ship's bottom, even if it does no more serious damage? In our recent ships, as I have said, attempts have been made to give a practical answer to this question. Seeing that the bottom must inevitably be broken through by the explosion of a torpedo which exerts its full force upon the ship, it obviously becomes necessary to provide, as far as possible, against the danger resulting from a great in-flow of water. This is the leading idea which has been kept in view in arranging the structural details of our ships to meet this danger, and the reader cannot fail to perceive that the double bottom and watertight subdivisions described above are as available against injury from torpedoes as they are against the injuries resulting from striking the ground. I may, however, add here that in our recent ships—particularly in the breastwork monitors 'Glatton,' 'Thunderer,' and 'Devastation'—great care has been taken to multiply watertight subdivisions in the hold to as great an extent as is possible, and that the depth of the double bottoms has been made very considerable, both of which changes have an important bearing on the subject now under discussion. The increased depth of the double bottom increases the probability that the inner skin may remain intact even after the outer skin is broken through, particularly if, as might be done, the spaces between the two bottoms had been previously filled with water, which would act as a protection to the inner bottom. The numerous watertight subdivisions now formed in this space also add materially to the ship's chances of escape from foundering when struck by torpedoes. The subdivisions in the hold proper, to which I have alluded, add still more to the ship's safety. They are formed by making watertight the partitions, or bulkheads, which enclose the magazines, store-rooms, lockers, passages, &c., in the hold of the ship, all of which can be done at a comparatively trifling additional expense, since these partitions are necessary to the proper stowage of the ship, and would exist even if they were not made watertight. Another series of subdivisions has been largely employed in our recent ships also by fitting watertight iron plating on the decks and platforms which come below the water-line; and by adopting watertight hatchways, or trunks, by which access is obtained to the parts liable to injury, without any danger of the ship being flooded if those parts were filled with water.* All these are, it must be remembered, precautionary measures; whether or not they will prove sufficient against attack by torpedoes is doubtful; but whatever may be the result of such a trial, it is clear that the ship's safety against accidents of more common occurrence is thereby increased to a very considerable extent, and that the system of internal subdivision must give a considerable degree of security even against the torpedo attack.

Hitherto I have been describing the structural arrangements of the lower parts of the 'Warrior' and 'Bellerophon;' a very few remarks will suffice respecting the upper parts in wake of armour. It has been explained in Chapter II. that the skin-plating behind armour in the 'Bellerophon' is nearly 1 inch thicker than that in the 'Warrior,' and that there are besides numerous longitudinal stringers in the 'Bellerophon' target, or side, while there is no corresponding arrangement in the 'Warrior.' These additions add greatly to the structural strength of the 'Bellerophon,' both as a ship and as a target, but at the same time they necessitate a considerable increase in the weight of hull, beyond what would be required if the skin-plating were identical in thickness with that of the 'Warrior.'

In brief, then, the changes made in the 'Bellerophon' and more recent ships involve the addition of an inner bottom, and the adoption of thick skin-plating and girders behind armour, besides a considerable increase in the depth and strength of the longitudinal framing, all of which changes tend to give greater strength and safety.

* Full particulars of these features of iron-clad construction will be found in chapters vii. and xi. of my work on 'Shipbuilding in Iron and Steel.'

But as these additions effect this result, it might well be anticipated that the total weight of hull would also be greater than if the weaker and less safe system of the 'Warrior' were carried out. The increased efficiency has, however, been accompanied by a considerable decrease in the total weight of hull—a decrease obtained by saving unnecessary weight in other parts of the ship, and by effecting a distribution of the material more in accordance with the true principles of construction. I am entitled to say this, because Dr. Fairbairn, in his important work on 'Iron Shipbuilding,' has gone much further in his approval of the 'Bellerophon,' or bracket-frame, system.*

In the 'Warrior' and the earlier iron-built iron-clads, the hull proper weighed quite as much as—in fact in some cases more than—it would have weighed if built of wood, but was, of course, much stronger than a wood hull would have been. In the ships that came between the 'Warrior' and the 'Bellerophon,' and more especially in the 'Minotaur' class, some improvement was

* At page 214 of that work Dr. Fairbairn says:—"The 'Bellerophon' being "the first ship built upon what we consider sound principles, we deem it "important to show in detail how the different parts are united so as to form "in combination a strong and effective ship. We may however observe, "*en passant*, that great credit is due to the Naval Constructor for having "freed himself from all preconceived opinions, and for having adopted every "improvement and every recommendation calculated to increase the efficiency "and durability of this novel construction, and to promote the transfer now "in progress in the Navy from wood to iron." Further on (at page 220), in speaking of the earlier iron-clads, he observes:—"As regards these vessels, they "do not contain the elementary strength of the 'Bellerophon' as exhibited "in the longitudinal keelson and cellular form of construction;" and in summing up his remarks on iron-clads (*see* page 236), he adds:—"Iron or steel "of the best quality, carefully distributed in its strongest forms, and applied "with judgment in the construction of ships, *on the cellular system with* "*double bottoms*, is in our opinion the only material that will meet the "requirements of an effective navy."

made, the weight of hull falling rather below the weights of armour, armament, and equipment carried. In the 'Bellerophon' still further progress was made in this direction, contemporaneously with the adoption of the special provisions for strength and safety enumerated above; and since the 'Bellerophon's' construction, the proportion borne by the weight of hull to the weights carried has been still more diminished. These statements will perhaps be more clearly understood by reference to the following tabular statements of the weights of hull and the weights carried for some of the principal ships of our Navy:—

	Weight of Hull.	Total Weights Carried.
Wood-built iron-clads:—	Tons.	Tons.
Caledonia	3382	3367
Pallas	1812	1844
Lord Clyde	3647	3979
Earlier iron-built iron-clads:—		
Black Prince	4969	4281
Defence	3500	2492
Achilles	5030	4495
Minotaur	5043	5232

	Weight of Hull, with thick Skin-Plating and extra Girders included.	Weights Carried.
Recent iron-built iron-clads:—	Tons.	Tons.
Bellerophon	3652	3798
Monarch (turret-ship)	3674	4632
Sultan	3961	4856
Audacious	2675	3224
Glatton (breastwork monitor)	2209*	2651
Thunderer (ditto) ..	3272*	5790

* This weight of hull includes also the very strong defensive plating on the upper decks and breastwork decks of these ships. The 'Glatton,' when at her fighting draught, carries, on the same weight of hull, 324 tons more weight of coal and water, so that the weights carried then reach a total of nearly 3000 tons.

A glance through these tables will put the reader into possession of a brief summary of the facts previously stated. In the wood ships 'Caledonia' and 'Pallas,' the weights carried are as nearly as possible equal to the weight of hull; while in the 'Lord Clyde,' one of our most recent wood armour-clad ships, the judicious use of iron strengthenings to the wood hull, and other improved methods of construction, brought down the weight of hull to about 300 tons less than the weights carried. Then in the first three of the iron-built iron-clads named, we find the weight of hull considerably exceeding the weights carried, and making those ships compare most unfavourably as regards carrying power with the wood ships, although doubtless much superior in strength. The 'Minotaur' occupies a more favourable position, for in her the weights carried exceed the weight of hull by 190 tons. Next come the ships built on the bracket-frame system, with their very strong framing and plating behind armour, their double bottoms, &c. The first ship of the type, the 'Bellerophon,' carries weights exceeding by about 150 tons the weight of the hull, an excess which is rather greater, in proportion to the displacement, than that of the 'Minotaur,' although the 'Bellerophon' is so much more strongly and safely built, and has included in her weight of hull the second iron skin and the external girders, both of which the 'Minotaur' is without, and which might fairly be placed in the weights carried. The importance of the last-mentioned feature will, perhaps, be better appreciated when it is stated that the weight due to the increased thickness of skin plating behind armour alone in the 'Bellerophon' exceeds 120 tons. The 'Minotaur,' however, being one of the most improved of the earlier iron-clads, ought to be compared with one of the vessels which succeeded the 'Bellerophon,' in order to contrast the two systems of construction fairly. Take the 'Sultan,' for example, and we find the weights carried exceeding the weight of hull by nearly 900 tons, while in the 'Monarch' the excess is more than 950 tons. The progress made since the 'Bellerophon' was built is very well illustrated by the comparison between that ship and the 'Monarch,' for the later ship, with a hull of nearly the same weight as the 'Bellerophon's,' carries 834 tons more than the 'Bellerophon.' Another very striking instance of the progress made since iron hulls came into vogue for iron-clad ships is afforded by the comparison of the 'Defence' with the 'Audacious.' The total weight of these ships and their lading is very nearly the same, the 'Defence' weighing 5992 tons, and the 'Audacious' 5899 tons when fully equipped. In the 'Defence,' however, the hull *exceeds* the weights carried by 1000 tons, while in the 'Audacious' the hull is *less* than the weights carried by 550 tons. The difference in favour of the carrying power of the 'Audacious' amounts to 730 tons, although she is specially strengthened and constructed on the bracket-frame system, while the 'Defence' is built after the 'Warrior' pattern. Perhaps the real magnitude of this saving will be better appreciated if I state that, if the 'Defence' had been built on the system of the 'Audacious,' and the armoured surface had remained the same, while in all other particulars the ship had been completed as she now stands, the saving in weight of hull would have been sufficient to have more than doubled the thickness of armour throughout. As it is, we find the 'Audacious' carrying 8-inch and 6-inch armour instead of the 4½-inch armour of the 'Defence,' having a total weight of armour and backing exceeding that carried by the 'Defence' by 210 tons, and carrying besides 520 tons greater weight of armament, machinery, coals, and equipment. All these advantages have been gained in this case, be it remembered, in a ship of comparatively small size, the 'Audacious' being of 2847 tons less tonnage than the 'Minotaur.'

The two ships 'Glatton' and 'Thunderer,' which stand last in the table, cannot fairly be compared with any of the other ships, on account of the difference of type which has been explained in Chapter II. It will be noticed, however, that the weights of hull given, although they include the very strong and heavy upper-deck and breastwork-deck plating, fall very considerably below the weights carried; and that in the 'Thunderer,' one of our most recent ships, the proportion of weights carried to weight of hull is higher than it is in any other ship. Some part of the improvement which I have here traced is due, no doubt, to the use of steel instead of iron; but thus far our experience with steel has been of such a character as to prevent its very general employment. It may be taken for granted, therefore, that improved structural arrangements are really the main source of the saving in weight of hull; and as a proof of the opinions of practical men on this matter, I may refer to the fact that nearly all private shipbuilders in this country who construct ships of war have followed the recent designs of the Admiralty, and have adopted the bracket system of construction for large iron-clads.

I have dwelt at some length on this feature of the subject, because to the minds of many persons it appears doubtful whether or not the improvement in thickness of armour in our recent ships has been obtained simply by decreasing the area of protected surface and concentrating the batteries. Undoubtedly this fact has aided somewhat in obtaining the increase in thickness, but the structural improvements have done much more. That this is so will appear when it is remembered that in the preceding table and statements, I have dealt only with *weights*, irrespective of thicknesses and quite apart from the disposition of the armour, or the extent of armoured surface in the ships compared. It surely needs no argument to prove that if, on a given displacement, a certain amount of weight is saved on the hull, it can be applied in increasing the weights carried, either of armour, armament, or equipment. This has been done in our recent ships, and I have shown the saving in weight of hull to be so considerable as to allow the weights of armour, &c., carried by these ships to bear a far greater proportion to the total weight, or displacement, than in ships built on the 'Warrior' system. In fact, so great has the saving been in many cases that ships of much smaller dimensions than the 'Warrior' carry an absolutely greater weight of armour. Such results as these may be, and no doubt are, less appreciated by the general public than some other features of the iron-clad question, but they certainly yield to no other in importance, for the savings in outlay already effected by them, in conjunction with better proportions, exceed a million sterling. It is necessary that these important facts should be borne in mind, and the nation be made acquainted with the progress attained even in the abstruser features of iron-clad ship construction.

CHAPTER V.

STEAMING OF THE IRON-CLADS.

THE consideration of the *steaming* qualities of the iron-clad ships of the Navy forms a subject not much, if at all, inferior in importance to the questions that have so far occupied our attention. The introduction of steam propulsion into war ships necessitated the reconstruction of all navies; and in the later reconstruction, incident to the adoption of armour-plating, the question of performance under steam has very properly occupied a prominent place. When the iron-clad system came into vogue, the wooden steam fleet had undergone a long and highly successful course of improvement. The hulls of every class of ship had been increased in length and fineness of form as successive vessels had been laid down, and their machinery had attained a state of relative perfection that had given to its manufacturers an absolute and uncontested pre-eminence. In order that the actual steaming qualities of the iron-clads may be understood, it is necessary to bear in mind what were and are the steaming qualities of our unarmoured ships, and for this purpose the following brief statement is given.

The earlier steam-frigates, such as the 'Dauntless,' designed in 1844; the 'Termagant,' of 1847; and the 'Imperieuse,' of 1850, were all ships of less than 10 knots' full speed at load-draught. The 'Tribune,' of

1850, went nearly 10½; the 'Shannon,' of 1855, 11½; and the 'Diadem,' of the same year, 12 knots. Somewhat later, before the iron-clads came in, a load-draught speed of 13 knots was just attained in the 'Ariadne' and the 'Orlando,' which are the fastest wooden steam frigates ever built for Her Majesty's Navy. Like progress was made in the steam line-of-battle ships, which were commenced in 1849. The speed of the 'Agamemnon,' designed then, and of the 'St. Jean d'Acre,' designed in 1850, but little exceeded 11 knots. The 'Hero,' built in 1854, had a bow lengthened 5 feet from the 'Agamemnon's,' and went nearly 11½ knots. In 1856 followed the 'Renown,' lengthened 10 feet amidships from the 'Hero,' which went over 11¾ knots; and she was succeeded in 1858 by the 'Defiance,' lengthened 10 feet at the bow from the 'Renown,' with what result is not known, as the last-named ship has never been completed and tried. Meanwhile, in 1854, the three-decker 'Victoria' was designed, and attained a speed of 12¼ knots at load-draught; and she was followed by the 'Howe,' made 15 feet longer at the bow, the latter ship attaining, when flying quite light (without masts, armament, or stores), a speed of 13½ knots. This speed, however, undoubtedly much exceeded the speed which would have been secured with the ship rigged and loaded for sea; and I may, therefore, state with perfect confidence that the fastest wooden line-of-battle ships, like the fastest wooden frigates, after a long course of improvement, realised no more than 13 knots as a crowning speed at deep load-draught.

The wooden corvettes and sloops were similarly improved in form and speed as successive ships were laid down. For example, the corvettes 'Conflict' and 'Highflyer,' designed before 1850, realised a little more than 9½ knots; the 'Pylades,' of 1852, reached nearly 10½ knots; the 'Pearl,' of 1853, attained 11 knots; and the 'Jason,' of 1858, which may be taken as the representative of our finest and fastest corvettes, went 12 knots on her load-draught trial. As to the sloops, those designed before 1852 attained speeds of from 6½ to 8 knots; the 'Cordelia' and 'Greyhound,' of 1855, went a little over 9 knots; and the 'Rinaldo,' of 1858, realised 9¾ knots, the highest speed attained by any vessel of her class. The limits of speed reached in the unarmoured corvettes and sloops may be —taken, therefore, as 12 and 9¾ knots respectively these speeds being attained only by the latest ships of each class, in which had been attempted every improvement that experience had shown to be desirable.

Keeping these facts in mind, let us pass to the consideration of the speeds attained by the iron-clads of the Navy on their load-draught trials. We find that the 'Warrior,' 'Black Prince,' 'Achilles,' 'Minotaur,' 'Northumberland,' 'Bellerophon,' 'Hercules,' and 'Monarch,' have exceeded 14 knots—the 'Bellerophon' having realised 14·2 knots, the 'Achilles' and 'Warrior' 14·3, the 'Minotaur' 14·4, and the 'Hercules' 14·69, and the 'Monarch' 14·937 knots—the highest speed yet attained by any of our armoured ships at load-draught. The 'Lord Clyde' and 'Lord Warden' have realised about 13½ knots. The remaining vessel of the 'Minotaur' class, the 'Agincourt,' has gone nearly 15½ knots when flying light, with no stores on board, and only her lower masts in, so that we have every reason to anticipate that she also will exceed 14 knots on the load-draught trial. Several of the ships of the 'Caledonia' class, converted from line-of-battle ships into iron-clad frigates, have realised about 13 knots; and the 'Pallas,' a ship of only 2372 tons, has slightly exceeded that speed; while the 'Penelope' has made a little more than 12¾ knots. The 'Royal Oak' and 'Valiant' have gone a little over 12½ knots, and the 'Hector' and 'Royal Alfred' are about one-fourth of a knot slower. The 'Defence,' 'Resistance,' 'Zealous,' 'Favorite,' and 'Prince Albert', have all realised about 11¾ knots. Among the smaller armoured vessels, the 'Scorpion' has attained 10½ knots; the 'Wivern,' 'Enterprise,' and 'Research,' have gone about 10 knots; the 'Viper,' gunboat, has gone nearly 9½ knots; and the 'Vixen' and 'Waterwitch,' also gunboats, have exceeded 9 knots.

From this summary, it will be seen that several of the iron-clads exceed in speed the fastest wooden line-of-battle ships by more than a knot—an increase very difficult to secure in high speeds; that two other armoured ships are half a knot faster than the fastest unarmoured vessels; and that the converted ships of the 'Caledonia' class are, with one or two exceptions, about equal in speed to the most improved type of line-of-battle ships. Of the remaining iron-clads having a less speed than 13 knots, nearly all are either what may be termed second-rate frigates, or turret-ships, or belong to the smallest classes. It is difficult to make a comparison between these ships and any wooden vessels, except in the cases of the 'Pallas,' which may be fairly contrasted with the first-class wooden corvettes, and of the 'Research,' which may be compared with the largest wooden sloops. The 'Pallas' has a speed a little over 13 knots, and thus exceeds the 'Jason's' speed by more than a knot; while the 'Research' is somewhat faster than the swiftest sloop of previous date, the 'Rinaldo.' As regards the speeds at full power, the iron-clads compare most favourably, therefore, with the fastest wooden ships of the various classes.

As great suspicions are sometimes expressed with respect to the results of measured-mile trials of speed, it may be well to give some confirmation of the above-stated facts. It will suffice if we confine our attention to the trials of some of our fastest iron-clads—the 'Warrior,' 'Minotaur,' and 'Bellerophon.' In the early part of the year 1868, trials were made with these ships, both on the measured mile and by six hours' runs in the open sea. The results prove that, under similar circumstances, there is but little difference between the speeds obtained by continuous steaming at sea and those realised on the measured mile. On the measured mile, both the 'Warrior' and 'Minotaur' exceeded 14 knots, and the 'Bellerophon' very nearly reached that speed; while at sea the 'Minotaur' and 'Bellerophon' went over 14 knots, and the 'Warrior' was only a trifle slower. These facts are interesting also when we consider that all the ships have been some time in commission, and that their recent performances are very nearly identical with those originally obtained on the measured mile. In this connection I may also refer to the fact that our fastest iron-clad, the 'Monarch,' averaged on the six hours' trial a speed only about one-fourth of a knot less than that reached on the measured mile.

But there is another feature of this question which is well worth attention, viz. the speed of the iron-clads under half-boiler power. In this respect, also, the result of an examination proves most satisfactory. The 'Achilles,' 'Black Prince,' 'Bellerophon,' and 'Hercules,' exceeded 12 knots; and the 'Warrior,' 'Minotaur,' 'Lord Clyde,' and 'Lord Warden,' fell very little below that speed. The converted ships realised from 10 to 11 knots—the 'Pallas' exceeded 11 knots, and the 'Resistance' went nearly 10½ knots. Of the remaining iron-clads, several attained from 9 to 10 knots, and none except the smallest fell below 8½ knots. The *half-power* speeds of a considerable number of the armoured ships, therefore, do not fall below the *full-power* speeds of the fastest wooden ships by more than a knot. The difference between the full-power speeds of the two classes is, consequently, quite as great as that between the full-power speeds of the wooden ships and the half-power speeds of the iron-clads. The fastest wooden frigates, when running comparatively light (being rigged, but not stored), only attained 11½ knots at half-power; and this speed would, of course, be considerably reduced when the full weights of provisions and stores were on board. That this reduction would ordinarily be considerable is proved by the fact that the 'Mersey' attained a full-power speed of nearly 13½ knots at full power when the stores were not on board, but only reached about 12¾ knots when complete for sea. The advantage possessed by the iron-clad fleet in half-power speeds must obviously be of great importance in sea-going ships. The iron-clads could, by economising their fuel, make longer passages under steam than could be made in the same time by the wooden ships; or, if required, they could keep the sea, without requiring fresh supplies of coal, longer than the wooden ships, supposing that all the vessels had to traverse equal distances in equal times. Add to this the fact that, in case of emergency, the largest vessels of the armoured fleet could, at full power, distance the unarmoured ships, and reach any place where their services might be required in a considerably shorter time; and it may fairly be concluded that in steaming qualities our iron-clads are superior to the wooden ships that immediately preceded them.

It will be observed that, in the preceding remarks, I have taken the measured-mile speeds as representing the real capabilities of both our armoured and unarmoured ships. Many persons, I am aware, regard this as a fallacious test of a ship's powers, and consider speed trials at sea—not six hours' runs—as the only true standards of performance. My own reasons for preferring to take measured-mile trials have been previously given in Chapter I.; and I need only state that, while sea trials in different ships are, almost without exception, made under very different conditions of engines, boilers, and stoking, with different degrees of foulness of bottom, and very often under different circumstances of wind and weather, measured-mile trials are conducted by experienced staffs of officers and stokers in such a way as nearly, if not entirely, to eliminate the effects of these secondary causes. Hence, in order to secure anything like fairness of comparison, it becomes absolutely necessary to refer to measured-mile trials; and a reference to the results of sea trials previously given (*see* pages 12 and 15)

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will, I think, convince every one that no estimate of a ship's actual steaming capability can be based upon such trials. I must add that the speeds put forward as attained by our iron-clad ships are not intended to be taken as those which the ships would continue to maintain at sea, say in a Trans-Atlantic voyage. It is perfectly understood, no doubt, that on the measured mile the ships are tried in nearly smooth water, and generally with a low force of wind—in short, under the most favourable circumstances. At sea, I need hardly say, the circumstances are not often so favourable, and the speeds realised are consequently less; besides which, the fouling of the bottom, the varying character of the coal and stoking, the different condition and management of the engines, and other causes, tend to produce, and sufficiently account for, very different performances in the same ship at different times. Most of these causes are beyond our control; but of late, great efforts have been made to prevent the loss of speed incidental to fouling; and in the 'Swiftsure' and 'Triumph,' the first attempt has been made to give iron-built iron-clad ships the advantages of a coppered bottom. Plans for sheathing the bottom plating of iron-clads with zinc have also been under consideration, and may possibly be carried out.

I have already referred to the difficulty of adding to speeds that are already high, and as but few persons at present feel the full force of this remark, it may be well to add a word or two on this point. It may be taken as roughly correct to say that, to increase a speed of, say, nearly 12 knots to over 14 knots, it will be necessary to nearly *double* the power—in some cases to quite double it. The following examples illustrate this :—

In Northumberland ..	3279 H.-P.	gave	11·729 knots.
" "	6558 "	"	14·132 "
In Minotaur	3497 "	"	11·842 "
" "	6949 "	"	14·328 "
In Achilles	2546 "	"	11·879 "
" "	5035 "	"	14·358 "
In Bellerophon	3119 "	"	12·103 "
" "	5966 "	"	14·227 "
In Hercules	4045 "	"	12·123 "
" "	8529 "	"	14·691 "

These figures show how dearly the last two knots of speed are purchased in all these ships, long and short; and they also serve to indicate that, when people speak, as they often do, of a "speed of 13 or 14 knots," or of a "speed of 14 or 15 knots," they speak with much vagueness, for the difference between 13 and 14 knots may mean a difference of 2000 horse-power, and the difference between 14 and 15 knots may mean even a much larger difference of power.

It may be of interest to add to this brief account of the steaming of our own ships some few remarks on the speeds attained by foreign iron-clads. Omitting for the moment the 'Rochambeau,' late the 'Dunderberg,' the fastest ship of the French navy is the 'Provence,' which is said to have a little exceeded 14 knots, and the other vessels of her class are said to go 14 knots. The 'Solferino' is also reported to have attained 14 knots, and her sister ship, the 'Magenta,' 13·7 knots. The vessels first designed, 'La Gloire' and her consorts, reached, it is said, from 13¼ to 13½ knots, and the ram 'Taureau' has attained nearly the same speed. The 'Belliqueuse' goes 12·5 knots, and the smaller iron-clads or floating batteries have speeds ranging from 7 to about 7¾ knots. On a comparison of these results with those previously given, it will be seen that our fastest iron-clads have higher speeds than those of the French; that the converted ships of the 'Caledonia' class are of very nearly the same speed as the 'Gloire' class; and that our smaller iron-clads have considerably greater speeds than the corresponding ships in the French navy. It should also be stated that these alleged speeds of the French vessels are taken from French authorities, and are much greater than could be fairly inferred from their known horse-power and the forms of their water-lines. No great confidence is, therefore, felt in the figures. Perhaps the most remarkable performance yet reported, however, is that of the 'Rochambeau,' or 'Dunderberg.' Before leaving America for France, she was tried at the request of her builder, Mr. Webb, and obtained a maximum speed of 11·7 knots with 3778 indicated horse-power. Since her arrival at Cherbourg some alterations have been made in her machinery, and other trials of speed have taken place. The 'Moniteur de la Flotte' has published an account of the trials, and from this it appears that the mean speed of 14·635 knots was obtained, six runs having been made; no statement of the indicated power appears to have been given. The vastly improved performance of the ship on her later trial has naturally caused some doubts to be cast upon the speed alleged, and even French writers have joined in the expression of such doubts. For instance, in his remarks on the subject, Admiral Paris points out* the great differences existing between the ship's capability as evidenced by her two trials, and adds:—"There is here reason for

* See page 205 of 'L'Art naval à l'Exposition universelle à Paris en 1867.'

"thinking, and for desiring the details of so remarkable "a change." In this opinion I entirely concur.

There is little definite information on the subject of the speeds attained by the American iron-clads. The fastest monitors are said to have realised 11 knots, but the speed of most of the ships of this class does not appear to have exceeded 7 knots, and in some cases the speeds attained have been even less than this. The greatest speed of the broadside frigate 'New Ironsides' also seems to have been 7 knots. These figures are for the most part taken from reports of American officers to the Navy Department, and may, therefore, be considered to prove conclusively that the speeds of all except a few of their iron-clads fall considerably below those of the smallest and slowest of our armoured ships, and that their fastest ships are more than three knots slower than our fastest.

There are scarcely any recorded facts with respect to the speeds of iron-clads belonging to other countries to put before the reader; but it may, I think, be fairly asserted that our own ships compare favourably in this respect with any vessels yet built.

Intimately connected with the speeds attained by our iron-clad ships stands the question of their coal supply; in fact, no proper estimate of a ship's steaming capability can be made without taking into account the time during which she can proceed under steam before the coal she carries is exhausted, as well as the speed at which she can proceed. A few facts in relation to this subject will doubtless prove interesting to the reader, especially as this feature of our iron-clads—and particularly of the ships built since my appointment to my present office—has again and again been pronounced unsatisfactory by writers and speakers professing to be intimately acquainted with the subject. The public has been repeatedly informed that, in order to increase the weight of armour, armament, engines, and boilers in armoured ships, the coal supply has been greatly cut down as compared with that given to our unarmoured steamships; and that a gradual progress in this wrong direction has been made since the construction of the earlier iron-clads. I may at once state that such criticisms are both unfair and untrue; and, I doubt not, the reader will agree in this opinion when he has read through the following brief statements of facts.

The old type of marine engine, with which our wood ships and the earlier iron-clads were supplied, was capable of developing from four to five times the nominal power, and the total weight of engines and boilers but little exceeded three-quarters of a ton per nominal horse-power. It had been gradually improved during a long course of years, and had been brought to such perfection that the guaranteed power was often exceeded on the measured-mile trial. The great draw-back, however, to its many excellencies was its large consumption of fuel; and, in consequence of this, the new type of engine, with surface condensers, super-heaters, and other contrivances for economising fuel, was introduced. This type is capable of developing from six to seven times the nominal power, and the total weight of engines and boilers about equals one ton per nominal horse-power. The weight of the new engines is thus considerably greater per nominal horse-power than the old, but the developed power is also greater, and, as I shall show hereafter, they are far more economical of fuel. Hence it happens that in comparing the coal supplies of two ships, one of which has the old-type engine and the other the new-type, it is necessary to take account, not only of the weights of coal carried, but also of the weights of engines and boilers, as the ship with the improved but heavier engines has, so to speak, a portion of the total weight of propelling apparatus and fuel converted into a permanent economiser of fuel—in other words, a portion of the weight which in one ship is given to fuel is in the other put into superheaters, &c., in order to economise fuel, so that it is not necessary to carry so great a weight of coal. Take, for example, the cases of the 'Warrior' and 'Hercules.' The 'Warrior,' with engines of 1250 H.-P. nominal, has 920 tons as her weight of engines and boilers, and 800 tons as her weight of coals, making a total weight of 1720 tons; while the 'Hercules' has engines, &c., weighing 1206 tons for 1200 H.-P. nominal, and carries 600 tons of coal, making a total of 1806 tons, or 86 tons more than the corresponding total for the 'Warrior.' It is true that the 'Warrior' carries 200 tons more coal than the 'Hercules,' but the 'Hercules'' engines have been made considerably heavier on purpose to economise fuel, and, as I shall show further on, she can steam about the same distance as the 'Warrior' can before her coal supply is exhausted. This is only a specimen of the contrasts existing between the unarmoured ships, or the earlier iron-clads, and the comparatively recent iron-clads with improved engines.

Another point to which I must advert before going further is the very mistaken notion that prevails respecting the times during which our iron-clads can proceed under steam alone before their coal is exhausted. One often hears it stated that those ships can only steam for two or three days continuously, it being assumed in nearly all cases that the measured-mile full-speeds would be maintained for the whole of the time; it is tacitly assumed also that in this respect our iron-clads fall far below our unarmoured war ships. To these statements and assumptions I entirely demur, for reasons which I will at once bring forward. In the first place, there can be no doubt that, while measured-mile performances are the fairest tests we possess of a ship's utmost actual steaming power, under the most favourable circumstances—with trained stokers and good coal, and with the engines and boilers at their best—they do not at all represent the conditions under which a ship usually has to serve at sea. When engaged in chasing an enemy, or any other service requiring great despatch, it would, of course, be necessary to drive a ship at as great a speed as possible, although even then it cannot be expected that the engine-power would be brought up to an equality with that developed on the measured mile, and the consumption of fuel, consequently, would not equal that corresponding to the measured-mile speed. But when engaged on general service, such extremely high speeds would not be required; and it is in obtaining such high speeds that the largest expenditure of engine-power and fuel is, as we have seen, involved. As I have shown, also, the half-power speeds of many of our iron-clads are but little less than the full-power speeds of our fastest wood ships, so that it is absurd to compare the times which iron-clads can proceed at full speed with those which wood ships can proceed, omitting altogether the consideration of the difference of speed in the two classes. Adding to this the foregoing considerations respecting the impropriety of taking the full speeds and rates of coal consumption from measured-mile trials, in order to measure a ship's capability for performing sea voyages under steam, it cannot fail to be seen that the popular opinion on the subject is inaccurate.

In order to obtain a just idea of the relative coal supplies of different ships, it becomes necessary, then, to determine how long those supplies will enable them to proceed at good, though not excessive, speeds, say at from 11 to 12 or 12½ knots. These would be very high speeds for ships of war to maintain at sea, as the fast Trans-Atlantic steamers do not average 12 knots. It must be remembered also that 13 knots was the crowning measured-mile speed attained by our wood ships, and that only a few ships reached that speed on their load-draught trials. The 'Mersey,' one of our longest wood frigates, only made 12·587 knots; the 'Galatea,' another long fine frigate, did not reach 12 knots on her last load-draught trial; the 'Duncan,' one of our finest two-deckers, although she exceeded 13 knots on the measured mile when flying light (neither rigged nor stored), failed to reach 12 knots on the only load-draught trial of which we have any record; and the 'Bristol,' which belongs to the class of our frigates inferior only to the 'Mersey' and 'Galatea' classes, did not much exceed 11¼ knots.

These four ships may be taken, therefore, not only as fair, but as more than average, specimens of our wooden war-ships—the 'Mersey' and 'Galatea' being, in fact, very exceptional cases; and to give the reader a better idea than words only can convey of the falseness of the notion that our wood ships had coal supplies superior to those of the iron-clads, I have in the following table given the results of careful calculations, based upon recorded trials, of the times and distances during which those ships, and some of our iron-clads, could steam either at 12½ or 11 knots per hour.

It is necessary to premise that, in the calculations upon which the table is based, the rate of consumption of fuel per indicated horse-power per hour has been estimated, both for the old and the new type of engine, from the results of our experience in numerous ships of the Royal Navy. These results may be briefly summed up in the statement that, for the old type, from 4 to 4½ lbs. per indicated horse-power per hour is a fair value, and, for the new type, from 2½ to 3 lbs. These figures will enable the reader to judge of the amount of the saving of fuel resulting from the adoption of the improved engines. I may add that, while the table gives the probable results which would be obtained with the ships named, as far as our knowledge of their performances extends, yet it is not put forward as more than a good approximation, as the various circumstances attending the steam-trials used are, as I have previously shown, such as to preclude the attainment of entirely accurate results. In the cases of the 'Duncan' and 'Bristol,' I have assumed that they might be driven at 12½ knots by their present engines;

but it is only fair to state that the powers required to be developed in order to attain this speed are far greater than were ever developed in those ships, and would equal the best recorded performances of the old type of engine. This, of course, gives these two ships a considerable advantage, crediting them, in fact, with greater steaming powers than they have been shown to possess. All the other ships have exceeded 12½ knots on trial, so that in estimating their capabilities there is no similar source of error.

TABLE showing the Times and Distances for which the under-mentioned Ships can Steam before the Coal is exhausted.

	Coal Supply.	Speed of 12½ Knots.			Speed of 11 Knots.		
		Time.		Distance.	Time.		Distance.
	Tons.	Days.	Hours.	Knots.	Days.	Hours.	Knots.
Unarmoured ships:—							
Duncan	520	2	21	860	4	19	1260
Bristol	364	2	20	850	4	3	1090
Mersey	850	5	4	1550	8	19	2320
Galatea	700	4	5	1260	7	2	1870
Armoured ships:—							
Warrior	800	4	18	1420	7	23	2100
Achilles	620	3	19	1140	6	9	1680
Minotaur	650	3	11	1040	5	20	1540
Bellerophon	560	4	11	1340	7	11	1970
Hercules	600	4	14	1380	7	17	2030
Monarch	600	5	5	1560	8	18	2310

From this table it will be seen that the 'Duncan' and 'Bristol,' which are, to say the least, more than average performers in our wooden steam fleet, would, under the very favourable conditions stated above, steam for a considerably less time, both at 12½ knots and at 11 knots, than all the iron-clad ships considered. The 'Mersey' and 'Galatea,' having the exceptionally large coal supplies named, can steam for a much longer time than the other wood ships, and the 'Mersey' can steam further at both speeds than any of the iron-clads except the 'Monarch,' although she does not greatly surpass the 'Warrior,' 'Bellerophon,' and 'Hercules.' The 'Galatea' cannot steam so far as those four ships, and but slightly exceeds the 'Minotaur' and 'Achilles.' So far, then, as this comparison goes, the iron-clads have a decided advantage, on the whole, over the representatives of our wooden fleet, and most of them are only beaten by the 'Mersey,' which, with her sister-ship, the 'Orlando,' stand alone in their very large coal supply. I need add nothing to these facts in order to show more fully the falseness of the impression that, in steaming capacity, as measured by the time the coal on board will last, our wooden ships are superior to our iron-clads.

There still remains the question of the relative coal supplies of our earlier and more recent iron-clads, the answer to which is also supplied by the preceding table. The 'Monarch,' it will be observed, stands at the head of the iron-clads in the times her coal will last at the speeds taken. Next to her, and at a very small interval, come the 'Warrior' and 'Hercules,' the latter of which, with her improved engines, can do almost as much with her 600 tons of coal as the 'Warrior' can with her 800. The 'Bellerophon' stands in nearly the same position relatively to the 'Hercules' that the 'Hercules' occupies with respect to the 'Warrior;' and both the 'Achilles' and 'Minotaur' fall very much below the 'Bellerophon,' although they carry greater weights of coal. So far, therefore, from the recent iron-clads being inferior in coal-carrying power (in proportion to consumption) to the earlier armoured ships, we find that one of them, the 'Monarch,' is superior to all, while the 'Bellerophon' and 'Hercules' are superior to all the other iron-clads named except the 'Warrior,' and are not much inferior to that vessel. It must be remembered also that the 'Warrior,' with her partial protection, is not burdened with anything like so great a weight of armour as the 'Hercules' (the difference amounting to more than 500 tons), although she is a considerably larger ship, and that she carries 114 tons less armour than the 'Bellerophon.' I need scarcely say that this very great difference in favour of the defensive powers of the later ships far outweighs the comparatively small difference in favour of the steaming capability of the 'Warrior;' and a small deduction from the weights of armour would enable the coal supplies of the 'Bellerophon' and 'Hercules' to be so increased as to make them far superior to the 'Warrior.' In fact, if the 'Warrior' is to be classed as an iron-clad alongside of the better protected ships, it is only proper to make some allowance for the fact that her coal supply has been made large at the expense of her weight of armour. The same thing is, in a measure, true of the other earlier iron-clads—the 'Minotaur' and 'Achilles'—but, even when this consideration is waived, we find, as I have said, that the 'Bellerophon' and 'Hercules' stand considerably above them.

I must observe, with respect to the 'Achilles' and 'Minotaur,' that the results of the trials of steaming at fixed speeds made in the Channel Fleet of 1867 show that their rates of coal consumption did not then occupy the position relatively to the 'Bellerophon's' rate which I have assigned to them in the foregoing remarks. The explanation of this apparent discrepancy is to be found in the fact that, during this cruise, the 'Bellerophon's' superheaters, and other arrangements for economising fuel, were not working at all satisfactorily, in fact, on some occasions, were absolutely ineffective; so that her rate of consumption rose as high as the rates in ships with the old type of engines. It would obviously be unfair to judge of the 'Bellerophon's' capability by her performances under such circumstances, as the additional weights which had been put into her in order to obtain greater economy were worse than useless; yet this has been done on several occasions, as I shall show in another chapter. The more reasonable course is, in my opinion, that which I have followed, viz. to take the average results of our experience in various ships—an experience which, in the case of the new type, is rapidly becoming more extensive—and thus to eliminate the sources of error arising from differences in coal and stoking, as well as in the condition and management of the engines. For these reasons, therefore, I consider the preceding figures to be fair representations of the steaming powers of the ships named.

As I have had frequent occasion in this and former chapters to make repeated reference to the great value I set upon measured-mile trials, I will reprint here a Paper which I read in 1867 at the Institution of Naval Architects, "On Trials of Steam Ships at the Measured Mile," and which was as follows:—

Nothing is more common now, in connection with steamship performances, than to hear the usual system of trial at the measured mile condemned as unfair, deceptive, and inferior in every respect to a more prolonged trial at sea. We scarcely ever attend a steamship trial without hearing this opinion freely expressed; it frequently takes the form of a newspaper paragraph, and I have even seen it stated in official documents by responsible persons.

Now, in order to satisfy ourselves whether this popular opinion is sound or not, it will be necessary to consider what are the objects with which the measured-mile trial is undertaken, and whether those objects may or may not be more satisfactorily accomplished by other means.

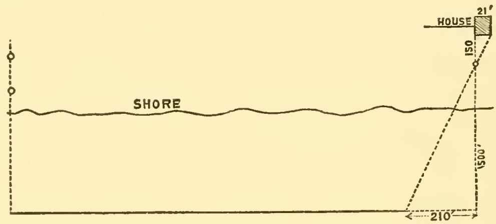
In discussing the first of these questions, it must be borne in mind that the measured-mile trial has, for convenience, come to fulfil objects for which it was not, I presume, resorted to in the first instance, and which could certainly be as well effected by a sea trial. Among these objects, I may mention the testing of the thorough efficiency of the boilers and engines when pressed to the full extent of their capabilities; the examination of the hull of the ship when subjected to the extreme power of the engines, with the view of ascertaining if any weaknesses or leakages exist; the examination of the connections of the hull and the engines, such as thrust blocks and other bearers, and the various steam and water pipes which are more or less intimately attached to the hull; and the trial of the draught to the boilers, and of the ventilating arrangements of the engine and boiler rooms generally. All these objects may, I think, be accomplished very satisfactorily on a continuous full-speed trial of several hours away from a measured mile; in fact, the test at sea would be more searching and thorough —in the case of the connections of the engines and the hull, for example—when performed at sea than it can be when performed in smooth water only.

The primary objects of the measured-mile trial are not, however, those which I have already named, but these, viz. the determination of the maximum steam power of a given ship's engines, and the true speed of the ship under the propulsive action of that power; and the determination of these facts under conditions which can be repeated in other ships, in order to afford scientific comparisons between them. The measured mile is also resorted to when the respective merits of different forms of propellers have to be tested; and, generally, whenever exact comparisons have to be drawn between the performances of steamships under like *external* conditions.

Now I, for one, cannot for a moment admit that a prolonged sea trial is better adapted than, or so well adapted as, a measured-mile trial for accomplishing these objects. On the contrary, I believe that, if the latter system of trial were to be replaced by the former, we should be left utterly without the means of making satisfactory comparisons between the performances of different ships, or even between the performances of the same ship at different times; and I am of this opinion because it appears to me evident that in the sea trials you must of necessity be subject to most of the disadvantages and derangements of the measured-mile trial, together with another set of disadvantages and derangements peculiar to the trial at sea.

The objections to the measured-mile trial are, I believe, these: It is presumed that the short duration of the runs upon the mile, with intervening periods usually of longer duration, affords opportunity for what is called "jockeying," in more ways than one—the chief way being that of "bottling up" the steam when off the mile, and letting it into the cylinders at full rush when on the mile; it is presumed further that the method of defining the length of the mile by the transit of posts or other objects on the land affords opportunity for deception; that the tides are likewise made available for increasing the apparent speed, especially in rivers; and, generally, it is alleged that the speed obtained on the measured mile in no way represents the actual steaming capabilities of the vessel when on actual service.

In dealing with these objections, it is necessary that we should very carefully discriminate between the use of the measured mile and its abuses. I freely admit that it may be, and very often is, abused, and made the means of securing for ships an utterly undeserved reputation for speed. To so great an extent are its abuses sometimes carried that I have seen a vessel whose maximum speed was 9 knots tried in such a manner as to secure an apparent speed of 11 knots, and have seen her announced in the newspapers of the next day as having attained the latter speed. On one occasion I observed, in addition to the "jockeying" below, the open—I may even say the barefaced—resort to three obvious sources of falsification. These were—1, the running of the vessel in the full strength of the tide when going with it, and near the shore in slack water when going against it; 2, the deduction of the average speed from an odd number of runs, of which the larger portion were made with the tide; and 3, the bringing of a wrong object on as a mark for the mile. This last device will be understood when I explain that at one end of the mile the marks were two posts, at the other end a post brought on with the side of a house; and the "dodge," if I may so call it, consisted in bringing the post on with the wrong side of the house. I have not the dimensions and distances involved, but it is easy to see from the accompanying diagram how the mile may be shortened by these means.

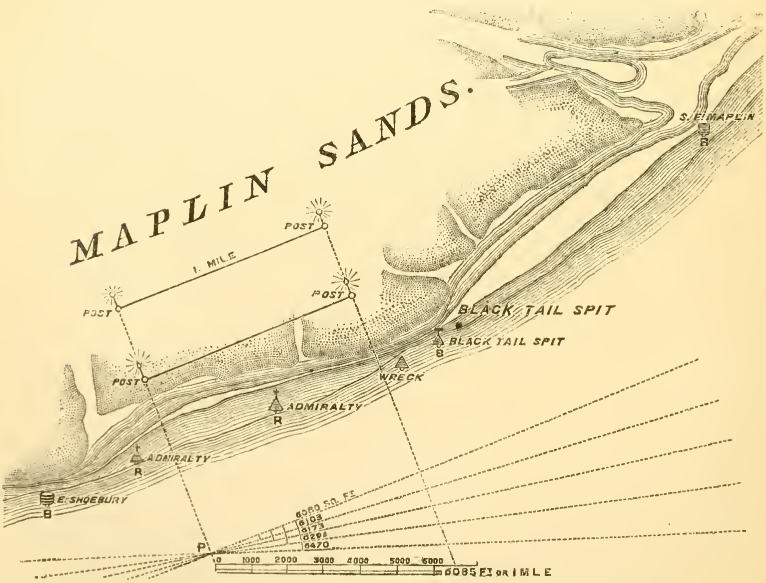


Presuming the breadth of the house to be 21 feet, the distance from it to the post 150 feet, and the average distance of the vessel from the post 1500 feet, you will at once see that this device shortened the mile by 210 feet, reducing it from 6080 feet to 5870 feet. A speed of $10\frac{1}{2}$ knots would thus be made to appear 11 knots from this cause alone.

The other two modes of securing a high nominal result, viz. those of using the tide as a source of speed, and the employment of an odd number of runs, are so manifest to every spectator that one almost wonders they are ever resorted to. But they are resorted to, nevertheless, and if I were not anxious to avoid giving personal offence, I would mention cases in which results that have been trumpeted to the world as extraordinary successes, have been secured by these means. And even more than this may be said; for I was informed not long ago, on authority in which I place implicit confidence, that in the case of a very fast steamship the announced result was obtained by selecting three runs out of several—two with the tide and one against it—and even this one run against the tide was somehow brought out much higher than any other of the runs in the same direction.

Now let me say once for all, and without the least apprehension of effectual contradiction, that no one of these last-named causes of error can enter into the official trials of Her Majesty's ships under the system upon which they now are, and for long have been, conducted. Those trials are carried out by a number of perfectly independent officers of the Royal Navy, who have no responsibility whatever for the vessel as far as regards her success or failure, who act under definite instructions, who record every result, and who report the results in full detail to the authorities at Whitehall. The standard miles are measured and marked by hydrographic officers; the exact nature of the marks is well understood by all on board; and the trials are usually attended by gentlemen of the press, whose observation of the proceedings is very close, and who are not usually slow in detecting errors in official operations.

On the other hand, there are sources of error that cannot well be avoided, which operate against the full success of vessels, the trials of which are so conducted. It is indispensable to the complete success of such a trial that the vessel should come in to the mile with her fullest speed; that that speed should be maintained throughout the mile; that the shortest line between the mile-posts should be run; and that the vessel's course upon the mile should be maintained without the use of the rudder. Any departure from either of these conditions must result in putting the apparent speed below the real speed; and it is obviously very difficult indeed to avoid a departure from some one or more of them during a prolonged trial of, say, half a dozen runs. The necessity for entering upon the mile at full speed, for maintaining that speed throughout the run, and for avoiding the resistance of the rudder, is obvious; but I have found the necessity of running on the shortest line between the marks so ill appreciated that I will trouble you with a few words upon it, notwithstanding the exceeding simplicity of the subject.



We have here a diagram of the measured mile at the Maplin Sands. Supposing a vessel that has to run the mile to enter upon it at the point P, going eastward, it is obvious that, in the absence of corrected compasses and a proper prescribed course, and in the absence of marks ahead and astern, she may run upon one of an indefinite number of lines passing through that point, and intersecting the lines through the mile-posts. But it is easy to see that only one of all those lines, viz. that which is perpendicular to the post lines, is exactly a mile in length between those post lines; every other line is longer than a nautical mile.

A line inclined at 5° to the true line, for example, is longer by nearly 8 yards; one inclined at 10° is longer by 31 yards; one inclined at 15° is longer by 71 yards; and if the angle be 20°, the increase of length is no less than 130 yards. A very simple calculation will show that a vessel which is really steaming at 14 knots will appear to be steaming at 13·94 knots if running on the line inclined at 5° on the true line; the 14 knots will be reduced to 13·71 if running on the 10° line; to 13·52 knots if running on the 15° line; and to 13·15 if running on the 20° line. Now, at the very important mile at Stokes' Bay, there were no marks whatever to define the true course of the ship (except in the clearest weather, when certain distant objects were visible) until recently, when the Admiralty, at my earnest request, laid down suitable buoys, which answer admirably. The measured mile at Plymouth is still deficient of these valuable guides.

It would be easy to show that in observing the transit of the poles or other objects great delicacy of observation is necessary when any important trial takes place. Such trials are, in fact, as I frequently have occasion to observe, not trials of knots, but trials of fractions of knots; and these turn upon a few seconds more or less. This is really a very important point, and one which is too little considered. It is often of great moment that a ship should attain a defined speed in knots. In the case of the 'Bellerophon,' for example, it was very satisfactory to me, and to persons of much more importance than myself, that a speed of 14 knots should be attained. The actual average speed attained was very nearly 14¼ knots, represented by an average run of 4 min. 13 sec. on the mile. Now a difference of only 5 sec. on the runs would have put the speed below 14 knots, and slight as the deficiency would have been, amounting to five-hundredths of a knot only, it would have been ample for one's rivals and enemies to have raised an outcry about. They have often done so on less grounds; that is, on none at all. At low speeds, a second or two are of much less importance. At very high speeds, the seconds are all in all. To enforce these facts, I will give a few figures:—

At a speed of 6 knots, a loss of 54 seconds would only occasion a loss of ½ a knot of speed.

At 7 knots, the ½-knot would be lost by a loss of 39 seconds.

At 8 knots, the ½-knot would be lost in 30 seconds.

At 9 knots, it would be lost in 23 seconds.

At 10 knots, in 18 seconds.

At 11 „ 15 „

At 12 „ 13 „

At 13 „ 11 „

At 14	knots, in	9	seconds.
At 15	„	8	„
At 16	„	7	„
At 17	„	6	„
At 18	„	5	„
At 19	„	4	„

These considerations show how necessary it is to conduct the measured-mile trials of steamships not only with impartiality but with great care if truthful and scientific results are to be obtained. Before quitting this part of the subject, I must, however, submit a few observations upon the "jockeying" to which I have already referred.

In the boiler-room the chief "jockeying" possible is, in my opinion, that of selecting better coal in one case than another, and this may be got rid of, and should, I think, be got rid of, by prescribing, in the Royal Navy at least, the uniform and invariable use of a given description of coal, which should be the best procurable. It is well known that the heating or steam-generating power of different descriptions of coal differs very materially, and it is only from the use of coal of the same kind on all trial trips that similar comparative results can be obtained. Allow me to observe, however, that changes in coal can only influence the development of power, and not the performances of ships. The latter are, of course, proportioned to the power developed, no matter by what means that power is obtained. It is, therefore, for the purposes of comparison between the engines and boilers of different ships, or between those of different makers, that it is desirable to use always the same kind of coal; and for those purposes that condition is almost indispensable. It may occur to some to say that the management of the fires, or, in other words, the stoking, may greatly modify the quantity of steam and power developed, and this is perfectly true. But the only means of approaching a standard in this respect is, in my opinion, to aim at doing the utmost in every case, by employing the same staff of stokers and others, and that staff of the most efficient kind, on every occasion. And this is what we practically do at Portsmouth and other Government ports in the trials of H.M.'s ships.

In the engine-room there will always, I fear, be some scope for "jockeying," but I believe this scope is practically much less than many imagine. In the trials of H.M.'s ships it is limited by the supervision of several engineer officers, as well as by the general consideration that, upon the whole, it is very doubtful whether frequent interference with the valves does not conduce to priming and to other derangements to such an extent as to make it more advisable to let the engines and boilers do their best continuously throughout the trial. I speak with some hesitation on this point, as there may be experienced "jockeys" present, and as I really am but an amateur observer in this respect; but I can with certainty state that every effort is made in the public service by the officers in charge to make the trials truthful, and on the very last trial I attended, the captain of the steam reserve forbade any interference with the engines during the whole period of the trial.

It only remains for me to state why I consider the prolonged trial at sea inferior to the measured-mile trial, and you will already have seen that it is on scientific grounds that I give it the preference. In the brief and manageable trial at the measured mile you can, when fully prepared, really develope for a given period the full power of the boilers and engines under the most favourable circumstances, and can also observe with exactness the speed obtained by the ship under the impulsion of that power. But send the ship to sea for a day, or even half a day (12 hours), and you at once lose the assurance that you are trying the power of the boilers and engines and the speed of the ship, and find that you are really testing not these, but the endurance of the stokers and engineers. This is the vital part of the question. I appeal to the experience of all present, and ask whether, even in ocean races, it is possible in closely contested races to satisfy the beaten party that the race was lost simply and solely by the inferiority of their steamer. It is not possible, because it is not the real qualities of the steamers that in all cases, or even often, decide such contests. In the most important and interesting ocean race that I ever attended (that between the 'Helicon' and 'Salamis') the faster vessel lost much of her credit owing to what I may call the accidents of the stoke-hold. In one vessel (the 'Helicon') we knew that we fell greatly short of our maximum speed, owing to our deficiencies in this respect; in fact, we had to go upon the first grade of expansion, and work easily for fourteen hours out of twenty-seven; and in the other vessel, the defeat which they even then sustained was boldly attributed to inferior coal. And so, I believe, it would ever be in ocean trials, whether by racing or otherwise. The longer the trial, after a certain length is passed, the less satisfactory will be the result as a means of comparison with other results. You can compare the results obtained on measured-mile trials; and although the formulæ which we apply to those results for obtaining the "constants" are but exceedingly imperfect standards of excellence, that does not detract from the validity of the results themselves, which are, in my opinion, far more valuable than any that could be obtained by prolonged sea trials, when viewed as data for scientific and practical comparisons between ships and engines.

In conclusion, let me say that my object in this chapter is not to oppose the resort to prolonged trials at sea for other purposes. For ascertaining the consumption of fuel, for finding out the most economical steaming speed, for comparing the load and light performances of vessels, and for many other important purposes which it would be easy to name—the ocean trial is invaluable, indispensable. All I desire to maintain is that the measured-mile trial is also a very valuable one for other and equally important purposes, and that it is an error, and a very serious one, to suppose that the trial at the mile could with advantage be dispensed with.

CHAPTER VI.

SAILING OF THE IRON-CLADS.

THE steaming qualities of our iron-clad navy being, as shown in the preceding chapter, highly satisfactory, the question arises, How do these armoured ships behave under sail? The importance of this subject, although wholly secondary to the steaming question, is sufficient to demand the brief consideration which I propose to give to it in this chapter.

The capacity for sea service must always form a prominent feature in the navy of a country like our own, which is essentially maritime, depends mainly upon its power at sea for its position among the nations of Europe, and has possessions in all parts of the world. Our wooden steam navy had gradually been made so efficient as to be capable of performing these services, both at home and abroad, most satisfactorily. The sailing qualities of the ships were not to any very great extent diminished by their possession of steam-power; and the latter was generally employed, especially in the earlier periods, as an auxiliary to, rather than as a substitute for, sailing power. In fact, the comparatively limited time which the coal carried by any ship would enable her to proceed under steam alone would have rendered the performance of long voyages and distant or cruising services almost impossible without a considerable spread of sail.

The necessity for sailing capability in iron-clads intended for such services is, no doubt, as great as it was in our wooden fleet; but as a considerable number of our armoured ships were mainly intended for European service, and more particularly for Channel service, they have had much less sail-power given them than the latest wooden line-of-battle ships and frigates were provided with. All our iron-clads, however, have a certain amount of sail-power as well as steam-power, except those specially constructed for coast defence and for ramming, and the new turret-ships 'Thunderer' and 'Devastation,' which have an unusually large coal supply, and can keep the sea for a considerable time, but which are not intended to perform the distant voyages and continuous sea services which cruising ships in our Navy have to undertake. The comparatively small proportion of sail-power in many of our iron-clads is partly due to the desirability of reducing the weights, and partly to the desire to avoid as much as possible the risk of fouling their screw propellers during action by wreck of masts, spars, and rigging. The effect of such canvas as these ships possess has, in most of them, been greatly diminished by the fact that their propellers do not lift. In the 'Warrior,' and some other ships with unprotected sterns, the screws have been made to lift in order to prevent this diminution of sailing capability; and some of the iron-clads now building have been similarly contrived. But this is not the case with the 'Achilles,' 'Minotaur,' 'Bellerophon,' 'Pallas,' and many other ships. In the 'Bellerophon' and 'Pallas,' the sailing has been further checked by the engineers giving exceedingly fine pitches to the screws, so that they stand almost directly across the ship's path, having the effect of what is technically known as "toggling" the vessel. But in spite of all these drawbacks, serious as some of them are, it cannot be said that the sailing performances of the iron-clads are, on the whole, unsatisfactory. The Reports of the Admirals in command of the Channel Fleet afford the best means of forming a judgment upon this point, and a few extracts from these Reports will doubtless prove interesting.

In the Report of Rear-Admiral Sir Sydney Dacres, for 1864, we find the following statements. During the passage from Lisbon to Portland, the sailing of the 'Warrior' and 'Black Prince' was good, enabling them to keep company with the 'Edgar' (screw line-of-battle ship) under sail only. Captain (now Admiral) Hornby, of the latter vessel, observes that, though under sail, the 'Edgar' "has generally an advantage; in a head sea, "as well as in steaming, the finer bows and long floors "of the iron ships give them a great superiority." In his remarks on the qualities of the iron-clads (see page 8 of the Parliamentary Return), Admiral Dacres says of the 'Warrior' and 'Black Prince' that, "even as "at present rigged, their sailing qualities on a wind on "long stretches make them equal to keeping pace with "vessels of the old class," and then adds, "the great "drawback to the many excellencies of this class is "that their extreme length interferes with their handi-"ness in many most important points." Among other points in which this unhandiness was felt, he mentions wearing and staying under sail, and the rounding-to of the ships when scudding. These drawbacks were, of course, incidental to the great lengths, and not to the armour-plating of the ships. In the course of his further observations, he states that the 'Defence' (a short ship) "is as handy in wearing and stays as any "one could desire;" and that the 'Prince Consort' and 'Royal Oak' (two of the short converted ships of the 'Caledonia' class) "are handy, though slow under "sail." Admiral Yelverton (in his Report for 1866) says, with respect to the sailing powers of the iron-clads: "On both these occasions I was able to judge of "the performance of the squadron, blowing hard and "with a heavy sea, and have no hesitation in saying "that, under all the ordinary circumstances of bad "weather in the Atlantic, I see no reason to apprehend "that the ships of this squadron would make worse "weather of it than any of our line-of-battle ships." He excepts two vessels from this statement, the 'Hector,' which has always proved an inferior sea-boat, and the turret-ship 'Wivern.' In his remarks on the individual merits and deficiencies of the ships, the Admiral states that the 'Achilles' is "a safe and good "sea-boat," although "from her great length most "difficult to handle;" that the Bellerophon "is "weatherly both in light and strong winds," although, as he supposes, the very large area of the balanced rudder tends "to stop the ship's way too suddenly "under sail," and often causes her to miss stays; that the 'Lord Clyde,' 'Ocean,' and 'Caledonia,' though not equal to the old line-of-battle ships as regards their sailing capabilities, are most efficient ships of war; that the 'Pallas' (as quoted in Chapter I.) "on all "occasions of sailing, whether on a wind or going free, "proved herself far superior to the rest of the "squadron," adding, "I may safely class her, in point "of sailing, with some of our good 36-gun frigates of "other days;" and that the 'Research' "sails well at "all times both when close-hauled and going free." In Rear-Admiral Warden's Report to Admiral Yelverton on the behaviour of the ships during the same cruise, we find them placed in the following order of precedence as regards performance under sail:— 'Pallas,' 'Research,' 'Bellerophon,' 'Ocean,' 'Hector,' 'Achilles,' 'Lord Clyde,' and 'Caledonia.' Admiral Warden adds—"With regard to the quantity of sail-"power carried by the several ships, I should say that "generally it is quite sufficient; nor do I think it "ought to be less, considering the various duties they "may be called upon to perform; nor do I consider "that it could be increased with advantage, or without "incurring the risk of impairing their efficiency under "steam. It is quite sufficient for all general purposes, "for assisting them to make long passages to distant "stations, for the purpose of economising fuel on "general service, as has been exemplified during the "last month." Admiral Yelverton's report confirms the accuracy of these remarks; but both officers agree in the opinion that, if the fleet were required to perform evolutions under sail, all the ships would need steam-power to ensure a certain and prompt performance of them. Admiral Yelverton further states, however, that, "as they are now rigged, they are able to keep "their positions in any assigned latitude and longitude, "tacking, and even wearing, with little doubt, pro-"vided there be plenty of sea-room, and that they are "not in line, nor called on to perform any manœuvres "or evolutions of a fleet." These are conditions which are, in most cases, satisfied when vessels are cruising or proceeding on long voyages; and the fact that all modern naval battles *must* be fought under steam renders it comparatively unimportant that our iron-clads cannot perform all the evolutions of a fleet under canvas as certainly or speedily as our old sailing ships could. It must be remembered also that these deficiencies in manœuvring power under sail are in some measure due to the fact that the iron-clads are screw steam-ships, and that in many of them, as I have said, the propeller cannot be lifted, this disadvantage being incurred in order to secure other advantages in time of action. Admiral Warden's Report on the trials of the Channel Fleet in 1867 does not give much additional information on the sailing qualities of the ships, beyond the fact that the change in the 'Achilles'' rig from four to three masts led to a far better performance; and the remarks respecting the apparent falling-off in the performance of the 'Pallas' (previously referred to), which is only explainable on the ground of difference of management, the ship and her rig having remained unaltered.

The Report on the Channel Fleet for 1868 does not throw much additional light upon the sailing capability of our iron-clads. Two trials of sailing took place on the 20th and 29th June, the details of which are given in a tabular form by Admiral Warden. On both occasions the trial was made "on a wind under all "plain sail," and the 'Warrior' was first, while the 'Bellerophon' was last. The 'Pallas' was second on the 20th, and fifth on the 29th, thus proving that her sailing power had not really fallen off, as had been inferred by some persons from her performance in 1867. The 'Defence' was third on both trials, and the 'Achilles' also took a high position, being fourth on the first trial and second on the other trial. No special remarks need, I think, be made regarding the performances of the remaining ships of the squadron. With respect to the 'Bellerophon's' performance, it will be sufficient to remark that these two trials only showed, to quote from Admiral Ryder's Report, that she "was the slowest of the eight ships on that point "of sailing, viz., on a wind under all plain sail," and that the results of previous trials have shown that her real position, as regards sailing capability, among the ships of the squadron is much higher than it would appear to be from those trials. To these facts regarding the sailing of our iron-clads I shall only add that the 'Hercules' has also been shown to be a very good vessel under sail, and in the opinion of one of the officers in the squadron is "next best to the 'Warrior.'" In this vessel the jointed balanced rudder admits of being used as an ordinary rudder when under sail alone, and by this means the rapid stoppage of the way caused by the simple balanced rudder of the 'Bellerophon,' when she is going about, is prevented, and there is consequently not the same liability to miss stays.

These facts will serve to show the reader that our iron-clads, whatever their imperfections as sailing ships, are not deficient in sailing powers as far as they are requisite in sea-going cruisers possessing steam-power also. The capability of these ships to undertake the most distant voyages cannot, however, be better illustrated than by a brief reference to the performances of one or two of them, and those not by any means the best sea-boats of the armoured fleet. Lord Henry Lennox, in one of his speeches on the Navy Estimates in 1868, referred to a voyage made by the converted iron-clad 'Ocean' from the Mediterranean to Batavia. In the course of this voyage the ship encountered very severe weather, especially after passing the meridian of the Cape of Good Hope on the way to St. Paul's Island in mid-ocean. Some idea of the violence of this storm may be obtained from the fact that every boat at the davits was stove. One of the officers, writing on this subject, observed—"No wooden ship could have "gone through it better, and a good many worse." He also stated that "under sail alone we have gone "12 knots," and that the runs made per day varied from 195 to 243 knots, the latter giving an average speed of more than 10 knots per hour. If any additional proof were required of the capability of our iron-clads to proceed to any part of the world, the voyage of the 'Zealous' to Vancouver's Island might be mentioned, as she also encountered heavy weather and behaved admirably.

At the same time I cannot help believing that, if we had not resorted to excessive length in the earlier iron-clads, we might have looked for better average performances in the squadron generally, and should have set up a higher standard of capability in all the essential movements of ships under sail. It is satisfactory to know that two of the powerful iron-clads now building, the 'Swiftsure' and 'Triumph,' are to carry lifting screws, and will have a large spread of canvas; so that the construction of the 'Thunderer' and 'Devastation,' without the compromises and drawbacks which the presence of masts and spars impose, will be attended by the construction of other ships for distant service possessing superior qualities as sailing vessels.

CHAPTER VII.

ROLLING OF THE IRON-CLADS.

THERE is no feature in the performances of our iron-clad ships which has been so much misrepresented and misunderstood as that of their rolling at sea. From the reports and criticisms of some persons, it would appear that these ships roll to an extent which is most excessive in comparison with wooden line-of-battle ships and frigates; and that in a very moderate sea-way the iron-clads cannot open their main-deck ports and fight their guns without shipping large quantities of water. I hope to give the reader the means of judging for himself as to the correctness of these views in the course of the following remarks, but think it proper at once to deny that they are true. In fact, instead of all our iron-clads being heavy rollers as alleged, several of them are remarkable for their steadiness, being much superior in this respect to the wooden ships, while the great majority are at least equal in steadiness to the line-of-battle ships and frigates. In support of this statement I will refer to a few of the Reports of the Admirals in command of the Channel Squadron. Admiral Smart says that the iron-clads he had with him in 1863 (which are by no means the steadiest of our ships) did not roll more than the screw line-of-battle ship 'Revenge.' From Admiral Dacres' Report for 1864, it appears that the 'Edgar' line-of-battle ship rolled through greater angles than any of the iron-clads, exceeding even the 'Prince Consort,' which is considered a comparatively inferior performer among the armoured ships. Admiral Yelverton's Report for 1866, and Admiral Warden's Reports for 1867 and 1868, do not bear directly upon this point, as there were no line-of-battle ships in the squadrons; but from the records of the maximum angles rolled through, it appears that several of the iron-clads behaved better than wooden ships would have done under similar circumstances.

The trials of French ships also go to prove that the iron-clads do not roll excessively, in comparison with wooden ships. I will give one example of this, taken from the reports of the squadron which was tried at sea in 1863. In the heaviest weather the ships experienced on this occasion, three out of five armoured ships rolled less than the 'Tourville' line-of-battle ship, and the other two iron-clads rolled very little more than the wooden ship.

These facts constitute a general answer to the statements so often made as to the heavy rolling of the iron-clads; a more detailed answer will be given further on. I will first turn, however, to the question of their fighting capabilities in a sea-way, as to which the public have been equally misinformed. Here, again, I must refer to the records of the trials of our Channel Squadrons, and I will take Admiral Warden's Report for 1867 as our guide. The long series of trials recorded in this Report show that, with one exception (the 'Lord Clyde'), all the iron-clads could have fought all their guns on all occasions, although in doing so they would, on several occasions, have shipped water through the main-deck ports. This shipping of water is not an unusual thing in wooden war ships, and naturally leads to the mention of a fact which is frequently overlooked in the discussion of this question of rolling. Our iron-clads are frigates, carrying, at least, the greater part of their guns on the main deck; but they are nearly all as large as, and many of them are larger than, line-of-battle ships. The line-of-battle ship, however, had at least two gun-decks; and frequently, when the ship rolled heavily, the lower-deck ports had to be closed, and the main-deck guns only could be fought. This difference between armoured ships and line-of-battle ships seems to have entirely escaped the observation of many writers and speakers. They expect the iron-clad, with her gun deck, say, 8 feet above water, to fight her guns in as heavy weather as that in which a wooden two-decker could fight her main-deck guns, carried, say, 15 feet above water, when the lower-deck guns of the latter would be rendered entirely useless by the sea washing over the ports, and necessitating their being closed. This is obviously most unfair and improper; but I may remark, in passing, that the wisdom of giving armoured upper-deck batteries to iron-clads—as has been done in recent ships—hence becomes apparent. It need only be added that in such dissimilar vessels as iron-clads and line-of-battle ships the number of guns which can be fought affords no test of the comparative rolling; and it is frequently found that the iron-clad frigates can fight their main-deck guns in weather when wooden frigates would have to close their ports.

Before proceeding to examine the records of the actual rolling of our iron-clads, I desire to call attention to a few popular but erroneous impressions on the subject. One of the most generally received of these is the belief that the heavy weights of armour carried on the sides tend to make iron-clads roll. To the unprofessional eye there does appear to be a "top-heaviness" in armoured ships; but this is more apparent than real. Comparing an iron-clad with a line-of-battle ship, we find the former with less lofty sides, and with a single gun-deck; so that, although the sides are covered with armour, the weights, as a whole, are not carried so high out of the water. For the sake of illustrating this point more fully, I will take the case of a converted iron-clad, say, of the 'Caledonia' class. The two-decked wooden ships which were turned into armoured frigates had their sides cut down considerably, and the main deck and its battery removed; while the armour, although about equal in weight to the parts removed, is not as high above water. The iron-clad is, therefore, less top-heavy than the wooden ship was previously to being converted; in other words, the conversion has the effect of bringing down the centre of gravity of the ship. The truth of this has been confirmed by actual experiment and calculation for several converted ships, and it is equally true of iron-built armoured vessels that they are less over-weighted than wooden line-of-battle ships.

The fallacy of the popular impression will, however, be seen still more clearly from a consideration of the behaviour of actual ships. The French have, as is well known, two vessels, the 'Solferino' and 'Magenta,' which are remarkable for being the only two-decked iron-clads ever built. Their external appearance is that of ordinary line-of-battle ships, with the exception of the bows, which are "spur-shaped," and specially constructed for ramming. They have two tiers of protected guns, and their armour extends to the upper-deck. Now, if overweighting on the upper portion is to be found in any iron-clad, it will assuredly be found in these high ships, with a gun-deck more than ordinary iron-clads possess, and with their armour reaching to so great a height; so that, according to the popular belief, they should roll excessively. So far from this being the case, it appears from French official reports that these vessels are far superior not only to the other iron-clads but also to the wooden two-deckers tried on the same occasions. The explanation of this singularly good behaviour will be given hereafter; but, for the present, it will suffice to say that this practical disproof of the correctness of the popular view admits of no answer.

It is not surprising, however, that those who think ordinary iron-clads "top-heavy" should also believe that ships with a small "free-board," or height of side above water, must be very steady; in fact, the one is repeatedly set forth, in the press and elsewhere, as a natural corollary to the other. The special subject in connection with which these remarks are most frequently made is the relative merits of low-decked turret-ships and broadside iron-clads, the former being supposed to roll much less than the latter. Here again facts contradict the general belief, and show that low-decked ships are not necessarily steadier than ordinary vessels. For instance, the turret-ship 'Wivern,' belonging to the Royal Navy, has a low free-board (about 4 feet), and is very lightly armoured, while her armament is also very light. Yet on one occasion her behaviour at sea was so bad that she had to be brought head to wind in order to prevent her shipping large, and, of course, dangerous, quantities of water, the extreme angle of roll rising to 27 degrees each way. This is not a singular case, as may be supposed. The 'Prinz Hendrik' also—a Dutch turret-ship which once received much praise—has rolled so heavily, when in the trough of the sea, as to make it very desirable to bring her head to wind. In contrast with this heavy rolling of low-decked ships, we can point to the 'Achilles,' which, according to Admiral Warden's Report, was comparatively quite steady in the trough of the sea under very similar circumstances, although she has lofty armoured sides; and also to the 'Hercules,' the steadiness of which ship is well known. It will scarcely be asserted, in the face of these facts, that by diminishing the height of a ship above water, and by this means alone, rolling may be almost entirely prevented. There can be no doubt that ships of the monitor type are, in general, very steady, although the reports of their commanding officers show that they sometimes roll considerably, but this steadiness is in a great measure due to the fact that the waves wash over their decks instead of striking against, and running up, the sides. Very serious disadvantages, of course, accompany the steadiness of these vessels. In this place I need only mention those connected with working the turret guns in a heavy sea. When waves are breaking over an ordinary monitor, she may remain comparatively steady, but the guns, being at such a small height out of water, could only be fought with difficulty, if fought at all. In similar weather a broadside ship would probably roll more than a monitor (although, as we have seen, this is not necessarily the case), but, having been constructed with lofty sides for the very purpose of fighting her guns under such circumstances, she could do so safely; and surely the fact that in fighting capability the broadside ship is superior more than outweighs the greater occasional steadiness of the monitor. The reader will not fail to remark also that the low-decked ships hitherto built are not sea-going, in the proper sense of the term, although proposals have been made to use them for sea service; whereas broadside ships can, as I have shown, make the longest passages, and encounter storms, with perfect safety.

Another point deserving notice is the belief entertained by many that mere weight, irrespective of height out of water, tends to produce excessive rolling in iron-clads. This is also an error, as the records of trials prove that the heaviest ships are also, in most cases, the steadiest—the 'Hercules,' for example, rolling much less than the 'Pallas,' and the 'Bellerophon' than the 'Research.' In fact, the heavier a ship is the greater is the resistance she offers to being set rolling, a statement which it is scarcely necessary to illustrate, as we are all familiar with the fact. It is true that great weight tends to sustain motion when it has begun, but even then it does not increase rolling. In fact, as far as the mathematical theory of rolling goes, a ship's behaviour is entirely independent of her weight, although the heavier ship has the advantage of requiring a greater effort to set her rolling, and is therefore, *cæteris paribus*, steadier than a lighter vessel. In this connection it is proper to state, that the amount of armour carried does not influence a ship's rolling as many suppose it does.

The 'Minotaur' and 'Achilles,' for instance, are equally steady, although the arrangement and weight of their armour are so very different; and other ships, quite as dissimilar in these respects, are very similar in their rolling. The form of a ship's bottom has been thought by some persons to have a great effect on her rolling, but this does not appear to be true, within the limits of form which are met with in actual ships, except as regards easiness of motion, which is largely influenced by the form of the ship in the neighbourhood of the water-line. These are some of the chief popular views on the subject of the rolling of iron-clads which require to be set right, and the consideration of which will not, I think, be unprofitable to the reader.

The difficulties with which a naval architect has to grapple in designing a steady iron-clad are not, and from the nature of the case can hardly be, realised by the public. For instance, it is not generally known that a ship's rolling depends largely upon, and varies with, the character of the waves she encounters in relation to the time in which she would perform an oscillation if set rolling in still water. A vessel may be very steady under some circumstances, and yet she may fall in with waves of even less magnitude, but of such a "period" as to gradually increase the angles to which she rolls. This can be illustrated from Admiral Warden's Report. The 'Warrior' and 'Lord Warden' rolled very similarly on several occasions, and it might reasonably have been assumed that they would behave alike under most circumstances; but on some trials, the only change in the circumstances being in the state of the sea, the 'Warrior' rolled much less than the 'Lord Warden.' Similar remarks apply to the relative rolling of the sister ships 'Lord Warden' and 'Lord Clyde,' the latter in general rolling much more heavily, but on one occasion being steadier than the former. This case is also interesting as an illustration of the fact that sister ships, built from the same drawings, do not always behave similarly. The designer, of course, cannot predict the weather which any ship may encounter, and if he could, the attempt would be hopeless to produce a ship which should behave equally well in waves of different "periods." All he can do is to give such properties to the new vessel as experience has shown desirable; and this has, I consider, in the great majority of cases, been done satisfactorily in our iron-clads.

Besides the influence of the wave-period upon a ship's rolling, there is the further consideration that changes in the weights carried produce corresponding changes in the rolling. These changes are to some extent unavoidable, being in a war ship principally due to variations in the quantity of coals, provisions, ammunition, and stores on board. In any criticisms on the rolling of iron-clads on particular occasions, it is consequently necessary to take into account not only the state of the sea, but also the stowage of the ship, as otherwise very false opinions may be entertained. The construction of the hull also exercises considerable influence on rolling. A wood-built iron-clad, for example, is very differently constructed from an iron-built armoured vessel, and the proportion of the weight of hull to the total weight of the ship and her lading (in other words, to the total displacement) also differs very considerably in the two ships. The centre of gravity of the wood hull is comparatively low. These facts tend to prepare us for the fact which the trials of the Channel Fleet have developed, viz. that on the whole wood-built ships roll more than those built of iron.

The manner in which the observations of a ship's rolling are made and recorded necessarily forms an important feature in any remarks on her qualities. In our own Navy, the records are made in accordance with a detailed scheme of instructions issued by the Admiralty, and embrace accounts of the state of the sea, and force and direction of the wind; the stowage, draught, and course of the ship; and the angles rolled through, as well as the number of oscillations per minute. The two last-named features supply information as to the range and the rate of the ship's rolling respectively. The angles recorded are always the *total* angles rolled through; in other words, the sum of the angles to port and starboard. The oscillations recorded are the number of times the ship passes from port to starboard, and *vice versâ*, per minute. Three instruments are in general use in our Navy for measuring the angles of roll—the pendulum, the clinometer, and the bar or batten instrument. The last alone is correct, and is used in all the ships of the French navy, the angle being determined by an observation of the horizon. The pendulum is a very bad instrument for measuring the roll, usually indicating larger angles than the ship moves through, especially when she is rolling heavily. We should anticipate this from the fact that, even when a vessel is rolling moderately, everything which is freely suspended on board is put into violent motion. In order to illustrate the errors of the pendulum and the mistakes which must arise from its employment, I need only turn to Admiral Warden's Report. On one occasion the 'Lord Warden's' rolling amounted to 11·4 degrees according to the pendulum, but only reached 9·1 degrees according to the bar instrument; and on another trial the indications of the two instruments gave 14·9 and 12 degrees respectively as the angle of roll. These are, as we shall see, by no means the greatest differences which are recorded, but are given as average specimens. The clinometer is a somewhat better instrument than the pendulum, but its indications are not reliable, as it also often gives a greater angle than the ship actually rolls. I will not enter at greater length into this subject, but think that enough has been said to bring home to the reader the necessity for careful observations with reliable instruments.

The theoretical investigations connected with the subject of rolling are of too abstruse a character to be introduced into this chapter. The labours of Mr. Froude (who has within the last few years taken the lead in this matter), and of the other gentlemen who have devoted their attention to the subject, have, however, resulted in the establishment of two great facts which can scarcely fail to be interesting to the general reader. The first of these facts is that the principal thing (although not by any means the only one) which influences rolling, is the distance between the centre of gravity of a ship and the point known to naval architects as the "metacentre;" the second is that a ship's rolling at sea is largely influenced by the period, &c., of the waves she meets with. Experience confirms the accuracy of both these deductions. As to the latter we need make no further remarks, since it has been previously illustrated by reference to the trials of the Channel Squadron; but the former requires a brief notice. Ships which have a great distance between the centre of gravity and the metacentre are technically termed "stiff," and will carry large spreads of canvas, but they usually roll with violence. On the other hand, ships which have a moderate distance between these points are not so stiff, and roll moderately; while, if this distance becomes very short, a ship will be very "crank," and might possibly be upset under some circumstances—for example, by accumulated motion resulting from the action of very long waves. In order to render this point clearer I will cite a few facts. In the French squadron referred to above there were five iron-clads, which stand in the following order as regards the distances between the centres of gravity and the metacentres—'Solferino,' 'Magenta,' 'Couronne,' 'Invincible,' and 'Normandie.' The 'Solferino' has the least distance, and is the steadiest ship, and the others are reported to have stood precisely in the order in which they are named as regards their rolling. In our own Navy similar results have been obtained. For example, the 'Achilles' has a distance of about 3 feet between the centre of gravity and the metacentre, and is a remarkably steady ship; whereas the 'Prince Consort,' with a distance of 6 feet, rolls much more than the 'Achilles.' It is even more interesting to remark that, although the 'Warrior' and 'Achilles' are nearly identical in external form, the former has a greater distance between these two points than the latter, and is not nearly so steady.

These illustrations will serve to show the desirability of making the distance between the centre of gravity and the metacentre—or, in technical language, the "metacentric height"—as small as is consistent with a proper amount of sail-carrying power, or stability, when a new iron-clad is being designed; and this course has been followed in all recent ships. The position of the metacentre is determined by the form and dimensions of a ship, especially at the water-line, and by the total displacement; and the position of the centre of gravity is fixed by the stowage of the weights on board, the disposition of the armour, and the mode of constructing the hull. On certain fixed dimensions there is a greater scope for altering the position of the centre of gravity than for moving the metacentre, and the results of our experience may be broadly stated as follows:—A high position of the centre of gravity tends to produce steadiness, and a low position tends to cause excessive rolling. The recognition of these principles leads to the explanation of some of the apparently strange facts connected with the subject of rolling. For instance, wood-built iron-clads have heavier hulls than those built of iron, and the weights of engines, boilers, &c., are placed low down, all of which tends to bring down the centre of gravity, and as the result the wood-built ships roll more heavily than the iron-built ships. There are, of course, great differences among the iron ships themselves, due in great measure to different positions of their centres of gravity resulting from variations in the armour, armament, heights of engines and boilers, and stowage. Take, for example, the two ships above referred to, the 'Achilles' and 'Warrior.' Their external forms are almost identical, but the 'Achilles' has an armour belt throughout the length, which the 'Warrior' has not, by which the centre of gravity is brought higher up; she also has other weights above the water which the 'Warrior' has not, and her displacement is greater than the 'Warrior's,' which brings down the metacentre, so that the combined effect of these changes is to make the 'Achilles' the steadier ship of the two. In recent ships, such as the 'Bellerophon' and 'Hercules,' the position of the centre of gravity has been raised, by means of deep double bottoms and other contrivances for carrying the great weights of engines, boilers, &c., as high up as possible.

The fallacy of the popular belief that rolling is caused by carrying heavy weights on the upper works of iron-clads is rendered still more apparent by these facts, which form a complete answer also to the attack made upon the 'Invincible' class in our own Navy. These vessels have, as before stated, armoured upper-deck batteries, the weight of which being carried at such a height above water has been said, not only by unprofessional writers and speakers, but by professed naval architects, to be conducive to rolling. The probability, amounting almost to certainty, is, however, that these upper-deck batteries alone would make the ships steadier, as they bring up the centre of gravity; although, on the other hand, the great sail-power of these ships, necessitating, as it does, a considerable amount of stability, has put a limit to this improvement. The good behaviour of the 'Magenta' and 'Solferino' also becomes intelligible when it is remembered that their lofty sides, their additional gun-deck, and the unusual height of their armour, all tend to bring the centre of gravity higher than it is in ordinary iron-clads.

In concluding these general remarks on rolling, I may state that the trials of our recent ships prove that, on the whole, this important and difficult subject has been successfully grappled with; and the trials of our most recent broadside frigate, the 'Hercules,' have shown her to be all that could be desired as a steady gun platform. The 'Lord Clyde,' 'Royal Oak,' and 'Prince Consort,' do undoubtedly roll more than the iron-built ships; but this, as we have already pointed out, is due in a great measure to the fact that they have wooden hulls. The 'Lord Warden' is steadier, the difference in behaviour being caused, most probably, by her upper weights being somewhat greater than those of the 'Lord Clyde,' a fact which tends to raise the centre of gravity, and therefore to prevent rolling.

I now propose to consider the results of actual trials of rolling, so far as the records given in the Reports on our Channel Squadron will enable me to go, and to give a brief *résumé* of these results. Admiral Dacre's Report for 1864 shows that on the four days when all the ships were together, the means of the extreme rolls recorded were as follow:—'Hector,' 10 degrees; 'Warrior' and 'Defence,' 10·25; 'Black Prince,' 11·05; 'Prince Consort,' 11·75; and 'Edgar' (wooden line-of-battle ship), 14·25. The 'Warrior's' rolling was measured by a different instrument from that used on board the other ships, so that she cannot be fairly compared with them. This record is, however, of great interest, on account of the comparison it renders possible between the behaviour of the iron-clads and the wooden two-decker, the latter proving the heaviest roller in the squadron. In Admiral Yelverton's Report for 1866, there are given examples of the comparative rolling of several of the iron-clads, obtained from three days' observations, of which the mean results are:— 'Achilles' and 'Bellerophon,' 6·6 degrees; 'Hector,' 11·3; 'Ocean,' 14·3; 'Lord Clyde,' 16·1; 'Pallas,' 17·3. These are, it will be remembered, the sums of the angles of rolling to port and to starboard. The only ship present at both trials was the 'Hector,' and she, from being steadiest on the first occasion, dropped into the third place on the second, although her rolling was not much greater. Hence it would naturally be inferred that the 'Achilles' and 'Bellerophon' were steadier ships than any of those present in the 1864 squadron; and this inference has been shown to be correct by further trials. The three heaviest rollers are wood-built ships, a fact which partly explains their behaviour. The small size of the 'Pallas,' as compared with the other ships, puts her at a great disadvantage as regards comparative rolling in ordinary waves.

Admiral Warden's Report for 1867 is much more detailed in its records of rolling than either of the preceding Reports. The performances of various ships are recorded separately, and there are, in addition, abstract returns giving the mean results of the rolling of all the ships tried on various occasions. The trials extended over portions of the months of August, September, and

October; and in my remarks upon the results I will, for convenience, follow the arrangement adopted in the Report, beginning with the returns for August. On the 12th of that month, records of the behaviour were made, when the four ships 'Minotaur,' 'Achilles,' 'Bellerophon,' and 'Lord Clyde,' were proceeding for 10 hours at a 5-knot speed under steam, the sea being nearly smooth. The 'Lord Clyde' was the only ship which rolled at all, and her maximum angle was only 3 degrees. From the 14th to the 17th of August, the 'Achilles' is stated to have rolled very slightly, the maximum angle being 4 degrees; the other ships are not mentioned. On the 20th, the squadron was under sail only, with a somewhat heavy sea on the beam and bow, and the total mean rolls, measured by the pendulum, were:—'Minotaur,' 4·8 degrees; 'Achilles,' 5·8; 'Bellerophon,' 6·8; 'Lord Clyde,' 12·3. On the 21st the 'Achilles' is reported to have rolled very slightly, her motion being scarcely perceptible, and the remaining ships are not mentioned; but on the 23rd, the squadron being under steam in a moderate sea, the pendulum gave the following total mean rolls:—'Minotaur,' 3·5 degrees; 'Bellerophon' and 'Achilles,' 4; 'Lord Clyde,' 6·75. It may appear strange that I should select the pendulum observations after remarking on the errors incident to the use of that instrument; the reason is that this was the only instrument with which all the ships were supplied. The 'Lord Clyde's' rolling was, no doubt, made to appear greater than it really was by these observations; and this is rendered certain by the fact that on the 20th, when the total mean roll was 12·3 degrees by the pendulum, that by the clinometer was only 10·4 degrees. It is to be regretted that the bar instrument with which the 'Lord Clyde' was furnished was not used on this occasion, the reason given being that the "main trysail sheet was hauled aft, and in the "way of fixing this instrument;" for if the observations had been made, the true behaviour of the ship would have been known. The total mean roll includes, as we have before stated, both the angles of heel to port and to starboard; when the 'Lord Clyde,' for example, had a total roll of 12.3 degrees, her roll to port was a little less than half that amount, and that to starboard a little more than half. The trials for August were not made in severe weather, with the exception of that on the 20th, on which occasion the 'Lord Clyde' could not have fought her main-deck guns for about three or four hours, although the other ships could have fought all their guns throughout the day. It must not be forgotten, however, that, even when rolling most heavily, the upper-deck guns carried in the armoured bow battery of the 'Lord Clyde' could have been fought, and would in all probability have proved most formidable under the circumstances.

Passing on to the September records, we find that the trials were made during the passage of the squadron from Portland to Berehaven. Only the 'Lord Clyde' and the 'Bellerophon' are mentioned in the abstract returns for the 4th and two following days, but by taking them in connection with the detailed reports for those days, we make out the following facts:—The 'Bellerophon's' total mean roll for the 4th was about 6 degrees by the pendulum, and the other ships did not roll so much. On the 5th, the ships encountered a heavy sea in crossing the entrance to the Irish Channel, and the 'Minotaur' rolled 12 degrees, the 'Achilles' 13, the 'Bellerophon' 15, and the 'Lord Clyde' 19. The next day, in very similar weather, the rolling, on the whole, resembled that of the 5th, although on one occasion the 'Minotaur' rolled 19 degrees, the 'Bellerophon' 29 degrees (16 to starboard, and 13 to port), and the 'Lord Clyde' 23 to starboard, and 24½ to port. These two days' trials constituted the severest tests of the rolling qualities of the iron-clads in the squadron, and it is consequently of great interest to enquire as to their fighting capabilities on these occasions. The 'Bellerophon' could have fought her guns with perfect safety on the 5th, although the captain states that "the "ports could not be kept permanently open." The reports do not state the capability of any of the ships to fight their guns on the 6th, except the 'Lord Clyde,' which could not have fought her main-deck guns, as the sea was washing entirely over the ports; and this was also the case with this ship at intervals on the 5th. I need hardly again draw the reader's attention to the upper-deck battery guns of this ship, which could, no doubt, have been fought with great effect and perfect safety, although no information is given in the report as to her capability, or otherwise, in this respect. No remarks are made as to the fighting capability of the 'Minotaur' and 'Achilles' on the 5th; but as they were steadier than the 'Bellerophon,' there is no doubt that they also could have fought their main-deck guns. On the whole, therefore, the results of these trials in heavy weather are very satisfactory.

The October trials extended over a much longer period, and the number of ships in the squadron was larger. On the 9th the ships were under canvas, with a long heavy sea on the beam, and the total mean rolls were moderate for all the ships except the 'Lord Clyde.' The 'Minotaur' rolled 6·1 degrees, according to the pendulum observations, but only 3·8 degrees by the batten instrument, another illustration of the inaccuracy of the pendulum. No record was made of the 'Bellerophon's' performance. All the other ships had bar or batten instruments, the observations with which gave the following total mean rolls:—'Achilles,' 5·9 degrees; 'Warrior,' 7·5; 'Lord Warden,' 9·1; 'Lord Clyde,' 21·5. With the exception of the 'Lord Clyde,' the rolling of the ships on this occasion was probably less heavy than that of wooden frigates would have been under similar circumstances. The 'Lord Clyde's' behaviour was not so satisfactory, as she rolled from 9 to 12 degrees each way, and the captain's report states that, "when at general quarters, although the "guns, with lower half-ports up, might occasionally "have been worked, they were practically useless, as "the sea washed into the muzzles directly they were "exposed." In the column headed "number of guns "that could be worked with safety," we find the remark "none;" but this does not, of course, include the protected upper-deck guns before referred to. On the next day, the 'Lord Clyde' rolled quite as heavily, but the other ships only rolled moderately, and could have fought all their main-deck guns. Their total mean rolls by the bar or batten instruments were:— 'Achilles, 2·2 degrees; 'Minotaur,' 2·7; 'Bellerophon,' 3; 'Warrior,' 6·1; 'Lord Warden,' 11·2. It is worth notice that the pendulum observations gave the 'Bellerophon' a total mean roll of 8·2 degrees on this occasion, although her actual roll was only 3 degrees. During the next three days, the weather was much more moderate, and the 'Minotaur' and 'Bellerophon' had no appreciable motion, while the 'Achilles' only rolled 1·4 degrees on the 11th, and 3·2 degrees on the 13th, being nearly steady on the 12th. The remainder of the squadron were also without much rolling motion, as will appear from the following total mean rolls of the 11th:—'Warrior,' 2·8 degrees; 'Lord Warden,' 4·9; 'Lord Clyde,' 6·5. On the 12th, their behaviour was very similar; and this was also the case with all the vessels, except the 'Lord Warden,' on the 13th. This vessel, as we have seen, was considerably steadier on all preceding trials than her sister ship, the 'Lord Clyde;' but on this occasion, while the other ships were comparatively steady, and the 'Lord Clyde' was only rolling 5·5 degrees, the 'Lord Warden' rolled 12 degrees. The explanation of this singular behaviour is, doubtless, to be found in the character of the waves among which she was rolling, as all other circumstances remained unchanged from the preceding day. The squadron was under steam on the 14th, with a long and heavy sea on the quarter. The rolling was considerable, but all the ships, except the 'Lord Clyde,' could have fought their main-deck guns, although the 'Bellerophon,' 'Warrior,' and 'Lord Warden,' would have shipped some water through the ports in doing so. The ports of the 'Lord Clyde' could be kept open, according to the captain's report, without shipping water; and yet it is added, "none of her guns could "have been fought without great caution." As other ships were shipping water when fighting their guns, this report can only be explained by supposing that there were defects in the arrangements for controlling and working the guns of the 'Lord Clyde.' The total mean rolls, measured by bar or batten instruments, on this trial were:—'Minotaur,' 6·2 degrees; 'Achilles,' 6·3; 'Bellerophon,' 9·4; 'Warrior,' 12·6; 'Lord Warden,' 14·5; 'Lord Clyde,' 21. Only two ships are mentioned as having rolled on the 15th: the 'Achilles,' which rolled as much as 10 degrees, and the 'Lord Clyde,' which occasionally rolled deeply; both ships could, however, have fought their guns.

The concluding series of trials recorded in this Report were commenced on the 25th of October, the 'Prince Consort,' 'Royal Oak,' and 'Pallas,' having joined the squadron. No abstract return is given for this day, but from the detailed reports it appears that, with a moderate breeze and a very long swell, the maximum roll of the 'Achilles' was about 6 degrees, by the pendulum; and that the average roll of the 'Warrior' was about 7 degrees, of the 'Prince Consort' about 9 degrees, and of the 'Royal Oak' about 10 degrees. The next day's records only give information with respect to four ships, of which the total mean rolls were:—'Achilles,' 2·5 degrees; 'Warrior,' 5·7; 'Royal Oak,' 10; and 'Prince Consort' (by pendulum), 10·4. The 'Prince Consort' was the only ship which did not carry a batten instrument, and her rolling was no doubt exaggerated by the pendulum observations. During the 27th and 28th the rolling was so slight as to require no notice; but on the 29th, in a heavy sea, and under steam, some of the ships rolled considerably. Taking the observations with the batten instruments in all the ships except the 'Prince Consort,' for which vessel the means of the pendulum and clinometer observations are taken, we find the total mean rolls to have been as follow:—'Minotaur,' 3·1 degrees; 'Achilles,' 5·9; 'Bellerophon,' 8·6; 'Warrior,' 9; 'Royal Oak' and 'Prince Consort,' 11·1; 'Lord Warden' and 'Pallas,' 12; 'Lord Clyde,' 27·4. All except the last-named ship could fight their main-deck guns; and in the captain's report for the day we find it stated that the 'Lord Clyde' "might have been "placed to have fought all her guns by bringing her "head to the swell." The records conclude with the trials of the 30th of October, when the sea was moderate, and the ships were under steam. The 'Minotaur' and 'Bellerophon' had no appreciable motion; the 'Achilles' only rolled 2·6 degrees; and the total mean rolls for the other ships were given by the batten instrument as follow:—'Lord Warden,' 4·7 degrees; 'Royal Oak,' 5·3; 'Prince Consort,' 5·7; 'Warrior,' 6·3; 'Lord Clyde' and 'Pallas,' 13. All the ships could have fought their main-deck guns on this occasion.

From these records of rolling it appears that the 'Minotaur' and 'Achilles' were the steadiest ships then in the squadron, the former having a slight advantage, which was probably due to her greater size and weight. These two vessels are rather superior to the 'Bellerophon,' which is steadier than the 'Warrior.' When the comparative smallness of the 'Bellerophon' in relation to these ships is taken into account, the high position she occupies as regards freedom from rolling cannot fail to appear remarkable. As previously stated, the wood-built ships roll more than the iron ships, although the best of them, the 'Lord Warden,' is but very little inferior to the 'Warrior.' The 'Lord Clyde's' behaviour is singularly bad, but as she is a sister ship to the 'Lord Warden,' there can be little doubt that she may be rendered much steadier by raising some of the weights, or by some other equivalent means—in fact, there is no *à priori* reason why she should not be equally steady with the 'Lord Warden' if the weights carried were similarly arranged. The remaining wood-built iron-clads were only present at a few trials, and were not tested by anything approaching to heavy weather except on the 29th October. As far as these trials go, however, the 'Prince Consort' and 'Royal Oak' appear to be nearly as well behaved as the 'Lord Warden,' and the 'Pallas' to be hardly as steady—a result not to be wondered at when the small dimensions of the 'Pallas' are taken into account. I would again call attention to the fact that throughout these trials all the ships, with the exception of the 'Lord Clyde,' could have fought all their guns on all occasions, although they would sometimes have shipped water through the ports.

The Report on the trials of the Channel Fleet in 1868 also contains detailed returns of the rolling of several of the iron-clads during the cruise which extended from 4th June to 6th July. I do not propose to go *seriatim* through these returns, as the weather was on nearly all occasions exceptionally fine, and shall simply state, with respect to most of the returns, that the figures given as the result of the observations made show that the 'Minotaur,' 'Achilles,' and 'Bellerophon,' are the steadiest ships; that the 'Warrior' is a little less steady; and that the other ships, particularly the 'Royal Oak,' are not nearly so steady, although they behave quite as well as unarmoured frigates would probably behave under similar circumstances. The 'Hercules' was not present. There were, however, a few days on which the behaviour of some ships was such as to deserve notice, and I shall briefly refer to those cases.

On the 8th of June, when the ships were under plain sail, with a moderate sea on the beam and quarter, the force of wind being 4 to 6, the 'Minotaur,' 'Bellerophon,' 'Achilles,' and 'Warrior,' were scarcely moving, their total mean roll not exceeding 2½ degrees, when the 'Defence's' roll was 8·8 degrees, the 'Royal Oak's' was 9·5 degrees, and the 'Prince Consort's' 10·3 degrees. Even the maximum roll on this occasion was, of course, very moderate, and all the guns could have been fought in all the ships; but the figures given are interesting as the means of comparing the behaviour of the different ships. On the 10th we find the total mean rolls recorded to be as follow :—'Minotaur,' 4·3 degrees; 'Achilles,' 5·2; 'Bellerophon,' 5·4; 'Prince Consort,' 7·7; 'Warrior,' 9·3; 'Defence,' 11·2; 'Royal Oak,' 14·3. The ships were under plain sail, the sea was "moderate and long on beam," and the force of wind 3, or less than on the 8th. All the ships rolled more on this occasion than on the 8th, except the 'Prince Consort,' which had a total mean roll 2½ degrees less. This circumstance can only be explained by the different character of the waves on the two days, as the ship's lading remained almost unaltered; and it affords another illustration of the varying effect which waves have upon a ship's behaviour. The 'Royal Oak,' although rolling considerably, could fight all her guns throughout the day. One other feature of the returns for this day deserves attention, viz. the fact that, while the total mean roll of the 'Minotaur' was 8·2 degrees according to the pendulum, it was only 4·3 degrees according to the correct observations of the batten instrument. It is no wonder, therefore, that Captain Goodenough states in his report that he considers the pendulum observations to be "more than useless," and that he recommends the exclusive use of the batten instrument. On the 11th we find that the 'Royal Oak' and 'Prince Consort' were rolling more heavily than on the previous day, while all the other ships were steadier, the squadron being under steam. In fact, during some parts of this day the 'Royal Oak' could not have fought her main-deck guns with safety, although the captain remarks in his report—"In a case of emergency, and by "watching the rolls, the guns on the highest side may "be used." The 'Prince Consort' was much steadier than the 'Royal Oak,' her total mean roll being 11·1 degrees, while the 'Royal Oak's' was 19·2, and she could fight all her guns throughout the day; but during a few hours about midday she rolled occasionally so deeply as to render it probable that water would have been shipped at the ports in fighting the guns. The only explanation that can be offered of the fact that these two ships rolled so heavily on a day when most of the other ships were comparatively steady must be found in the relative influence which the state of the sea had upon their rolling. The case of the 'Prince Consort' is especially interesting, as we find her on the 8th rolling more than any other ship in the squadron; on the 10th, in rougher weather, rolling less than the 'Warrior,' 'Defence,' and 'Royal Oak'; and on the 11th, when there was no wind, and the squadron was under steam, again rolling more than any ship except the 'Royal Oak.' Throughout the cruise the 'Royal Oak' continued to be, except on a few occasions, the heaviest roller among the large ships in the squadron, but the only times when she could not fight her guns were the few hours on the 11th, previously referred to, and from 5 to 6 o'clock on the morning of the 12th, when she was rolling 10 degrees to starboard and 11 degrees to port. On the latter occasion the captain's report states that the guns might have been fought during the interval of the roll.

No remarks are necessary respecting the returns of rolling from the 12th to the 19th of June, when the 'Pallas' joined the squadron, as the weather was very fine and the rolling very moderate. On the 21st of June, when the 'Minotaur' and 'Bellerophon' were practically still (their mean total roll being nine-tenths of a degree), the 'Warrior' was rolling 1·4 degrees, the 'Achilles' 2·1, the 'Prince Consort' 3·1, while the roll of the 'Royal Oak' was 7·7 degrees, that of the 'Defence' 9·4 degrees, and that of the 'Pallas' 13·4 degrees. Although the 'Pallas' was rolling more than the other ships, she could fight all her guns and keep all her ports open. On the 22nd and 23rd the only ships whose total mean roll exceeded 6 degrees were the 'Royal Oak' and 'Pallas,' both of which rolled heavily as compared with the other ships, although they were able to fight all their guns throughout the day. On one or two occasions during the remainder of the cruise, the 'Pallas' distinguished herself by rolling considerably more than the other ships, particularly on the 28th, when she had a total mean roll of 16 degrees, while the ship which had the next greatest roll, the 'Royal Oak,' only rolled 5·3 degrees. It must be remembered, however, that the 'Pallas' is much smaller than any of the other ships, and that, although she sometimes rolled more heavily, all her guns could be fought on all occasions.

The returns for 1868 do not, as I have said, throw much light on the probable behaviour of our iron-clads in heavy weather at sea, but as all the ships except the 'Defence' had been present in the 1867 squadron, this is the less to be regretted. The little which we can learn is, however, confirmatory of the conclusions drawn from the former trials, and tends to show, not only that our iron-clads do not roll excessively, but that most of them are comparatively steady. Trials at sea have shown that our last large broadside ship, the 'Hercules,' is probably the steadiest of all the iron-clads; certainly she ranks with the very best of them.

The whole subject of rolling, in both its theoretical and its practical aspects, is still very unsettled; and from the nature of the inquiry it can hardly be brought to exact results. Theoretical investigations have done much to clear away misapprehensions with respect to the causes of, and remedies for excessive rolling, and have brought out the two great facts above-mentioned

—the effects of the metacentric height and of the wave period upon a ship's rolling in a sea-way. Practical observations and experiments have also been of great service, despite their inaccuracy and incompleteness, and have proved that theoretical conclusions agree very closely with actual performance. What is wanted in order to advance our knowledge of the subject still further is a series of carefully conducted trials with ships of different types, under varied circumstances of wind and weather, the observations being made and the results recorded in a more reliable manner than heretofore. I would not be misunderstood in these remarks, as I have no intention to throw discredit upon the reports which appear in the Parliamentary Papers. In fact, as far as the Admiralty regulations go, there is little or nothing left to be desired in the mode of conducting the trials of rolling; but any one who goes carefully over the records cannot fail to remark that in many respects they are very imperfect. We have already referred to the fact that in many cases the angles of rolling were measured by different instruments in different ships, and have shown this to be a fruitful source of error. Of late this fault has been remedied by using the bar or batten instruments in all, or nearly all, our ships, and by this means checking the errors of the pendulum and clinometer observations. When uniformity in the method of conducting the trials and recording the results has become more general, we shall obtain more valuable and reliable information with respect to rolling than we now possess, and may hope to advance correspondingly in the improvement of our iron-clads. The most valuable aid to this end must, however, be derived from the advanced scientific attainments of our naval officers, as the trials conducted by officers who have mastered the theory of rolling, and are cognisant of the special points requiring settlement, cannot fail to be more valuable than those carried out in a spirit of blind obedience to regulations, without any regard to, or knowledge of, the underlying principles.

CHAPTER VIII.

DIMENSIONS OF THE IRON-CLADS.

REFERENCE has already been made to the differences in dimensions and proportions existing among our iron-clads. I now propose to enquire at greater length into those differences, and to describe in as popular language as possible the principles which have been developed in the designs of various ships. In order that the reader may readily grasp the facts connected with this subject, I have arranged them in the following table, which gives the lengths, breadths, and proportions of the longest and finest of our wooden vessels, as well as those of our most important iron-clads :—

Ships.	Length.		Breadth.		Proportion.
	Ft.	Ins.	Ft.	Ins.	
Wood ships :—					
Longest three-decked line-of-battle ships ..	260	0	61	0	4·3
,, two-decked ,, ,, ..	254	9	55	4	4·6
,, frigates	300	0	52	0	5·8
Iron-clads :—					
Warrior class	380	0	58	4	6·5
Minotaur ,, ...	400	0	59	4¾	6·7
Defence and Resistance	280	0	54	2	5·2
Hector and Valiant	280	2	56	4	5·0
Caledonia class (converted ships)	273	0	58	6	4·7
Lord Clyde and Lord Warden	280	0	58	11	4·7
Bellerophon	300	0	56	1	5·3
Pallas	225	0	50	0	4·5
Favorite	225	0	46	9½	4·8
Prince Albert (turret-ship)	240	0	48	1	5·0
Hercules	325	0	59	0	5·5
Penelope	260	0	50	0	5·2
Monarch } (turret-ships)	330	0	57	6	5·7
Captain } (turret-ships)	320	0	53	0	6·0
Invincible class	280	0	54	0	5·2
Thunderer class (turret-ships)	285	0	58	0	4·9
Rupert (ram)	250	0	53	0	4·7

On looking through this table, the reader cannot fail to be struck with the increase in size and proportions in our earliest iron-clad frigate, the 'Warrior,' as compared with the longest and finest ships which preceded her. The length is 80 feet greater than that of the longest wooden frigates, and the displacement of more than 9100 tons is 3000 tons greater than that of our largest wooden two-decked ships. These great changes were considered desirable in consequence of the adoption of armour-plating over about 213 feet of the amidship part of the broadside. The objects kept in view in the design were the carrying of a considerable weight of armour on a long fine ship, of which the form was suited to a high speed relatively to the engine-power. It is well known that these objects were most satisfactorily attained, the high estimated speed having been secured with a moderate proportional expenditure of power.

The partial system of protection being considered objectionable, for the reasons previously stated, the 'Minotaur' class was designed. In these ships the intention was to combine complete protection with a proportional economy of steam-power similar to that obtained in the 'Warrior.' The very large dimensions given in the table, and the load displacement of over 10,200 tons, were then considered the least possible in order to fulfil the conditions laid down, and to enable the requisite weights of equipment to be carried. In this case also the high estimated speed has been obtained on trial, but, owing to their great length, these vessels, even more than those of the 'Warrior' class, have been found unhandy and wanting in manœuvring power, a feature of the utmost importance in war ships. Without for the present entering into the discussion of the relative merits of long and short iron-clads, which will be considered at length in the following chapter, it will be sufficient to state that in my opinion the designs of these two classes of ships were in error in this respect—that, in order to save a comparatively small amount of engine-power, very long, large, costly, and unhandy ships were constructed. In war ships it is no merit to have a large proportion of weights carried to steam-power developed, if that proportion is obtained by means of excessive length and size; and an armoured ship should rather carry a large weight of armour and guns upon a short, cheap, and handy hull, a good speed being obtained by an increase in the steam-power.

In the designs of the 'Defence' and 'Resistance,' which were prepared soon after the 'Warrior's,' the dimensions and proportions were much more moderate, and the estimated speeds were lower. These ships are only 280 feet long, and the proportion of length to breadth exceeds 5 to 1; but the 'Hector' and 'Valiant,' of the same length, are 2 feet broader, and have a proportion of about 5 to 1, these modifications having been made in consequence of the different disposition of the armour. In the converted ships of the 'Caledonia' class, there was, of course, comparatively little room for change from the original designs prepared for two-decked ships of the line. The length was increased by about 20 feet, and the breadth remained almost unchanged, their dimensions, when converted, being 273 feet long by 58½ feet broad, and the proportion of length to breadth being nearly the same as in the finest two-deckers. The French converted ships of the 'Gloire' class are nearly identical in proportions with the 'Caledonia' class, but are about 18 feet shorter, and it is of interest to know that these moderate proportions have been retained in nearly all the ships of the Imperial Navy. In some ships the proportion of length to breadth has been raised to 5 to 1, and in a few of the floating batteries it is as low as $2\frac{1}{2}$ to 1, but the latter ought hardly to be classed with ships.

Having sketched the particulars of the dimensions and proportions of the earlier iron-clads, it becomes necessary to refer to the adoption of more moderate proportions in the 'Bellerophon' and other recent ships. The opinions entertained by me on this much controverted subject of long and short ships have been repeatedly stated in public, and for the present I shall deal only with the results of the trials and experiences made with these ships, observing that the new method of design is based upon the considerations that a war ship should be handy, and therefore of moderate length; and that the high speeds thought desirable can be obtained with fuller lines and a shorter ship, by adding somewhat to the engine-power. The increased manœuvring power, and the reduction in prime cost, resulting from the adoption of moderate proportions, more than make amends for this small addition to the steam-power.

This new method received its first illustration in the 'Bellerophon,' and has undergone in that vessel a series of trials, the results of which are, on the whole, of a most satisfactory character. In order to enable the reader to judge for himself on this point, the following tabular statements are given, which also afford the means of comparing the offensive and defensive powers of this vessel with those of longer ships. It may, however, be proper to state beforehand that the 'Bellerophon,' having a central and a bow battery on the main deck, and being protected throughout the length at the water-line, is so much superior offensively and defensively that she cannot be satisfactorily compared with the 'Warrior' or 'Black Prince,' which are only protected amidships. Still it is worthy of remark that the 'Bellerophon' compares with the 'Black Prince' as follows, the measured-mile trials being taken as the indices of steam performance; observing that in this and the following comparison the excess in weight of the thicker backing adopted in the longer ships is not regarded, as this is fully counterbalanced by the much stronger skin-plating, and the longitudinal girders behind armour, fitted in the 'Bellerophon':—

	Bellerophon.	Black Prince.
Weight of armament	359 tons	340 tons
" armour	1089 "	975 "
Thickness of armour	6 inches	$4\frac{1}{2}$ inches
Resisting strength of armour, estimated as the square of the thickness	36	20
Speed	14·17 knots	13·604* knots
Horse-power (indicated)	6521	5772
Cost	£364,327 (to which add a percentage for dockyard charges)	£378,310

The advantage thus lies with the 'Bellerophon' in every point of the comparison, excepting perhaps the cost (when swelled by the dockyard charges), and the

* In this and the following Table on page 172 I have given the maximum speed attained by the 'Black Prince' at load draught in the first seven years of her existence, as the 14-knot trial of 1868 came after the bulk of this chapter was written, and is irreconcilable with all her former trials.

engine-power. In addition, she possesses extreme handiness as compared with the 'Black Prince,' which would be anticipated from the fact that she is 80 feet shorter. It may be objected to this comparison that the 'Black Prince' is inferior in performance to her sister ship, the 'Warrior;' but while this is true, it is no less a fact that both vessels are embodiments of the same principle. If, however, the 'Warrior' were taken as the representative long ship, it would still appear that the 'Bellerophon' had the advantage as respects armour and armament—and, of course, as respects handiness—while only very little inferior in speed. The 'Warrior's' indicated horse-power is, as we should expect, considerably less. This point will be examined further on in discussing the results of recent trials.

The objection made above to the comparison of the 'Bellerophon' with the 'Black Prince' on account of their different systems of protection does not apply to the comparison of the 'Bellerophon' with the 'Achilles,' as both vessels have a central battery and a water-line belt. The following table will give a good idea of the contrast between the two ships :—

	Bellerophon.	Achilles.
Weight of armament	359 tons	297 tons
" armour	1089 "	1200 "
Thickness of armour	6 inches	4½ inches
Resisting strength of armour, estimated as before	36	20
Speed	14·17 knots	14·35 knots
Horse-power (indicated)	6521	5722
Cost (net)	£364,327	£470,330

The 'Achilles,' it must be remembered, is of the same dimensions and proportions as the 'Warrior,' being 80 feet longer and of more than 2000 tons' greater displacement than the 'Bellerophon;' yet we find the latter carrying thicker armour and a greater weight of armament than the 'Achilles.' The total weight of armour carried by the 'Achilles' is, it is true, greater than that carried by the 'Bellerophon,' but in the larger vessel it is spread over a very long hull, and is therefore only 4½ inches thick in the thickest part, whereas the 'Bellerophon' carries 6-inch plating. The 'Achilles' has a small advantage as respects speed and indicated horse-power; this slight superiority being purchased at a cost of which the money value is represented by 106,000*l.*—the difference between the first cost of the two ships—and of which the real value cannot be estimated without also taking into account their relative powers of offence and defence. The latter may, to some extent, be understood from the foregoing table, but this must be supplemented by the superior handiness of the shorter ship. The difference of indicated power, amounting, as it does, to only 800 H.-P., really represents about 120 H.-P. nominal of the new type of marine engine. This fact is worth notice, as the additional cost for engines of this increased power would not exceed 8000*l.* or 9000*l.*, and this still leaves a very large margin (approaching one hundred thousand pounds) between the first costs of the two ships. It may, however, be thought that the expense involved in maintaining the additional power—extra fuel, &c.—during the period of the ship's service, would tend to still further decrease this margin, and tell against the shorter ship. That this would not be the case will be evident when it is observed that every means has been taken in the new type of engines to economise fuel; and that the experience gained on actual service goes to prove that this aim has been most satisfactorily attained. It will also be obvious that the longer ship would require a larger number of men in the crew; and that consequently the total cost of maintaining her will be considerably greater. On the whole, then, it may be fairly concluded that it would have been most improper to have made the 'Bellerophon' as long and as large as the 'Achilles' in order to save a small amount of power, and thus to have sacrificed the other and very important advantages enumerated above.

In the succeeding chapter I shall again have to refer to steam-trials made with the 'Bellerophon,' and shall therefore pass on now to notice some of the other iron-clads, constructed since that vessel, in which similar moderate dimensions have been adopted. Several of these ships have been tried at sea, and the results obtained have been equally satisfactory with those obtained with the 'Bellerophon.' The 'Lord Clyde' and her sister ship, the 'Lord Warden,' are included among those vessels, and are perhaps the most striking illustrations of the advantages of the new system of construction. They are 280 feet long, about 59 feet broad, and have a load displacement of about 7700 tons. The proportion of length to breadth is thus very little more than $4\frac{3}{4}$ to 1, while in the 'Bellerophon' it is about $5\frac{1}{3}$ to 1, in the 'Warrior' $6\frac{1}{2}$ to 1, and in the 'Minotaur' $6\frac{3}{4}$ to 1. The sides of these short broad ships are completely protected, and there are in addition powerful bow batteries on the upper deck. The armour is $4\frac{1}{2}$ and $5\frac{1}{2}$ inches thick, and there is besides an inner skin of $1\frac{1}{2}$-inch iron between the outside planking and the timbers of the frame, extending entirely around the battery for a depth of 10 feet. The armament is also very heavy, and the speed realised under steam is about $13\frac{1}{2}$ knots. The reader will gain a better idea of these vessels, however, from a comparison of some of their more important particulars with the corresponding particulars of the 'Warrior' class. I have taken the 'Lord Clyde' and the 'Black Prince' as the representatives of the two classes in the following comparison :—

	Lord Clyde.	Black Prince.
Length	280 feet.	380 feet
Weight of armament	376 tons.	340 tons
" armour	1379 "	975 "
Speed	13·43 knots	13·604 knots
Horse power (indicated)	6064	5772
Cost	£294,481 (to which add a percentage for dockyard charges)	£378,310

In speed and indicated horse-power, the 'Black Prince,' it will be seen, has a very slight advantage; but the short ship has some advantage as regards armament, and an immense advantage as regards armour, cost, and handiness. With these facts before him, I cannot imagine any one maintaining that the proper course to have adopted in designing the 'Lord Clyde' would have been to make her 100 feet longer than she is, to take away more than one-fourth of her armour and part of her guns, to deprive her of all bow and stern fire from protected guns, to leave almost half her length wholly unprotected, and to spend at least 50,000*l*. more upon her, in order to make her performance under steam quite equal with the same power to that of the longer ship.

Other examples might be given of the favourable results obtained with short ships. The 'Lord Warden' has been as successful as the 'Lord Clyde,' and the 'Pallas' (225 feet long and 50 feet broad) has realised over 13 knots. With these facts before him, the reader will not, I think, be surprised to find that the 'Hercules,' although she has about 1300 tons' greater displacement than the 'Bellerophon,' has very nearly the same proportion of length to breadth; and that in the 'Monarch,' 'Penelope,' and the 'Invincible' class, similar moderate proportions and dimensions have been retained.

The 'Hercules' is the last ship tried, and it is but just, in conclusion, to state that in her, on a displacement of about 8700 tons and a length of 325 feet, a total weight of armour of 1481 tons is carried, the thicknesses employed being 9, 8, and 6 inches. The 'Black Prince' carries 975 tons of 4½-inch armour, on a length of 380 feet and a displacement of about 9250 tons. The 'Black Prince' has only the amidship part protected, while the 'Hercules' has an armour belt throughout her length, rising to the height of a lofty main-deck; in addition to central, bow, and stern batteries, in which the guns are efficiently protected. Add to this the facts that the shorter and smaller ship carries about 140 tons greater weight of armament than the 'Black Prince,' and can command an all-round fire from guns sheltered behind armour, while the battery guns of the long ship only have the ordinary broadside training (about 30 degrees each way), and some idea will be gained of the advances that have been made in the powers of offence and defence of our iron-clads simultaneously with the reduction of their proportions and dimensions from those first adopted. The speed attained by this vessel (the

'Hercules') on her load-draught trial (14·69 knots) is greater than any other iron-clad (except the 'Monarch') has realised at load draught; the engine-power required to drive her at that speed was, of course, very large; but I have always held the opinion that the additional power required on account of her moderate proportions was much more than compensated for by the saving in first cost and the superior handiness which result, and I provided for such additional power in the original design. As I shall have occasion hereafter to refer at some length to the comparative performance under steam of this ship, and of a design of longer and finer form which, except in handiness, would be her equal as an engine of war, I shall not discuss the subject further here.

It may be thought by some persons that in the preceding remarks too high a value has been put upon *handiness* in iron-clad war-ships, but that this is not the opinion of experienced seamen will appear from the following extracts from Reports of trials of ships composing the Channel Fleet. In his Report for 1864, Admiral Dacres observes :—" As the speed of a steam " fleet is only equal to that of its slowest ships so the " recent evolutions with ships of such different length " and form have gone far to show that the rapid " manœuvring of a fleet must be regulated by its longest " ships, for the diameter of the circles described by the " 'Black Prince' and 'Warrior,' being, say, 1000 yards " at moderate speed, a fleet of which they form part " must move in circles with a radius of 500 yards, " instead of about 250, which could be done by vessels " of the length and steering as readily under steam as " the 'Hector:' but to convince of the unhandiness of "these vessels from their length with the present "means in our power of steering ships, I need only add "that, where other vessels require only to be two cables "apart, the 'Warrior' and 'Black Prince' must be "kept four cables." In another paragraph he says:— "The great drawback to the many excellencies of this "class of vessel (the 'Warrior') is that their extreme "length interferes with their handiness in many most "important points." In 1866, Admiral Yelverton wrote as follows of the 'Achilles,' which is of the same dimensions as the 'Warrior':—"With all her good "qualities, the 'Achilles' is, from her great length, most "difficult to handle; and this defect in action, more "especially if engaged with a turret-ship, might be her "ruin. . . . I feel certain that this ship might, and "probably would, have to go out of action to turn "round, thus exposing herself, in almost a defenceless "position, to the fire of more than one of the enemy's "ships." In concluding his Report, he added:—"As the "result of this cruise I feel bound to award the first "place to the 'Achilles.' I am, however, of opinion "that her great length is an insurmountable objection, "and have no hesitation in saying that ships of the "'Bellerophon' class, from their size and general han-"diness, particularly under steam, will prove more "efficient and valuable for war purposes."

In the Reports of the trials of the Channel Fleet in 1868, Admiral Warden says that "the 'Bellerophon' is "the readiest and most easily handled under steam" of all the ships in the squadron. Admiral Ryder remarks—"There can in my opinion be no doubt that, as "a general rule, the short class has and must have the "advantage, as regards general handiness, under steam "alone, over the long class," and in nearly the same words speaks of the comparative handiness of the two classes under sail alone, provided the short class have sail enough. The same opinion is expressed in most of the Reports of the captains of the different ships, Captain Goodenough, of the 'Minotaur,' in a tabular form of the merits of the various vessels, giving the 'Bellerophon' more than twice as many marks for "handiness for "manœuvre" as he gives to any of the long ships, and Captain Vansittart, of the 'Achilles,' stating that "there "cannot be a doubt the shorter ships are handier under "steam, sails furled, than their longer companions." In these Reports also the question of handiness in connection with the power of ramming, or avoiding an enemy's charge, is considered, and the general opinion entertained is, as Admiral Ryder puts it, that "the short "class must, amongst broadside ships, have the advan-"tage over the long class for giving effect to ramming, "and also, but to a less extent, for escaping from being "rammed." The latter feature obviously possesses great importance, since there can be little doubt but that in future naval actions much will depend upon it, and the experience of Lissa proves that quickness of turning is absolutely essential in order that a ship may avoid being rammed. I shall revert to this subject hereafter.

With these high estimates of the value of handiness before him, the reader will feel a greater interest in the following facts as to the relative turning powers of our long and short iron-clads. On the measured-mile trials of ships of the Navy it is usual to perform a complete circle under full steam-power with the helm hard over, and to record the diameter of the circle traversed as well as the time occupied in turning. As these trials are conducted by experienced staffs of naval and professional officers, and under very similar circumstances, they afford the best means which are accessible of testing a ship's manœuvring powers. In the following table I have given the results of these trials for a few ships, in order to enable the reader to judge for himself as to their comparative handiness.

	Time.		Diameter of Circle.
	Min.	Sec.	Yards.
Minotaur	7	38	939
Warrior	9	10	1050
Achilles	7	15	Not recorded
Bellerophon	4	9	559
Lord Warden	4	48	600
Lord Clyde	4	56	631

The great advantages possessed by the three short ships, both as respects the time of turning and the circle traversed, are so apparent as to require no comment. The 'Bellerophon,' it will be seen, is the handiest ship, although she is 20 feet longer than the 'Lord Warden' and 'Lord Clyde,' her superiority being due, no doubt, to the balanced rudder with which she is fitted. Her moderate length is, however, the great cause of her handiness, as is evident from the fact that the other two short ships, having ordinary rudders, are so much superior to the three long ships, and so little inferior to the 'Bellerophon' herself. Besides being much handier, the short ships require fewer men at the steering wheels than the long ships; and in this respect the 'Bellerophon' stands pre-eminent, as her balanced rudder has the special advantage of requiring only a moderate force to put it over to a considerable angle—for example, on the measured-mile trial 8 men steered the 'Bellerophon' with her rudder at an angle of 37 degrees, whereas the 'Minotaur' required 18 men at the wheel, and no less than 60 more at the tackles (total 78), with the rudder at only 23 degrees. It may be interesting to add that on the 'Lord Clyde's' trial 12 men were at the wheel with the rudder at 25 degrees, thus proving the otherwise obvious fact that short ships require much less power to steer them.

The results obtained with the 'Hercules' in the trials of turning power made on the measured mile in Stokes' Bay are, however, of even a more striking character than those just referred to. When steaming at full speed (14·691 knots), with 16 men at the steering wheels, and the helm over to about 40 degrees, she reversed her course—that is, completed the half-circle—in 1 minute 50 seconds. She turned the whole circle in 4 minutes, its diameter being 527 yards when turning to starboard, and 597 yards when turning to port, giving a mean of 562 yards. In time of turning the 'Hercules' is therefore somewhat superior to the 'Bellerophon,' while the circles of turning of the two ships are almost identical. Comparison is needless between the 'Hercules' and any of the long ships named in the preceding table. It is, however, only proper to state that this heavy ship can turn in less time than any war-ship afloat; and that there is no merchant-ship of considerable size, whether twin-screw or single screw, which approaches in speed of turning this ponderous and powerful iron-clad.

Sea trials of the turning powers of ships are not as reliable as those made at the measured mile, this difference arising principally from the facts that at sea different ships are very differently managed, and that so much is left to the individual opinions of the officers in command. Notwithstanding these differences of opinion and management, the records of trials of the Channel Squadron show most strikingly the superior handiness of the shorter ships. Taking Admiral Warden's Report for 1867, we find a table of the results of trials of steaming in circles, from which I have abstracted some of the performances of the 'Minotaur,' 'Achilles,' 'Warrior,' 'Bellerophon,' 'Lord Clyde,' and 'Lord Warden,' in order that the previously stated facts may receive further confirmation. For convenience I have selected the highest and the lowest trial speeds, 12 and 5 knots respectively, and have arranged the results in two groups, taking account only of the trials with the helms hard over. At the high-speed trial neither the 'Minotaur' nor 'Lord Warden' were tested, not having attained the required speed, but the remaining vessels performed as follows:—

	Hard Starboard.		Hard Port.		Mean.	
	Time.	Diameter.	Time.	Diameter.	Time.	Diameter.
	Min. Sec.	Yards.	Min. Sec.	Yards.	Min. Sec.	Yards.
Achilles ..	6 40	616	6 40	620	6 40	618
Warrior ..	7 21	753	8 11	768	7 46	760
Bellerophon	4 40	365	4 55	437	4 47	401
Lord Clyde ..	4 56	377	4 52	379	4 54	378

These results agree in their general character with those of the measured-mile trials, although, from the fact that the ships were not at full speed, the two sets of observations are not strictly comparable. The 'Lord Clyde's' behaviour was, it will be noticed, considerably better on this occasion than on the measured-mile trial as far as the distance traversed in turning is concerned, the time of turning remaining almost unaltered; while the 'Bellerophon' took more than half a minute longer on the sea trial than on the measured mile, and turned in a much smaller circle, although the mean diameter of the circle she traversed was greater, than that moved through by the 'Lord Clyde.' As regards the behaviour of these short ships relatively to the long ships, the results are almost as satisfactory in this case as on the measured-mile trials. On the measured-mile trials of the 'Hercules' above referred to, when under half-boiler power, a speed of a little more than 12 knots was attained, and the figures given in the report of her turning the circle at this speed are fairly comparable with those given in the preceding table. In going round with helm a-starboard, the time of completing the circle was 4 minutes 36 seconds, and the diameter of the circle was 590 yards; with helm a-port, the time was 5 minutes 20 seconds, and the diameter 651 yards; the mean therefore was, for time, 4 minutes 58 seconds, and for diameter 620 yards. In time of turning at this speed the 'Hercules' is, so far as these figures can be relied upon, a little inferior to the 'Bellerophon' and 'Lord Clyde;' the space traversed in turning is greater than that moved through by those two ships. She is much superior to the 'Warrior' and 'Achilles' in time of turning, although the diameter of the circle is almost the same as for the 'Achilles,' but is much less than that for the 'Warrior.'

At the lowest trial speed of the Channel Squadron, 5 knots, the shorter ships were also proved to have similar advantages, the results being as follow :—

	Hard Starboard.			Hard Port.			Mean.		
	Time.		Diameter.	Time.		Diameter.	Time.		Diameter
	Min.	Sec.	Yards.	Min.	Sec.	Yards.	Min.	Sec.	Yards.
Minotaur ..	13	0	570	12	11	596	12	35	583
Achilles ..	13	18	618	12	35	615	12	56	616
Warrior	10	51	687	12	18	532	11	34	609
Bellerophon ..	9	5	270	8	32	420	8	48	345
Lord Clyde ..	9	54	392	9	52	388	9	53	390
Lord Warden	8	55	386	8	15	393	8	35	389

The 'Lord Warden's' behaviour on this trial is very striking as compared with that of the 'Lord Clyde,' her sister ship, and with that of the 'Bellerophon;' the latter vessel having taken a little longer to go about, but traversed a smaller circle. But even when the 'Lord Clyde,' the least handy on this trial, is taken as the representative short ship, her behaviour is so superior to that of either of the long ships as to render further remarks superfluous. Taking these facts, then, as to actual performance in connection with the opinions of the high authorities quoted above, and the repeatedly expressed beliefs of almost all naval men, it must, I think, be admitted that too high an estimate has not been put upon the value of manœuvring power in ships of war, and that the superiority of the short ships in this respect has not been overrated.

In concluding this chapter, I may remark that it has been my duty to carry into practice principles of design totally opposed to those exemplified in the 'Warrior' and 'Minotaur;' but that our experience with long and short iron-clads may be fairly stated as follows :—That the short ships may be driven as fast as the long ships by a moderate addition to their engine-power; that in turning power and general handiness under steam and sail the short ships are much superior; and that the great reduction in the prime cost of short ships much more than makes amends for the addition to the steam-power. That this is so, the preceding facts and figures will prove; and that it was reasonable to anticipate those results before actual trials had taken place, it will be my endeavour to show in the following chapter.

CHAPTER IX.

FORMS AND PROPORTIONS OF IRON-CLADS.*

HAVING, in the preceding chapter, given a summary of the dimensions and proportions adopted in our principal armoured vessels, and compared the powers and performances of some long and short ships, I now propose to discuss the question of the forms and proportions of iron-clads from a more theoretical point of view, illustrating and enforcing the conclusions arrived at by means of reference to recorded facts.

Scientific writers upon the forms and resistances of ships have generally recommended the adoption of forms of least resistance, and have taken no account whatever of the effect which the weight of the material in the hull should have upon the form of a ship. The most cursory glance will, however, be sufficient to show that this generalisation cannot include the designs of all ships. Take, for example, the vastly different conditions to be fulfilled in a merchant-ship and in an iron-clad war-ship. The former is designed to carry cargo economically, and the weight of hull forms a comparatively small fraction of the total displacement; while the latter is in reality a floating fortress, constructed with a view to efficiency in powers of offence and de-

* Part of the substance of this chapter was given in a Paper on "Long and Short Iron-Clads," read before the Institution of Naval Architects in March, 1869.

fence, and carrying great quantities of armour, the weight of which depends upon the form and proportions of the hull. The merchant-ship may, with advantage, be made long and fine, since the requisite carrying power can be secured as well by means of great length as of great beam, and the proportion of speed to engine power is thus increased. In the iron-clad, however, any addition to the length leads to a corresponding increase in the area of the surface to be armoured, and in the unproductive weight to be carried; while a reduction in the length leads to a considerable decrease in that area, and in the total weight of armour.

The impossibility of correctly prescribing any general form of ship, in disregard of the armour, will exhibit itself even more strikingly if we consider independently one end of a ship, say the bow or entrance. To fix our ideas, we will take the case of the 'Minotaur,' for which ship it has been found by actual calculation that in still water the weight of the first 80 feet of the bow exceeds its displacement by about 420 tons. This excess of weight must clearly be floated by the central part of the ship where the buoyancy exceeds the weight; and the length of this part being 250 feet, while its mean breadth is about 56 feet, its immersion must be increased by about 13 inches, in consequence of the unsupported weight forward. This additional immersion increases the area of the midship section which has to be propelled through the water by from 60 to 65 square feet. Now, let us imagine this bow to be so shortened and shaped—on the one hand increasing its buoyancy, and on the other diminishing its weight—as to produce an equilibrium between its total weight and buoyancy.

No doubt by making it bluffer we shall increase its resistance to motion through the water, but we shall at the same time lighten the burden upon the central part of the ship, and reduce the total area of the midship section to be driven as well as the total weight. It is easy to see that by this means we may succeed in getting the same speed with a given power as would have been obtained by employing the longer and finer, but much heavier, bow. This is the essence of the principle which I have laid down, and carried out in practice.

In the design of all merchant steamships the conditions to be fulfilled are so similar, and the proportions of weight of hull, equipment, and cargo to displacement are so nearly the same, that we should expect to find a similarity of form in the greater number of these vessels. Nor is our expectation disappointed, for although differences do exist, they are not usually of a very striking character, and this fact makes the adoption of the ordinary "constants" for steam performance a very fair standard of excellence for merchant-ships. For armoured war-ships the case is very different, and these constants are by no means to be taken as standards of merit, as I shall show almost immediately.

The constants here referred to are, I need hardly say, estimated from the two formulæ—

$$(1)\quad \text{Constant} = \frac{(\text{Speed})^3 \times \text{Midship Section Immersed}}{\text{Indicated horse-power.}}$$

$$(2)\quad \text{Constant} = \frac{(\text{Speed})^3 \times (\text{Displacement})^{\frac{2}{3}}}{\text{Indicated horse-power.}}$$

These formulæ are always used in calculating the results of the trials of ships of the Navy. In them it is assumed (1) that, within certain limits, the resistance to a ship's motion varies as the square of the velocity, and that, therefore, the propelling power must vary as the cube of the velocity; (2) that the resistance also varies, *cæteris paribus*, as the area of immersed midship section in the first formula, and as the two-thirds power of the displacement in the second formula; (3) that the indicated horse-power bears a constant ratio to the useful work of the engine, *i.e.* to the power actually available for propulsion. These assumptions are not, of course, strictly accurate, but they are sufficiently so to render the constants of much service in comparing performances, and in determining the engine-power needed in a new design.

I may remark in passing, that the method of calculating the horse-power just referred to is much more reliable than any methods based upon more theoretical investigations. Nor is this a matter of surprise when it is remembered that the difficulties surrounding the subject of fluid resistance are very great, and that the amount of experimental knowledge possessed regarding it is very small. On the other hand, a glance through the elaborate table of trials printed by the Admiralty enables one to select a few ships, similar in form and proportions to the new design, and from the constants obtained by those ships to calculate the horse-power required for the estimated speed with a very fair amount of accuracy.

While recognising the value of the constants, however, I cannot entertain the opinion that they should form the sole standards by which all steam-ships, armoured as well as unarmoured, should be judged. Such an opinion virtually amounts to a belief that the chief aim of the naval architect ought to be the lowering of the proportions borne by the indicated horse-power to the speed attained, to the midship section immersed, and to the displacement. As far as *form* alone is concerned, this view is, no doubt, correct; but obviously, if carried out in its entirety, it would lead to the construction of ships that would carry no weights except those of the propelling apparatus. This is, of course, an extreme case, and it may be thought unfair to argue from it the folly of the system as a whole. But if economy of steam-power is the chief desideratum in ship design, the case imagined is also the fullest development of the principle; and if we once admit other considerations besides form—such as cargo-carrying power, first cost, and handiness—the failure of the constants as criteria is tacitly acknowledged.

There can be no doubt that in merchant-ships increased proportions and fineness of form have led, and do lead, to increased carrying power, and to economy of steam-power; and that in such cases the constants of performance have higher values. The lightness of the hull would, in my opinion, tend to produce these results, and I have previously stated that for merchant-ships—and it is true also in a great measure for unarmoured war-ships—the constants are very fair standards of excellence. But with iron-clad ships, if a similar mode of comparison were followed, we should in many instances be comparing vessels of which the armour was of extremely different degrees of efficiency, and should, at the same time, wholly exclude this important fact from our consideration.

For example, if the 'Warrior' and 'Bellerophon' were compared, we should have the former with comparatively thin armour-plating extending over a little more than half the length; and the latter protected with thicker armour throughout the length at the water-line, besides having armoured central and bow batteries. It would obviously be most delusive, in comparing these ships, to waive all consideration of these facts, and to take constants of performance as the sole criteria. In fact, such a course would be equivalent to requiring that the proportion of weight of hull (including armour) to the displacement should be considerably greater in the shorter than in the longer ship. At the same time the other most important points connected with first cost, character and weight of armament, and handiness, would be entirely neglected.

In short, constants of performance can only be of use in comparing the merits of two iron-clads when there is similarity, or at least equality, of construction, armour, and armament; and when this condition is satisfied, the conclusions based upon the values of the constants must be supplemented by considerations of cost and handiness. The merits of iron-clad ships do not consist in carrying a large proportion of weights to engine-power, or having a high speed in proportion to that power; but rather in possessing great powers of offence and defence, being comparatively short, cheap, and handy, and steaming at a high speed, not in the most economical way possible, but by means of a moderate increase in power on account of the moderate proportions adopted in order to decrease the weight and cost, and to increase the handiness. It must be obvious that, if a ship 300 feet long, plated all over with given armour, carrying a given armament, and costing, say, 300,000*l.*, steams at a given speed with a given power, it would be a mere waste of money and a sacrifice of handiness to build her 400 feet long, at a cost, say, of 380,000*l.*, for no other object than that of driving the greater weight at the same speed with about the same power; in other words, for the mere purpose of raising the constants.

It may, perhaps, be objected to this statement that the trials of actual ships do not show that a ship 300 feet long can be driven at the same speed, with about the same power as a ship 400 feet long, when the armour is equally efficient in the two ships. Now, I need hardly say that in dealing with speed trials great care is required in order to ensure a fair comparison of the performances of any two ships. So many causes of difference exist that, until it is known that they are either inactive, or else acting similarly, in the ships compared, the comparison is of little worth. The quality of the coal, the character of the stoking, the condition of the engines, and the state of the bottom, as well as the force of the wind and condition of the sea, are the chief causes of error in such comparisons; and the reports on the performances of our iron-clads prove that greater varieties of speed are due to these, so to speak, secondary causes than are shown to exist when the ships are first tried on the measured mile. This is, as I have previously shown, a most important fact, requiring to be borne in mind when the policy of our naval construction is being discussed; for the present I only refer to it as connected with the speeds actually attained on trial.

With these prefatory remarks I desire to call attention more closely to the results of a series of trials, already briefly referred to in former chapters, which took place in the spring of 1868, and which were conducted in such a manner as to eliminate, as far as possible, the effects of these sources of error; care being taken to ensure equally good coal and stoking, the bottoms being cleaned almost immediately before the trials took place, and the engines, as the trials showed, being in excellent condition. The ships tried were the 'Minotaur,' 'Bellerophon,' and 'Warrior;' but, for the present, I shall confine attention to the two first-named vessels, as their performances will throw some light on the point now under discussion. It has been found, by actual calculation, that the weights per square foot of the protecting material—armour and backing—in these ships, when uniformly distributed over the surface of the side from the lower edge of armour up to the upper deck, are very nearly identical; so that it may fairly be assumed that, if the 'Bellerophon' were completely protected, she would have quite as strong armour as the 'Minotaur,' the excess in thickness of the skin-plating in the 'Bellerophon' over that in the 'Minotaur' being put into armour. Hence, it follows that these ships may be taken as representatives of the 300-foot and 400-foot ships previously referred to.

Before being tried by a six-hours' run at sea, the ships were put over the measured mile in Stokes' Bay, where the 'Minotaur' attained a speed of 14·411 knots with an indicated power of 6702 H.-P., and the 'Bellerophon' realised 13·874 knots with an indicated power of 6002 H.-P. With a greater power by 700 H.-P., therefore, the 'Minotaur' beat the 'Bellerophon' by about half a knot. This trial does not help us much in our investigation, but the six-hours' trials are of exactly the right character for our purpose, since on them the indicated horse-powers were, as nearly as possible, identical. On this trial, when the 'Minotaur' had only been out of dock nine days, she made 14·165 knots with 6193 H.-P.; and on a similar trial the 'Bellerophon,' which had been twenty-one days out of dock, made 14·053 knots with 6199 H.-P. As the Controller of the Navy remarked in his report on these trials, "the 'Bellerophon' had the disadvantage "of having been twice as long in the water as the other "two ships, and at this time of the year (the spring) "the growth of weeds is particularly rapid;" so that, allowing for the greater foulness of her bottom, it may be fairly stated that her speed was nearly identical with that of the 'Minotaur,' when the engines of the two ships developed equal power. I do not for a moment intend it to be supposed that a single trial of each of these ships, however carefully conducted, is sufficient to establish the general principle that 300-foot and 400-foot ships, of the character previously described, always should steam at the same speed with about the same power. But, on the other hand, it is right to state that on this, the only occasion when such ships have been tried under similar conditions, they did perform in accordance with that principle; and this fact shows the want of force in the objections supposed to be based on the results of steam trials.

Having compared the performances of the 'Minotaur' and 'Bellerophon' on this trial, it may not be amiss for me to refer briefly to the results obtained with the 'Warrior' under similar circumstances, although I wish to repeat the opinion that the differences in offensive and defensive power between her and the other two ships preclude anything like a fair comparison. On the measured mile, the 'Warrior's' speed was 14·079 knots and her power 5267 H.-P.; and on the six-hours' trial at sea, the speed was 13·936 knots, and the power 5092 H.-P. Hence it appears that on the measured mile the 'Bellerophon' was about one-fifth of a knot slower than the 'Warrior,' although her engines developed about 430 H.-P. more than those of the longer ship; and on the sea trial, with 1100 H.-P. less, the 'Warrior' was only about one-ninth of a knot slower than the 'Bellerophon.' The additional power required in the 'Bellerophon,' as compared with the 'Warrior,' is undoubtedly considerable, and, taking the sea trial as a test, may be assumed to fall somewhat below 1000 H.-P. indicated, when a speed of about 14 knots is realised. The nominal horse-power corresponding to this additional power may, with the new type of engine, be roughly estimated at 150 H.-P., and its supply would involve an outlay of about 10,000*l.* This is to be regarded as the price paid for superior handiness, for much more efficient armour and armament, and for an enormous reduction in the prime cost of the ship as a whole—a price which it has always been acknowledged would probably have to be paid, and for which provision was made in the design of the engines, while it is really trifling when compared with the results obtained. I need not do more than refer to the facts that the expense involved in maintaining and providing fuel for this additional power is much more than counterbalanced by the additional outlay required for the maintenance of the much larger crew of the longer ship; and that in cost of repairs the short ship is sure to fall below the other.

But while I thus recognise the more economical steam-performance of the 'Warrior' when compared with the 'Bellerophon,' I must again draw attention to the facts previously stated respecting the relative performances of the 'Minotaur' and 'Bellerophon.' Both of the long ships had their extreme length given them in order to make them economical of steam-power, and I have therefore a perfect right, if I choose, to select the 'Minotaur' as the representative of long ships instead of the 'Warrior,' and to say that the 'Bellerophon' can be driven at equal speed with about the same engine-power. I shall only add that the obvious conclusion to be drawn from the relative performances of the two long ships is that more moderate proportions and less fineness of form than had been employed in the 'Warrior' might with advantage have been adopted in the 'Minotaur' when it was determined to completely protect that ship, instead of increasing her proportions to the extent that was done.

I may remark in this connection that, to again quote from the Controller's report, "these experiments prove that, "with good coal and good stoking, there is but "little difference between the results of a trial at the "measured mile and one lasting for six hours on "the open sea, all the circumstances being alike;" and the fairness of the measured-mile trials as tests of steaming capabilities is thus strongly established.

The discussion of the merits of our long and short iron-clads, as developed in their various trials at sea, has often run into error, on account of the speeds attained having alone been considered, and the horse-powers developed at the time of trial having been neglected. Such a course is obviously incorrect, as the connection between horse-power and speed is indissoluble; and it has been truly said that complaints of fallings off in speed, which were really due to smallness of horse-power, amount to complaints that the hull did not drag the engines along at a greater rate than that at which they were working. The fact is that all the long iron-clads have engines of the old type, which had been gradually improved upon, until—apart from the great consumption of fuel—it had been made to approach perfection, and not only was the development of the guaranteed power ensured, but in many cases that power was considerably exceeded. The recent short iron-clads, on the other hand, have the new type of engines with surface-condensers, superheaters, and other novel arrangements, which, like all newly introduced mechanical contrivances, are liable to occasional failures that could hardly have been foreseen, and can be easily remedied, but that, for the time, cause very mistaken notions of their true character. As experience is gained in the construction and working of these improved engines, they, like the older type, will no doubt be perfected; but, at present, their performance is not nearly of so certain a character as that of the more wasteful type which preceded them. It has happened, in consequence of this fact, that on some occasions the power developed in, and the speed obtained by our short ships at sea, have fallen considerably below the corresponding results on the measured-mile trials; and in published reports of these so-called failures, the low speeds have been given without any mention being made of the want of engine-power. One instance of this will suffice. The 'Bellerophon's' engines, of 1000 H.-P. nominal, were designed to work up to about $6\frac{1}{2}$ times, and on the measured mile did develope the estimated power and drive the ship at 14·17 knots. About a year after this trial, the 'Bellerophon' was again tried at sea with the Channel Squadron, and only made 11·8 knots, the indicated power being only a little more than $4\frac{1}{2}$ times the nominal (4580 H.-P.). This comparatively small development of power was the result of failure in the working of the superheaters and other arrangements intended to secure the estimated results, and the speed was furtherreduced by the excessive foulness of the bottom. These facts were not of course known to the public, to whom the statement of the full speed attained seemed quite conclusive evidence of her inferiority as a steam-ship, no thought being given to the question of how great, or how little, an amount of power was developed. In fact, on this occasion, adverse critics became quite jubilant, considering that the question of "long *versus* short ships" had received a practical demonstration that admitted of no reply. The folly of such criticisms has, however, been shown by the further trials made with the 'Bellerophon' both on the measured mile and at sea, which have confirmed the correctness of the original measured-mile trial as a standard of steaming capability.

The results of the trials of all the short ships may be summed up in the statement that, when the engine-power has reached the amount guaranteed, the estimated speed has been attained, but that, when the power has fallen off, the speed also has necessarily declined. It is not the function of a ship to propel her engines, but to be propelled by them at a speed exactly proportioned to the power exerted; and this is a complete answer to a multitude of complaints respecting the performances of one or two short ships.

As far as our experience goes, then, I am warranted in making the assertion that in armoured ships, as the extent and thickness of the armour to be carried are increased, the proportion of length to breadth should be diminished, and the fulness of the water-lines increased; and that the shorter, fuller ship can be propelled at as great a speed as the longer, finer ship, with about the same, or only a little greater, horse-power. The constants of performance will undoubtedly be lower in the shorter ship; but they are only hypothetical standards of merit, and the benefits in point of first cost, handiness, and maintenance, resulting from moderate proportions, are tangible facts, far outweighing in importance the small economy of steam-power resulting from the adoption of greater proportions and fineness of form.

One other point requires attention when we are discussing the propriety of building very long iron-clads—the fact that in such ships the proportion of frictional resistance to direct head resistance becomes considerably increased. It appears probable even that, if very extreme proportions were adopted, the advantages resulting from the reduction in head resistance would be more than counterbalanced by the increase in frictional resistance. To illustrate this statement, I will suppose a fully armoured ship to be lengthened amidships, and made finer at the extremities with a view to increased speed in proportion to engine-power. In such a case a great weight of armour would be added; the strength of the hull proper would require to be increased; and the immersed surface would be made so much greater as to render it questionable whether the saving in horse-power, or the increase of speed, if any, would be at all commensurate with the increased cost, or make amends for decreased handiness. Adding to this the considerations that a greater area of immersed surface means a greater area subject to fouling, and that one of the chief causes of falling off in speed of a sea-going iron-built ship is foulness of bottom, we may, I think, fairly conclude that this is a feature of the question which ought not to be overlooked.

That this is so will perhaps appear more clearly if I refer to the results of one or two trials of actual ships. Before doing so, I would observe that the advocates of long iron-clads have at various times urged the importance of increasing the proportions borne by the displacement and the midship section to the indicated power, and have declared our recent iron-clads to be wanting in these, which they consider the "chief elements of naval architecture." Having so fully stated my own opinion on this matter in a previous part of this chapter, I need hardly say that in using, as I shall do, these measures of efficiency, I only wish to make a comparison between two long ships in a manner of which those who favour long iron-clads must approve, and that I by no means approve of this method of comparing the merits of armoured ships.

The trials to which I refer are those which took place in the spring of 1868, in which the 'Warrior,' 'Minotaur,' and 'Bellerophon,' were engaged. Taking the six-hours' trials at sea of the two long ships, it is found that the proportion of horse-power to displacement in the 'Minotaur' was 603 to 1000, and in the 'Warrior' 553 to 1000, while the proportion of horse-power to midship section immersed was 468 to 100 in the 'Minotaur,' and 404 to 100 in the 'Warrior.' In other words, the horse-power is *less* per ton of displacement, and per square foot of midship section in the 'Warrior' than in the 'Minotaur,' although the latter is the longer ship, and has the greater proportion of length to breadth. It is proper to state that the 'Minotaur' steamed faster than the 'Warrior,' so that her proportion of horse-power was on that account somewhat greater than that of the 'Warrior;' but in order that the proportionate expenditure of power might be the same in the two ships, the 'Minotaur's' indicated power would have to be diminished by more than 500 H.-P., which is doubtless a greater diminution than would be necessary if the 'Minotaur' were driven at the 'Warrior's' speed. Here then we have a result which follows from the adoption of a standard of merit brought forward by the advocates of long iron-clads, but which goes against the theory that increased length and proportions tend to increased economy of steam-power. I shall be glad to see this seeming contradiction explained, if that be possible; for my own part I am inclined to think that these facts are confirmatory of the opinion previously expressed, that in very long ships the increase of frictional resistance is so considerable as to become, at least, as important as the decrease in direct head resistance. At the same time I do not wish to appear to base a general theory on one or two trials; and there can be little doubt that limits do exist at which the increase of length ceases to be beneficial, whether these limits have as yet been reached or not.

In the course of the year 1868 attention was drawn to the relations which should subsist between the form and dimensions of iron-clad ships and the weight of material in the hull, in a paper read by me before the Royal Society, and since published in their 'Transactions.' By the phrase "weight of material" I mean the weight of hull per unit of surface, say, per square foot, and when the armour is included, this is very different in different ships, varying with the extent and thickness of the armour. The methods and arguments of the paper are, in reality, applicable to both completely and partially armoured ships, including in the latter class ships like the 'Warrior' without any protection at the extremities, and the very much more efficient ships with armour-belts, and central, bow, or stern batteries. In order to make a fair comparison, however, between ships having different arrangements and thicknesses of armour and backing, I have thought it proper to distribute the total weight of protecting material over the whole length of the broadside in each case; thus, in fact, turning all ships into equivalent, but completely protected ships, for the purpose of comparison. By this means a fair idea can be obtained of the relative defensive powers of the ships considered, before any steps are taken to compare their performance under steam. To afford a general view of the methods employed and the results arrived at, I have given the following abstract, which is a reprint of that sent to the Royal Society :—

"*Abstract of Paper sent to the Royal Society* '*On the*
"*Relation of Form and Dimensions to Weight of*
"*Material in the Construction of Iron-Clad Ships.*'

" The object of the paper is to show that the pro-" portion of length to breadth in a ship, and the form " of her water-lines, should be made in a very great " degree dependent upon the weight of the material of " which her hull is to be constructed—that an armour-" plated ship, for example, should be made of very dif-" ferent proportions and form from those of a ship " without armour, and that, as the extent and thickness " of the armour to be carried by a ship are increased, " the proportion of length to breadth should be dimi-" nished, and the water-lines increased in fulness.

" It is highly desirable that this subject should receive " the attention of men of science, not only because it " bears most directly upon both the cost and the effi-" ciency of future iron-clad fleets, but also because it " opens up a theoretical question, which has hitherto, " the author believes, received absolutely no considera-" tion from scientific writers upon the forms and resist-" ances of ships, viz. the manner in which the weight " of the material composing the hull should influence " the form. Prior to the design of the 'Bellerophon,' " the forms of ships were determined in complete dis-" regard of this consideration, and even the most recent " works upon the subject incite the naval architect to " aim always at approaching the form of least resist-

" ance. The investigations given in the paper show, " however, that the adoption of a form of least resist- " ance, or of small comparative resistance, may, in fact, " lead to a lavish outlay upon our ships, and to a great " sacrifice of efficiency; while, on the other hand, the " adoption of a form of greater resistance would con- " tribute in certain classes of ships to great economy " and to superior efficiency.

" In order to indicate clearly, but approximately " only, the purpose in view, the author first considers " the hypothetical cases of a long and a shorter ship, " both of which are prismatic in a vertical sense. The " length of the long ship is seven times its breadth, and " its horizontal sections consist of two triangles set base " to base. The length of the short ship is five times its " breadth, the middle portion being parallel for two- " fifths of the length, and the ends being wedge-shaped. " It is assumed also that, at a speed of 14 knots, the " long ship will give a constant of 600, and the short " ship a constant of 500 in the Admiralty formula :—

$$\frac{\text{Speed}^3 \times \text{Mid. Section}}{\text{Indicated horse-power.}}$$

" The draught of water is in each case 25 feet, and " the total depth 50 feet.

" It is taken for granted that the form of the long " ship has been found satisfactory for a ship of such " scantlings that we may consider her built of iron of " an uniform thickness of 6 inches, the top and bottom " being weightless.

" Now, let it be required to design a ship of equal " speed, draught of water, and depth, but of such

" increased scantlings (whether of hull proper or of " armour) that the weight shall be equivalent to an " uniform thickness of 12 inches of iron, the top and " bottom being weightless as before. First, the new " ship has the proportions of the long ship given to her, " and, secondly, those of the shorter ship. In each case " the engines are supposed to develope seven times " their nominal horse-power, and to weigh (with boilers, " water, &c.) one ton per nominal horse-power. The " coal supply in each case equals the weight of the " engines, so that both ships will steam the same dis- " tance at the same speed. But as the equipment of " the smaller ship will be less weighty than that of the " larger ship, we will require the larger ship to carry " 2000 tons, and the smaller 1500 tons additional " weight.

" Assuming the breadth extreme in each case to be " the unknown quantity, we can, from the Admiralty " formula given above, deduce an expression for the " indicated horse-power; thence under the assumed con- " ditions the weights of engines and coals can be found; " and these being added to the weights of hull (calcu- " lated on the assumption that the sides are of 12-inch " iron) and to the weights carried, give an expression " for the total displacement in tons of each ship. " Another expression is found for this displacement " by finding the weight of water displaced. The two " expressions are equated, and a quadratic equation is " formed, from which the breadth extreme is deter- " mined, and from it all the other values can be found.

" The accompanying table shows the results obtained " by this method for the two classes of ships :—

	Long Ship.	Shorter Ship.
Length, extreme	581 feet.	342 feet.
Breadth	83 „	68½ „
Nominal horse-power	1,350 H.-P.	1,337 H.-P.
Indicated „	9,450 „	9,359 „
Weight of hull	12,570 tons.	7,576 tons.
„ engines	1,350 „	1,337 „
„ coals	1,350 „	1,337 „
„ carried	2,000 „	1,500 „
Total displacement	17,270 „	11,750 „

"It will, therefore, be seen that, by adopting the "proportions and form of the shorter ship, a ship of "the required scantlings and speed will be obtained, "on a length of 342 feet, and a breadth of 68½ feet; "whereas if the proportions of the long ship are adopted, "the ship, although of the same scantlings and speed "only, will require to be 581 feet long and 83 feet "broad, the steam-power in both cases being as nearly "as possible the same.

"Considerations of this character, worked out more "fully, led the designer of the 'Bellerophon' to depart "so considerably from the form and proportions of the "'Minotaur.'

"The next part of the investigation is based upon "the official reports of the measured-mile trials of the "'Minotaur' and 'Bellerophon,' when fully rigged, and "upon calculations made from the drawings of those "ships. It is assumed that a prismatic vessel having "the same mean draught as each of these ships, and "having the same form and dimensions as the mean "horizontal section—which equals the mean displace-"ment in cubic feet, divided by the mean draught of "water—will give the same constant as the ship herself "at the assumed speed of 14 knots, which, as nearly as

" possible, equals the speed obtained by both the 'Mino-" taur' and the 'Bellerophon' on the measured mile. " For each ship the weight of the armour and backing " is supposed to be uniformly distributed over vertical " prismatic sides of the dimensions of the armoured " sides, and the weight of hull is similarly distributed " over vertical prismatic sides of the dimensions below " water of the mean horizontal section, and above water " of the armoured side. The actual weights carried by " the ships are thus transferred to what may be termed " representative prismatic vessels, having the same con-" stants of performance as the ships. The detailed " calculations in the paper show that the weight per " square foot of the material in the hulls of the two " ships, when distributed over the sides of the repre-" sentative prismatic vessels, is very nearly the same " for both, and the same holds with respect to the " weight per square foot of armour and backing. The " 'Minotaur' is rather heavier in both respects, but, for " the reasons given in the paper, the means of the " values found for the two ships are taken, and are " found to be :—

Weight per square foot of hull		= ·152 ton.
,,	,,	armour and backing = ·11 ton.

" The questions next considered are these :—Pre-" suming it to be necessary to build another ship " which shall also steam 14 knots, carry the same " proportionate supply of coal to engine-power, and " proportionate quantities of stores, but shall have her " armour and backing of double the weight of armour " and backing of the 'Bellerophon' and 'Minotaur,' " then, 1st, what will be the size, engine-power, and

" cost of the new ship of the 'Minotaur' type, and " having the same mean draught and depth of armour; " and, 2nd, what will be the size, engine-power, &c., if " built on the 'Bellerophon' type, and having her mean " draught and depth of armour? this condition im- " plying of course that the same constants of perform- " ance as before will be realised in each case. On " account of the great disproportion in size between the " two types of ship, it is obvious that the smaller one " will require much less weight of equipment. It is " assumed, therefore, that the additional weights of the " smaller ship (exclusive of engines, boilers, and coals) " amount to 700 tons, and those of the larger ship to " 1000 tons. The developed power of the engines, " proportionate supply of coal, and the weight of en- " gines, &c., are taken exactly the same as in the hypo- " thetical case first given.

" By proceeding with the investigation for each case " in a way similar to that sketched for the hypothetical " ships, only treating the breadth extreme of the mean " horizontal sections of the new ships as the unknown, " the following results are obtained. The new ship of " the 'Minotaur' type which fulfils the required con- " ditions will be nearly 490 feet long, 72½ feet breadth " extreme, and have a total displacement of 14,250 tons, " while the new ship of the 'Bellerophon' type is 380 " feet long, 71 feet breadth extreme, and has a total " displacement of 10,950 tons. It thus becomes obvious " that a correction is needed in the weight per square " foot of hull in the new ship of the 'Minotaur' type, " as her length has been so greatly increased; it is " considered that an increase of at least 10 per cent. is

" required, and this is the allowance made. On the " other hand, the new ship of the 'Bellerophon' type " is still shorter than the 'Minotaur' herself, and the " displacement is not much greater than the actual dis- " placement of the 'Minotaur,' so that no correction is " needed in her weight per square foot of hull. When " the correction has been made for the new ship of the " 'Minotaur' type, the final results in round numbers " are as follow for the two classes of ship :—

	New Ship of Minotaur Type.	New Ship of Bellerophon Type.
Length	510 feet.	380 feet.
Breadth	75 ,,	71 ,,
Tonnage	13,770 tons.	8,620 tons.
Nominal horse-power	1,080 H.-P.	1,080 H.-P.
Indicated ,, ...	7,560 ,,	7,560 ,,
Weight of hull	7,100 tons.	4,460 tons.
,, armour and backing	5,190 ,,	3,630 ,,
,, engines and coals ..	2,160 ,,	2,160 ,,
,, stores carried	1,000 ,,	700 ,,
Displacement	15,450 ,,	10,950 ,,

"Taking the cost per ton at 55*l.* (which is the " average cost per ton of tonnage for the hulls of " armour-clad ships), the saving made by adopting the " new ship of the 'Bellerophon' type would amount to " 283,250*l.*, or considerably more than a quarter of a " million sterling.

" It must also be considered that the ship of the " 'Bellerophon' type would cost less for maintenance " and repair, and be much handier in action.

"The last investigation in the paper is purely " theoretical, and consists of a determination of the " dimensions which would be required in two ships, of " which the horizontal sections are curves of sines, and " which are prismatic vertically, if they were built with

" the same weight per square foot of hull (say $\frac{1}{10}$ ton) " as the 'Bellerophon,' but carried twice the weight of " armour per square foot (say $\frac{6}{23}$ ton). In these cases " the bottom is taken to have weight as well as the " sides, the speed for both is 14 knots, the draught of " water is 25 feet, and the depth of the armoured side " 24 feet. One of the ships is seven times her breadth " in length, and the other is five times. Professor " Rankine's rule for the calculation of horse-power and " speed is employed, and the same conditions of engines, " &c., are assumed as have been indicated previously. " The larger ship carries 1350 tons additional weights, " and the smaller 900 tons.

" The results obtained for these ships are as follows, " when expressed in round numbers :—

	Larger Ship.	Smaller Ship.
Length	585 feet.	425 feet.
Breadth	84 „	85 „
Nominal horse-power	1,270 H.-P.	980 H.-P.
Indicated „	8,890 „	6,860 „
Weight of hull	7,586 tons.	5,540 tons.
„ armour and backing	6,124 „	4,470 „
„ engines and coals ..	2,540 „	1,960 „
„ carried	1,350 „	900 „
Displacement	17,600 „	12,870 „

" These results are very different in detail from those " obtained in the cases based on the actual trials of the " 'Bellerophon' and 'Minotaur,' but not more so than " might have been anticipated from the adoption of " such a different form of ship and mode of calculating " resistance. The 2000 horse-power which is needed by " the larger ship above the power required by the " smaller ship is principally due to the difference

" between the immersed surfaces of the two ships, and " is spent in overcoming friction. The immersed mid-" ship sections, it will be remarked, only differ by a " very small amount.

" This last investigation serves to show that the " theoretical best form of ship being taken, and the " most recent rule being applied in the calculations, " the speed of 14 knots can be obtained in the short " type of ship at a surprisingly less cost and size than " the long type requires, and this result agrees with " that of the preceding investigation based on actual " trials."

I will now refer briefly to another aspect in the case of long *versus* short ironclads. Supposing two ships to be constructed, having the same central, bow, and stern batteries, and the same height of port above water; the same depth and thickness of armour in the water-line belts; the same proportion of weight of hull to total surface; and the same equipment and armament; with engines of the same type, and with weights of coal which would enable them to proceed equal distances at the same speed, would the advantage, on the whole, rest with the ship which had the form and proportions of one of our long iron-clads, say the 'Minotaur,' or with the ship having more moderate proportions, say those of the 'Hercules'?

It will be obvious that this is a different case from those considered in the Royal Society paper, and one in which the disadvantage of the long ship as compared with the short ship is not so great as in those cases. In the wholly armoured ship, in passing from a short to a long ship, we increase the armour very largely; while in the case now about to be discussed, we propose to lengthen the belted portion only of the armoured surface, and therefore get the benefit of length with a less burden of armour. Still we shall see that, even in this case, the short ship is to be preferred to the long.

I have taken the 'Hercules' as the representative short iron-clad, and have used the known quantities representing her weights of hull, of equipment and armament, and of engines, boilers, and coals at the time of her trial, and of armour and backing on batteries and belt, in order to determine the corresponding quantities in the new design for a ship having the same form and proportions, below water, as the 'Minotaur,' but in other respects fulfilling the same conditions as the 'Hercules' in the manner explained above. I have also taken the indicated horse-power developed in, and the full speed realised by, the 'Hercules' on her load-draught trial in order to determine the proportion of indicated to nominal horse-power in the engines which would drive the new ship at the same speed, thus ensuring that the new ship shall have engines of an identical character with those of the 'Hercules.' In determining the coal supply of the new ship I have considered it proper to provide such a weight as would enable her to proceed at the half-boiler speed attained by the 'Hercules,' as far as the 'Hercules' could steam at that speed. This is obviously just to the long ship, as the half-power speed is the maximum which would be employed in all cruising services when under steam.

As the result of careful calculations made in accordance with the above-stated conditions, I am enabled to give the following dimensions and particulars of the new ship; and in order to compare them with the corresponding features in the 'Hercules' at the time of trial, have arranged the subjoined table :—

	New Ship.	Hercules.
Length between perpendiculars	385 feet.	325 feet.
Breadth extreme	57 ft. 2 in.	59 ,,
Tonnage B.O.M.	5936 tons.	5226 tons.
Nominal horse-power	925 H.-P.	1200 H.-P.
Indicated ,, ...	6585 ,,	8529 ,,
Weight of hull	4574 tons.	4022 tons.
Weight of armour and backing, in belt ..	1518 ,,	1292 ,,
,, ,, ,, on batteries	398 ,,	398 ,,
,, engines, boilers, and coals	1460 ,,	1826 ,,
,, equipment and armament	1138 ,,	1138 ,,
Displacement	9088 ,,	8676 ,,

From these figures it will be seen that the new ship would be 60 feet longer, and 1 foot 10 inches narrower, than the 'Hercules,' and that she could be driven at the same full speed by engines having a nominal power 275 H.-P. less than the engines of the 'Hercules.' Her tonnage, however, is 710 tons greater than that of the 'Hercules,' and her construction would consequently cost considerably more, while her engines would cost less, and her expenditure of fuel not be so great as that of the 'Hercules.' Hence, apart from the question of handiness, it becomes necessary in contrasting the merits of these ships to determine the difference of prime cost approximately. Taking 55*l.* per ton of tonnage as the cost of the hull, which is a fair average for iron-clads, and taking 60*l.* per nominal horse-power as the cost of the machinery, which is also a fair average, we obtain the following results :—

		Tons.		£.		£.
Excess in the prime cost of the hull of the new ship over that of the 'Hercules'	=	710	×	55	=	39,050
		H.-P.				
Decrease in the prime cost of the machinery of the new ship from that of the 'Hercules' ..	=	275	×	60	=	16,500
Excess in the prime cost of the hull and engines of the new ship over that of the 'Hercules' ..	=					£22,550

This will, I think, be admitted to be a considerable saving, and one which can scarcely fail to show the desirability of building ships of moderate proportions, even if we have to increase the engine-power in order to obtain the very high speed.

There may, however, still be a suspicion in the minds of some advocates of long ships that the additional cost of maintenance for the more powerful engines of the 'Hercules' would in a comparatively short time make up for the difference in the prime cost, although that difference is considerable. I shall attempt to show what the difference of cost of maintenance may amount to, in order to clear up this point; but before doing so, I must draw attention to the fact that the new ship, being more than 700 tons burden greater than the 'Hercules,' will require an addition of at least fifty men to her crew, and that the cost of their maintenance will be considerable. Taking 70*l.* as the average total cost per man per annum, this would involve an additional annual outlay on the large ship of 3500*l.* From calculations based upon the average consumption of coal in ships with the improved type of engine, it appears that the cost of fuel in the new ship, for a day's steaming (24 hours) at half-boiler power, would be less than that in the 'Hercules' by a little over 15*l.* Hence it follows that the saving of wages and provisions in the 'Hercules,' as compared with the new ship, would cover the difference in the cost of steaming at 12 knots for 229 days, of 24 hours each, in the year. I need hardly say that our iron-clad ships are not under steam for anything like that time in a year, and consequently the difference in cost of fuel for the two ships would be much more than counterbalanced by the smaller expenditure required on the crew of the 'Hercules.'

Even if this necessary difference in the numbers of the crew were waived, it will be obvious from the facts just stated that the *interest*, at a low rate, on the difference of prime cost, would quite make up for the additional cost of fuel in the 'Hercules,' supposing her to be in commission and on general service. This matter, in my opinion, is thus placed beyond question.

Having disposed of this objection, it is only fair that I should call attention to the facts that the 'Hercules,' being smaller, is sure to be less costly in repairs than the new ship would be; and that as she is 60 feet shorter she cannot fail to prove much handier. In several parts of this chapter, I have had occasion to refer to this latter feature of short iron-clads; and it may be thought that undue stress has been laid upon the point. The *resumé* of the estimates put upon handiness by eminent naval officers, given in the preceding chapter, will, however, show that this is not the case.

On a review of the facts stated in this chapter, it can, I think, be scarcely doubted that the policy of building armoured ships of moderate length and proportions is superior to that of adopting greater length and fineness of form. The change from the 'Minotaur' to the 'Bellerophon' was undoubtedly very great; but I submit that experience has shown it to be a proper one, and the construction and trials of other ships of nearly the same proportions have tended to confirm this view. In prime cost, handiness, and general efficiency short ships have been shown to be better than long ships. In economy of engine-power long ships may be, and in some cases undoubtedly are, superior to short ships; but since this economy is inconsiderable in proportion to the total saving, it may be fairly concluded that the shorter iron-clads are, on the whole, greatly to be preferred.

CHAPTER X.

COST OF THE IRON-CLADS.

IN dealing with the cost of our iron-clads, and especially in comparing the cost of those built in the Royal Dockyards with those built by private shipbuilders, it is extremely difficult to lay down a proper basis for what are known as "incidental and establishment" charges, which ought to be added to the net cost of labour and material. The private builder has to find a slip or dock, building-plant, offices, officers, clerks, and so forth, in addition to the requisite labour and material. The Government has to do the same; but while the builder has a direct interest in limiting incidental expenses to the utmost, the Government, on the contrary, has both to incur expenses having nothing whatever to do with shipbuilding and to regulate their shipbuilding means with a view rather to contingencies which may arise than to the actual circumstances of the moment. In other words, the Government own as well as build ships, and both in shipowning and in shipbuilding they have to maintain large reserves.

The net cost of dockyard-built ships being known, the proper addition to be made to it for incidental expenses remained undetermined; and in attempting to settle this addition, the persons concerned went from one point to another, until at length in 1865 they determined to distribute the entire cost of all the naval establishments, at home and abroad, over the actual work done. In consequence of this determination, every ship built, say at Chatham or Pembroke, became subject to a charge of no less than 51¾ per cent. on the net cost of labour and material expended upon her. The effect of the sudden imposition of so enormous a charge upon dockyard work may readily be imagined; nevertheless, it may be well to aid the imagination with one example. Two iron-clads were built in succession at Chatham Dockyard, under circumstances as nearly as possible alike, in so far as the actual current expenses of the establishment are concerned, viz. first the 'Achilles,' and then the 'Bellerophon.' The 'Bellerophon' was much the smaller ship of the two, and her net cost was 106,000*l.* less than that of the 'Achilles;' but coming under the new system of incidental charge, she had a sum of 123,411*l.* added to her actual cost; while the 'Achilles,' under the previous system, escaped with but 13,981*l.* as incidental charge. The latest figures which I have noticed on this point are as follow:—

	Achilles.	Bellerophon.
	£.	£.
Actual cost of hull	375,473	256,114
,, ,, engines and fittings	69,117	88,612
,, ,, masts, sails, stores, &c.	25,740	19,601
Total actual cost for labour and materials	470,330	364,327
Arbitrary, incidental, and establishment charges	13,981	123,411
Nominal total cost	484,311	487,738

Here it will be seen that, by an arbitrary system of charge, a ship which really cost 106,000*l.* less than another is made to appear to have cost 3000*l.* more.

I am glad to see that one effect of Mr. Seely's Parliamentary Committee of 1868 has been to sweep away the more extravagant features of this system of charge.

This illustration will suffice to show how necessary it is to lay down some reasonable and fixed percentage as a basis for all comparisons between the cost of dockyard-built and private-built ships. It will, I think, be generally admitted that $12\frac{1}{2}$ per cent. upon labour and material is, or ought to be, an ample addition for establishment and other incidental charges, exclusive, of course, of all consideration of *profit* to the builder, which does not affect the question—first, because the Government has not to make a commercial profit by their work; and, secondly, because private firms often build iron-clads for little or no profit—at least so they themselves allege. Many private builders have assured me that 10 per cent. is generally sufficient to cover all expenses, and I have never heard the sufficiency of $12\frac{1}{2}$ per cent. questioned. Let us take it for granted, then, that $12\frac{1}{2}$ per cent. upon actual outlay is all that need be added to the cost of dockyard-built ships to complete the expenditure upon them. We certainly could build iron-clads either at Chatham or Pembroke for this percentage under fair conditions.

Assuming this allowance to be made for incidental charges on dockyard-built ships, and that the same percentage is allowed on the actual outlay at the dockyards necessary to equip and complete for sea contract-built ships, it may be interesting to examine what the actual cost of our iron-clads has been, say up to the commencement of the year 1868, choosing this date because, when this chapter was first written, the figures were readily available up to that time, and also because this date closes a period of seven years from the launch of the 'Warrior,' thus giving an ample range for experience and comparison of dockyard and contract work. In giving these figures, I shall take first the contract-built broadside ships which were then completed, and the dockyard-built ships of a similar character; after which I shall consider the expenditure upon the broadside ships then unfinished, and upon turret-ships, unfinished and finished.

CONTRACT-BUILT BROADSIDE SHIPS.

	Actual Outlay on Labour and Materials.				Total with 12½ per cent. on the actual outlay at the Dockyards.
	Hull.	Engines and Fittings.	Masts, Sails, Stores, &c., until complete for Sea.	Total.	
	£.	£.	£.	£.	£.
Warrior	282,581	74,409	22,164	379,154	385,188
Black Prince ..	283,511	74,482	20,317	378,310	384,064
Defence	203,229	34,357	15,836	253.422	257,109
Resistance	208,571	33,765	15,784	258,120	262,427
Hector	237,911	45,738	10,969	294,618	299,050
Valiant	264,443	48,323	12,449	325,215	327,917
Agincourt	362,771	83,277	9,590*	455,638	458,020
Minotaur	371,446	79,328	28,081	478,855	485,340
Northumberland	360,439	72,691	11,126*	444,256	445,905
Viper	42,287	7,611	3,309	53,207	54,194
Vixen	46,331	7,869	3,320	57,520	58,679
Waterwitch ..	43,080	13,642	3,308	60,030	60,879
Grand totals ..	2,706,600	575,492	156,253	3,438,345	3,478,772

I have previously explained that most of the contract-built ships named above had to be completed for sea in Royal Dockyards, and that in such cases it is necessary to add 12½ per cent. to the actual outlay at the dockyards, in order to arrive at the totals, which can be fairly compared with the totals for dockyard-built ships.

* These two ships had not been fully rigged and equipped when this account was made up.

For instance, the completion of the 'Warrior' for sea involved an actual outlay of over 48,000*l.* at a dockyard in labour and materials; and 6000*l.* has been added, in consequence, to the sum of the payments to contractors and the dockyard expenditure, in order to arrive at what we have agreed to regard as the fair total cost. The same thing is true in various degrees of all the other ships. I next pass to the completed dockyard-built broadside ships, upon which the following sums had been expended up to the date considered:—

GOVERNMENT-BUILT BROADSIDE SHIPS.

	Actual Outlay on Labour and Materials.				Total with 12½ per cent. on the actual outlay at the Dockyards.
	Hull.	Engines and Fittings.	Masts, Sails, Stores, &c., until complete for Sea.	Total.	
	£.	£.	£.	£.	£.
Royal Oak ..	189,381	45,310	19,846	254,537	280,518
Prince Consort ..	174,392	52,603	15,554	242,549	266,173
Caledonia	212,763	51,895	18,672	283,330	312,034
Ocean	201,651	52,162	17,417	271,230	298,451
Royal Alfred ..	221,765	47,512	22,263	291,540	321,881
Zealous	170,292	54,134	14,832	239,258	262,235
Lord Clyde ..	212,167	63,602	18,712	294,481	323,175
Lord Warden ..	236,197	68,279	18,367	322,843	354,520
Pallas	144,003	39,810	10,384	194,197	213,391
Favorite	122,423	24,016	10,206	156,645	173,146
Research	56,734	10,125	6,263	73,122	80,986
Enterprise ..	51,762	8,676	3,480	63,918	70,794
Achilles	375,473	69,117	25,740	470,330	520,362
Bellerophon ..	256,114	88,612	19,601	364,327	398,736
Grand totals ..	2,625,117	675,853	221,337	3,522,307	3,876,402

The only remark that need be made on this table is that the percentage for incidental charges, being taken upon the actual outlay at the dockyards, does not, of course, apply to the machinery, since all our ships' engines are made by contract; and in the lump sum paid to the contractor his percentage for such charges is included.

In order to complete the statement of the expenditure upon our armoured fleet up to the date above mentioned, I must add the particulars of the sums spent upon unfinished broadside ships, and upon turret-ships up to the same date, January, 1868. The former stand as follows:—

UNFINISHED BROADSIDE SHIPS.

Contract-built Ships.	Total Payment on Account of Contract.	Government-built Ships.	Total Outlay on Labour and Materials.	Total with 12½ per cent. on Actual Outlay at the Dockyards.
	£.		£.	£.
Audacious ..	19,330	Hercules ..	275,325	302,315
Invincible ..	8,868	Penelope ..	151,497	166,227
		Repulse ..	181,239	197,663
Total	28,198	Total	608,061	666,205

The turret-ships stand as follows:—

	Total Outlay on Labour and Materials.	Total with 12½ per cent. on Actual Outlay at the Dockyards.
	£.	£.
Captain	139,864	139,864
Monarch	175,513	194,152
Prince Albert	207,549	215,158
Royal Sovereign	133,980	150,431
Scorpion	112 587	112,922
Wivern	119,672	120,245
Total	889,165	932,772

A few remarks are necessary with respect to the expenditure on these turret-ships. The 'Captain' and 'Monarch' were unfinished when the expenditure given for them was calculated, the former being under construction at Messrs. Laird's yard at Birkenhead, and the latter at Chatham Dockyard. The expenditure on the 'Captain,' therefore, consisted solely of the payments on account of the contract, while the 12½ per cent. allowance has been added in the case of the 'Monarch.' All the remaining vessels have been completed for sea, and all are contract-built except the 'Royal Sovereign.' This ship, it will be remembered, was altered from a three-decked line-of-battle ship, and only the cost of the conversion is charged against her in the preceding table, no account being taken of the original cost. The contract-built turret-ships have been completed in the dockyards, so that they come under the 12½ per cent. rule; and in the case of the 'Prince Albert,' the addition made to the total outlay is, it will be seen, nearly 8000*l.*—the outlay on labour and materials in the dockyards having exceeded 60,000*l.*

Bringing the above sums together, we have for the total expenditure on iron-clad ships up to January, 1868:—

	£.
Contract-built broadside ships, completed	3,478,772
" " unfinished	28,198
Government-built broadside ships, completed ..	3,876,402
" " unfinished ..	666,205
Turret-ships, finished and unfinished	932,772
Grand total	8,982,349

Thus far I have, for the reasons previously assigned, dealt only with the details of the expenditure on our iron-clads up to the commencement of 1868. It may be interesting if, before concluding this chapter, I add a brief statement of the expenditure on iron-clads for the year 1868, bringing the information up to January, 1869. This expenditure, in round numbers, was as follows:—

	£.
Contract-built broadside ships	306,000
" turret "	128,500
Government-built broadside ships	301,000
" turret "	126,250
Total expenditure for the year 1868	861,750
" up to January, 1868 (as above) ..	8,982,349
" " 1869	9,844,099

In round numbers, therefore, our iron-clad navy has cost the nation ten millions sterling up to the commencement of the present year.

This expenditure commenced in May, 1859. The total annual expenditure upon the navy, year by year, since that period, has been (in round numbers) as follows :—

	£.	
1859-60	12,700,000	
1860-61	13,000,000	
1861-62	13,500,000	
1862-63	11,800,000	
1863-64	10,700,000	
1864-65	10,600,000	
1865-66	10,200,000	
1866-67	10,500,000	
1867-68	12,700,000	
1868-69	11,100,000	(estimated)
Total	£116,800,000	

Out of this 116 millions sterling, 10 millions only have, as we have seen, been expended upon the building and equipment of new iron-clads, the remaining 106 millions having been expended upon other objects. It is desirable that this fact should be better understood than it is at present. There are many influential persons who seem to think that it is upon new iron-clad ships that millions have been annually spent of late years, whereas, in point of fact, one million per year, or less than *one-eleventh* of our outlay on the navy, is all that has been expended in this way; and I venture to say that it would be very difficult to prove either that our present magnificent and powerful iron-clad fleet has been dearly purchased at ten millions, or that any other ten millions of the one hundred and sixteen have secured for the country a more valuable result.

I shall trust myself to add but little respecting the savings effected by the introduction of the short iron-clads upon my plan in place of the long and costly ships that preceded them. The saving has been—and is known by successive Boards of Admiralty to have been—at the rate of nearly or quite 100,000*l.* per ship, and numerous ships have been built.

CHAPTER XI.

TURRET-SHIPS.

I NOW come to the consideration of the turret-ship question, a question which has, to a large extent, passed out of that controversial state in which it too long remained. Recent circumstances have removed the objections which I felt to writing publicly upon this subject, and have made it possible for me to discuss it with all necessary freedom, and to attempt to state both sides of the question with perfect fairness.

The turret system possesses both so many advantages and under certain circumstances so many disadvantages that its introduction almost necessarily occasioned much division of opinion among naval officers and naval architects; but I must say that I have always considered that this controversy has been unnecessarily embittered by the unrestrained manner in which its advocacy has been urged. The inherent merits of the system are, however, so great that the only effect of this error of advocacy has been to somewhat retard its extensive adoption. I may do myself the justice to add that the views which I am now about to set forth are those which I have held from the beginning.

The first and most obvious advantage of the turret system consists in the facility which it affords for training large guns smoothly and easily through large arcs, and for making the same guns available on both sides of the ship. This is an advantage which has never been questioned, and which certainly needed no extravagant statement of its worth; but unfortunately, in putting it forward, some of the promoters of the turret system, in its early days, associated it with the assertion that large guns could not, in fact, be mounted and worked upon the broadside, or, indeed, upon any other plan whatever. To this it was obviously impossible to assent, and the experience subsequently acquired—first in the 'Bellerophon,' with 12-ton guns, and afterwards in the 'Hercules,' with 18-ton guns—has shown that there was no foundation for such an assertion. Indeed, upon the very face of the matter, it is obvious that it would be contrary to all mechanical principles to suppose that a central pivot has so great an advantage over an end-pivot as to make it perfectly easy to work a 200-ton turret upon the former, while it was impossible to work a 20-ton gun only upon the latter. It may not be uninteresting to observe that one of the favourite illustrations of the extreme advocates of turrets was drawn from a mechanical arrangement of the very reverse character, viz. the turn-table at the Greenwich Railway terminus. This was often cited as an instance of the facility with which the great weight of a locomotive engine can be turned round a centre, after the manner of a turret; whereas a glance at the arrangement itself will show to any one that it is in fact strictly analogous to the slide of a broadside gun, turning round a pivot at the end, through part of the circle.

With Captain Scott's gear, guns even of the largest class are now trained with all necessary ease on the broadside; the same is true of the turret, the real advantage of the latter consisting in the fact that while the arc of training of the turret gun may be made very great without any increase in the size of the port, it is impossible to obtain a large arc of training with a broadside gun, or with a gun mounted broadside fashion, without enlarging the port and weakening the ship's side considerably in its immediate neighbourhood. For this reason, and for some others that will follow, I have always looked forward to a large adoption of the turret system in those classes of ships in which masts and sails are not requisite, or in which they can be so subordinated to the turret armament as to leave it in possession of this its prime advantage, viz. a large range of horizontal command.

The next point to which I shall advert is the capability of fighting the same guns on both sides of the ship. There can be no doubt that this is, in the abstract, an advantage, but it is one which is attended with great drawbacks in the turret system. The chief of these is the very large weight of armour in various forms, much of which has to be devoted to the protection of the guns, and which may be roughly taken as double the amount that is requisite on the broadside system, gun for gun. In other words, with a given weight you can protect and work eight guns, mounted on the broadside, four on each side of a ship, about as effectually as you can protect and work four guns only mounted in two turrets; and looking to the history as well as to the prospective circumstances of naval warfare, it must of necessity be better to have four guns to fight with on each side simultaneously than to have only four altogether, whatever facility of training the latter may possess. This point has been very much lost sight of by many advocates of the turret system, whose notion no doubt was, and in many cases perhaps still is, that you can carry even more guns on the turret plan than on the broadside plan. The fact is, however, quite otherwise, and would be even more favourable to the broadside system than it is, if the same sacrifice of independent training were made in the case of broadside guns as is made with turret guns, viz. that of fixing two guns side by side, and depriving both of all independent training. For it must be borne in mind that even in the largest turret-ships of our own and other navies—excepting the 'Royal Sovereign,' the 'Prince Albert,' and two or three vessels built in Russia and America—there are but two turrets, and that the two guns in each of these are so connected as to be compelled to train together; whereas every gun of the eight in an equivalent broadside ship has a perfectly independent set of motions. If, on the other hand, we were to mount broadside guns in pairs, it would be quite practicable to shorten the central batteries, and give to the broadside ship an even greater attacking force on each side than the turret-ship has available for both sides. It will be necessary to bear this aspect of the question in mind when we come to consider more closely the relative merits of turrets and broadside ships in respect of their attacking powers.*

* This proposal to mount guns in pairs at broadside ports is by no means a novelty. For example, Mr. J. B. Eads, of St. Louis, Missouri, an eminent

I have already intimated that the enlarged adoption of the turret system has usually been associated in my mind with those classes of vessels in which masts and sails are not required. It is well known that others have taken a wider view of its applicability, and have contended that it is, and has all along been, perfectly well adapted for rigged vessels. I have never considered it wholly inapplicable to such vessels; on the contrary, I have myself projected designs of sea-going and rigged turret-ships, which I believe to be safe, commodious, and susceptible of perfect handling under canvas. But most assuredly the building of such vessels was urged by many persons long before satisfactory methods of designing them had been devised; and my clear and strong conviction at the moment of writing these lines (March 31, 1869) is that no satisfactorily designed turret-ship with rigging has yet been built, or even laid down.

The most cursory consideration of the subject will, I think, result in the feeling that the middle of the upper deck of a full-rigged ship is not a very eligible position for fighting large guns. Any one who has stood upon the deck of a frigate, amid the maze of ropes of all kinds and sizes that surrounds him, must feel that to bring even guns of moderate size away from the port-holes, to

engineer, who constructed the 'Baron de Kalb,' 'Carondelet,' 'Mound City,' and other casemated and turreted iron-clads which did good service on the western rivers during the late Civil War, has worked out the details of a plan of this kind. In his arrangement the guns are mounted on turntables, in pairs, which are trained together, while the battery is constructed in such a manner as to admit of the same guns being fought on both broadsides. Full details of the scheme are given in a letter to the Secretary of the United States Navy, since published by Mr. Eads.—(New York, D. Van Nostrand, 1868.)

place them in the midst of these ropes, and discharge them there, is utterly out of the question; and the impracticability of that mode of proceeding must increase in proportion as the size and power of the guns are increased. But as a central position, or a nearly central position, is requisite for the turret, this difficulty has had to be met by many devices, some of them tending to reduce the number of the ropes, and others to get them stopped short above the guns. In the former category come tripod masts, in the latter flying decks over the turrets: the former have proved successful in getting rid of shrouds, but they interfere seriously with the fire of the turret guns, and are exposed to the danger of being shot away by them in the smoke of action; the latter are under trial, but however successful they may prove in some respects, they will be very inferior in point of comfort and convenience to the upper decks of broadside frigates. In the case of the 'Monarch,' which has a lofty upper deck, neither the tripod system nor a flying deck for working the ropes upon has been adopted. A light flying deck to receive a portion of the boats, and to afford a passage for the officers above the turrets, has been fitted; but the ropes will be worked upon the upper deck over which the turrets have to fire, and consequently a thousand contrivances have had to be made for keeping both the standing and running rigging tolerably clear of the guns. It seems to me out of the question to suppose that such an arrangement can ever become general in the British Navy, especially when one contrasts the 'Monarch' with the Hercules' as a rigged man-of-war. Nor is the matter at all improved, in my opinion, in the case of the 'Captain' and other rigged turret-ships in which the ropes have to be worked upon bridges or flying decks poised in the air above the turrets. Such bridges or decks, even if they withstand for long the repeated fire of the ship's own guns, must of necessity be mounted upon a few supports only; and I am apprehensive that in action an enemy's fire would bring down parts, at least, of these cumbrous structures, with their bitts, blocks, ropes, and the thousand and one other fittings with which a rigged ship's deck is encumbered, with what results I need not predict.

It is for these reasons, and for others of like nature, that I object to some features of every rigged turret-ship which I have yet seen. The only description of rigged turret-ship which I believe would be at all likely to succeed sufficiently to justify its large adoption is one which I contrived at the Admiralty some years ago, but of which no example has yet been built. In this type of ship the turrets are placed as near the ends of the ship as is consistent with proper ease of motion in a seaway; the all-round fire is secured to them; but the whole of the ship's side between the turrets is carried up to a spar-deck, which deck is prolonged as far as is necessary to embrace the foremast and mizenmast, and to receive their running gear. The head-ropes present the only difficulty that attends this plan; but as part of the plan is to have even the deck before and abaft the turrets situated at a good height above the water—10 to 12 feet—these head-ropes could, no doubt, be satisfactorily dealt with. This kind of ship would unquestionably possess good sea-going and cruising qualities; her turrets would possess that unbroken command of the horizon which is the only justification for their use;

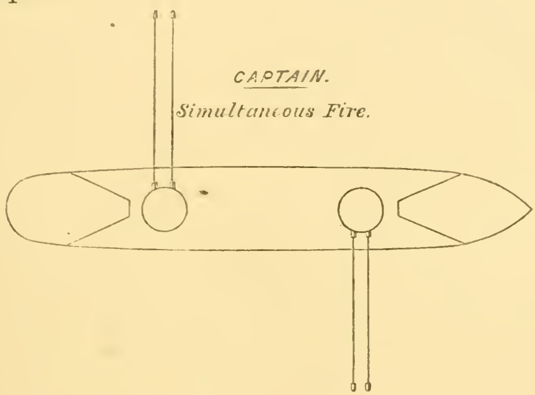
and she might be as well-rigged and commodious a ship as a broadside vessel. The only thing to be considered is whether even this ship would be better, or so good, as a well-designed broadside vessel, which may be fairly open to question. At present, with our limited experience, I express no conclusion upon this point.

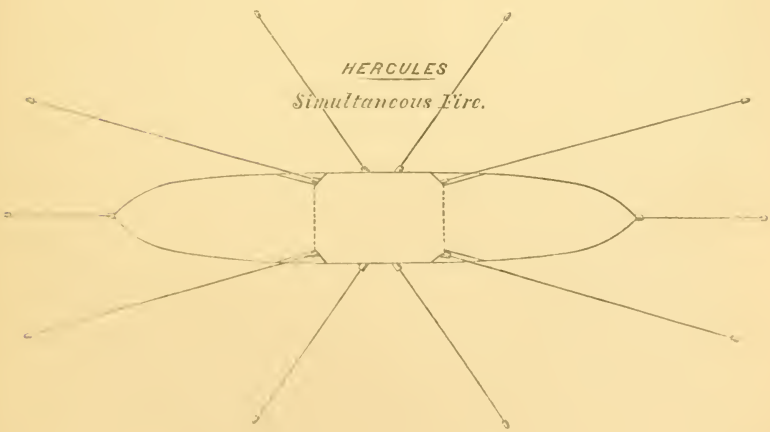
It is well known that both in the 'Captain' and in the 'Monarch' the turrets have been deprived of their primary and supreme advantage, that of providing an all-round fire for the guns, and more especially a head fire. This deprivation is consequent upon the adoption of forecastles, which are intended to keep the ships dry in steaming against a head-sea, and to enable the head-sails to be worked. When it first became known that the 'Monarch' was designed with a forecastle (by order of the then Board of Admiralty), there were not wanting persons who considered the plan extremely objectionable, and who took it for granted that as a turret-ship the new vessel would be fatally defective. The design of the 'Captain' shortly afterwards, under the direction of Captain Coles, with a similar but much larger forecastle, was an admission, however, that the Board of Admiralty did not stand alone in the belief that this feature was a necessity, however objectionable. Both these ships, therefore, are without a right-ahead fire from the turrets, the 'Monarch' having this deficiency partly compensated by two forecastle ($6\frac{1}{2}$-ton) guns protected with armour, while the 'Captain' has no protected head-fire at all, but merely one gun ($6\frac{1}{2}$-ton) standing exposed on the top of the forecastle. The question arises—and a very serious question it is—what is the amount of the sacrifice thus made?

This question is much too lightly passed over by many persons, who would have us believe that, if turret-guns or central-battery guns can be brought within 15 or 20 degrees of the line of keel, that is all that will really be necessary in war. To this I demur; this I deny. If we consider the matter closely, it will be observed that, in chasing, the disadvantage of having to turn 15 or 20 degrees from your course would, in many cases, be very great, not to say fatal to success; for in chasing a ship of nearly equal speed you would be reduced to the necessity of either abstaining from firing a shot, or of letting the enemy escape. If by steaming at your utmost you could but just gain on her, by diverging from your course you would evidently lose her. On the other hand, if you failed to diverge, you would be subject to her stern-fire throughout the chase, without the means of replying or of doing her any harm. And besides all this, there is the very important fact that it is extremely difficult to aim with accuracy with the ship swerving right and left under the action of the helm. Or, taking the case of having to break a line of battle, it may easily be seen how extreme a disadvantage you would labour under by being unable to fire within less than, say, 20 degrees of the line of keel. I say 20 degrees, because, although in both the 'Monarch' and 'Captain' guns can with care and contrivance be brought within a less angle, I believe that in actual warfare this would not, in fact, be so, especially after the smoke of the action had begun to embarrass the sight. Now, what are the facts of the case? Suppose a fleet formed in line of battle, and a turret-ship, with her guns shut in by a forecastle 20 degrees on each side, to be approaching. At a distance of 4000 yards, which is within range, this forecastle would cut off from the men in the turrets all sight of a fleet extending over a distance of more than 2500 yards, at right angles to her course. In other words, more than twenty ships as large as the 'Hercules' could lie one ahead of the other in line, and the turret-ship in question, which we suppose to be steaming up to them, would be incapable of getting a shot at any one of them without diverging from her course. At 2000 yards more than ten such ships would be concealed by her forecastle; at 1000 yards five of them; and at 500 yards three of them. The forecastle would, in fact, prevent such a ship from bringing her guns to bear upon any part of a ship as big as herself, and lying within her own length of herself right across her path. These I hold to be very serious facts, and the more so as this loss of right-ahead fire is now peculiar to turret-ships. In point of fact, the 'Captain' is the only iron-clad ship of recent construction which is unable to fire ahead from behind her armour.

A thousand objections to turrets are, however, swept away the moment we do away with masts and spars in turret-ships. The only formidable difficulty that then remains is that of raising, carrying, and lowering the boats with proper facility and security. And this, I do not hesitate to say, is a more important point than is supposed by some advocates of turrets. They say, and so far say with truth, that in action the boats of every man-of-war are not only liable to destruction, but are almost certain to be destroyed; it is therefore, they argue, of but little moment whether they are to be lowered with facility or not. But it is hard to admit that no means should exist for readily lowering a boat even in a time of action, and there are obviously numerous occasions out of war in which the ready use of the boats should be practicable simultaneously with gun exercise and practice. But by placing the guns in the middle of the ship, and from that position firing in all directions—which is, or should be, the specialty of turret-ships—this is made impossible, and it ought to be frankly avowed that in respect of the ready use and easy stowage of their boats real turret-ships, with all-round fire, are at a great disadvantage compared with broadside ships.

Let us now consider a little more fully the offensive and defensive powers of turret-ships, premising that we are dealing with vessels carrying two turrets. In considering their offensive powers, it is necessary to bear in mind the fact, to which a passing reference has already been made, that they are all limited to the means of firing at any moment in two directions only. It is astonishing how little considered, probably how little recognised, this extraordinary feature of turret-ships has hitherto remained. In a broadside ship each gun is an independent element of attack, and all the guns of such a ship may be directed upon separate points. In the case of the 'Hercules,' for example, notwithstanding the concentration of her armament, and neglecting her unprotected upper-deck guns, she can bring eight 18-ton and two 12-ton guns to bear on separate points, thus striking out in ten different directions simultaneously with powerful guns. The 'Captain,' on the contrary, is limited to two directions only. No doubt the turret-ship can hit much harder in those two directions than the other ship hits with each of its ten blows. The shock of two 600-lb. shot from 25-ton guns, with full charges and at short range, striking within a few feet of each other, must be terrific; but so also must be the effect of a concentrated broadside from the four 18-ton guns of the 'Hercules;' and my present position is that, while the latter ship possesses the faculty of dealing such broadsides in combination with the power of using each gun independently, the turret-ship is absolutely without this power, and is limited to concentrated fire alone. If it be said, by way of reply, that every step taken in the direction of increasing the size and diminishing the number of guns is to some extent open to a similar objection, I must observe that this is not in my opinion a correct view of the case, for the objection holds against an undue limitation of the independent action of guns of equal power. For example, let us suppose the 'Hercules,' instead of being armed with four 18-ton guns on each broadside, to be armed (as she might be) with three 25-ton guns, the latter being of equal weight per gun with the 'Captain's' and 'Monarch's.' Her battery will then obviously possess the power of firing six such guns simultaneously in as many separate directions, while the turret-ship can fire simultaneously in two directions only. On the other hand, it must be borne in mind that the broadside ship can never concentrate more than three such guns upon a single point while the turret-ship can concentrate four; and that the arcs through which these four can be concentrated on each side of the ship are greater than the arcs within which the broadside fire is limited. It is very difficult to set just comparative values upon these diverse capabilities of guns mounted on the two systems, but when the multitudinous attacks to which a ship is liable in a general action are remembered, the fact that a turret-ship is deprived of simultaneous fire in all but two directions assuredly deserves the most serious attention of naval men. The accompanying diagram illustrates the relative powers of the 'Captain' and 'Hercules' in this respect.





Intimately connected with this last consideration is another, which, to my mind, appears of much greater importance still. I allude to the fact that, as all the fire of a turret-ship must emanate from two points, all the attack upon her may be attracted to those two points, which unfortunately have the disadvantage of being most clearly marked out, being the centres of two conspicuous cylinders. And besides this, a special danger appears to me to result from the circumstance that, in order to send a shell into the interior of a turret, it is not necessary to aim at a port at all, but to direct your fire upon the centre of the turret on either side of which a port is situated. The accuracy of fire attained with guns at sea will never be so great as to make it easy, under ordinary circumstances, to aim at a port and hit it; but the accuracy already attained is sufficient to justify the belief that, by aiming at the centre line of the turret between the ports, there would be a very fair probability of your lodging a shell in one or other of the two adjacent ports. It is fortunately true that the turret ports are small, and that the guns approximately fill them when run out; but after making every allowance for these things, I still feel that turret-ships most invite attack precisely where they are most vulnerable, and where a couple of shells would place them *hors de combat*. I am also afraid that with guns placed so extremely close to each other as they are in turrets, a slight derangement of the mechanism of one may effectually silence the other, even without shot or shell entering the turret. It will probably be left for future naval actions to show how far my apprehensions in these respects are well founded; but I confess that it appears to me doubtful whether a smart captain, in a ship armed with numerous light guns, might not under favourable circumstances range up to a heavy turret-ship, and, by maintaining a continuous fire directed at the centre of her turrets, get shell or shrapnel into her ports and place her *hors de combat* without allowing her to deliver a single shot. Smarter things than this have often been done in war both on land and on sea, and the mere possibility of its occurrence ought to exercise some restraint upon those persons who, without experience, and even without reflection, would have us send the entire navy of the country to sea in turret-ships; for however small the risk may prove to be in ships like the 'Thunderer,' with lofty and unembarrassed guns, it would certainly be increased in ships with lower turret ports and carrying masts and rigging, the fire of which would be less at the command of the captain and gunners.

It has been generally taken for granted of late that the revolving of the turret is not practically liable to being stopped by the blows of shot, and the experiments made at Portsmouth by firing the 12-ton guns of the 'Bellerophon' at the turret of the 'Royal Sovereign' have been supposed to establish this view. I was not present at those experiments;* but I carefully studied them afterwards, and to my mind they never have appeared in the least degree conclusive, and for an obvious reason, viz. that no shot struck what I consider to be the vulnerable place, which is the junction of the turret with the deck. The experiments were satisfactory on the other point—the impunity of the revolving apparatus, as fitted in the 'Royal Sovereign,' with reference to the fire of 12-ton guns; but this was never in my judgment the point in doubt. My conviction is,

* I was out of health, at Malvern.

and always has been, that a large shot striking the deck quite close to the turret, with considerable force, will inevitably block the turret and prevent it from revolving. An iron glacis-plate, sloping upwards towards the turret, will not in my opinion hinder this; but will, on the contrary, facilitate it. I have never yet seen, and do not expect to see, a large shot moving with great velocity strike any mass of iron without driving much of the mass before it through a space of at least many inches; and the iron of a turret glacis-plate, when so driven forward, must of necessity be driven into the turret and so fix it. A horizontal glacis-plate would be much safer than a plate sloping upwards; and perhaps the safest arrangement of all would be a *reversed glacis*, sloping downwards towards the turret, the junction of which with the turret could not be struck at all, except by a dropping shot, which could not strike with any great velocity or force.

The foregoing remarks apply primarily, and perhaps almost exclusively, to turrets which pass down through a deck after the manner preferred by Captain Coles. In the case of monitor turret-ships of the American type, the junction of the turret with the deck upon which it stands is protected by a massive ring of iron surrounding the base of the turret—an arrangement which, in my opinion, would be safe and satisfactory only on the condition of the ring being of much larger proportions than it has usually been made. In discussing this question, Mr. Eads, of St. Louis, Missouri, of whose ability and experience I have previously had occasion to speak, in a letter to the Secretary of the Navy, writes as follows:—

"I believe that the distinguished inventor of the "monitor system has advocated the use of engines of "sufficient power to rotate the turret without its being "raised by the central spindle, and while its weight "rests entirely upon the deck. This would make it, "however, no less liable to have its rotation stopped if "the wall were swelled downwards at any point in the "plane of its base in consequence of the impact of "the projectile near the deck, unless the power of the "engines was sufficient to drag it around despite such "irregularities, a provision against such casualties that "would involve great additional weight and cost of "machinery. The use of a heavy base-ring around the "turret or around the pilot-house, to protect the joint "at the deck, or at the base of the pilot-house, is but a "partial remedy for a radical defect in the rotating "system. The base-rings around the monitor turrets "found necessary to protect the joint of the 10-inch "walls against 10-inch round shot at Charleston are "about 5 by 15 inches in cross-section. It is an "interesting question, and one having an important "bearing on the value of the monitor system, to know "how much would be required to protect 15-inch "walls at this joint against 15-inch shot, to say "nothing of the larger projectiles that have been found "practicable. It is but a poor argument in favour of "retaining a system which has such a vulnerable point "of attack to prove that turrets have been repeatedly "under fire without being damaged at their weakest "place, when this weak point has on other occasions "been struck and the turret disabled thereby. The "argument against such a system has a double force "when we remember that the means of strengthening "this point against heavier projectiles have never been "tested, and the result of their failure in action may "involve the capture of the ship."

I cannot conceal from myself the fact that there is much ground for the remark with which this extract closes, and I certainly see reason to fear that a naval action may open up more elements of derangement and danger in turret-ships than some are willing to believe at present.* Meantime it is, and will remain, our duty to diligently forecast and guard against such results to the utmost of our ability.

Before concluding this part of the subject, it may be well to observe that those small and fast sea-going turret-ships carrying very heavy guns, which were once so much urged upon the Admiralty even in Parliament, are proving to be what I and some others always said they were, viz., mere chimeras of the brain. In order to carry 25-ton guns, the turrets of the 'Monarch' have had to be made 26½ feet in diameter; the 'Captain's,' for the same guns, are still larger; and the 'Thunderer's,' to carry 30-ton guns, have been made more than 31 feet in diameter. There are some practical gunners who contend that all these turrets should have been of much greater size. It will not, therefore, be extravagant to assume that turrets for 50-ton guns will require to be about 35 feet in diameter.

* In this connection I say nothing respecting the experience in actual warfare had with the Danish turret-ship 'Rolf Krake,' and similar vessels, because the shot and shell by which the turrets of those ships were struck were so extremely light as to put the effects of their impact altogether out of comparison with the projectiles of our present naval guns.

Now, 35 feet is the full breadth of many sloops of war; the new corvettes, 'Druid' and 'Briton,' of nearly 1400 tons, are of only 36 feet extreme breadth, and are therefore obviously incapable of carrying a 35-feet turret inside of them. The new fast corvettes of 2320 tons, the 'Volage' and 'Active,' are of but 42 feet extreme breadth, and therefore, even if they could sustain the weight of such a turret, would have but a space of 3½ feet on either side between the outside of the turret and the outside of the ship. In fact, the space would in reality be much less, as the extreme breadth of the ship would not exist abreast of the turret. A few considerations of this kind, coupled with the difficulty of driving small ships carrying great weights at a high speed, are sufficient to show that small and fast turret-ships, heavily armoured and armed, are entirely out of the question.

The combination of the turret system of mounting naval ordnance with the monitor type of vessel in the American navy, and the occasional performances of ocean voyages by American monitors, and by vessels of similar type, have led many to contend that vessels of that type may be taken as efficient sea-going ships, adapted for the general purposes of a navy like our own. My opinion, on the contrary, is that no monitor of the American type—*i.e.* a monitor with her turrets standing upon the low deck, unprotected by a breastwork, and with all her hatchways, &c., opening through the low deck—can be considered a satisfactory sea-going vessel. Such a vessel, depending, as it does, upon the watertightness of the junction between the turret and the deck, and obtaining that watertightness by means of the weight of the turret closing the junction, is unable to revolve her turret and fight her guns in a seaway, a circumstance which alone renders her unfit for fighting actions at sea. And besides this, let partisans say what they will about the dryness of monitors, nothing can possibly prevent a pure monitor vessel from being deluged by the sea in rough weather, to an extent which is as incompatible with proper ventilation and comfort as it is with fighting efficiency. It is for this reason that I have devised the Breastwork Monitor System, which has been briefly described in the Chapter on Armour, and the characteristic feature of which is that all the openings into the ship which are to be used at sea are comprised within an armour-plated breastwork, the top of which is situated, even in small vessels, at a height of 8 or 10 feet above the sea level, and at a height of about 12 feet in the 'Thunderer' class. But even with this provision, monitors are, in my opinion, incapable of steaming against a head sea unless they are either of very large dimensions, and therefore make up for deficient height by enormous deck area, or else are fitted with sunk forecastles like that of the 'Thunderer.' Nor can it be doubted, I think, that even this class of ship will often be deluged forward by the sea, and consequently all its fittings will be so arranged as not to subject the ship to leakage from this cause.

The experience gained with the American monitors is not by any means so uniformly satisfactory as has been supposed. It has been stated in the most public manner that in weather when the transports off Fort Sumter had to run for safety, the monitors lay like ducks on the water, dry and seaworthy, and were never disabled from firing their guns. Of the following monitors which took part in the operations off Fort Sumter, in Charleston Harbour, viz. 'Passaic,' 'Weehawken,' 'Montauk,' 'Patapsco,' 'Catskill,' 'Nantucket,' and 'Nahant,' we have the following accounts: —The captain of the 'Passaic' says that in making the passage from Hampton Roads to Beaufort, when off Cape Hatteras, the wind freshened from the S.W., "causing the ship to pitch and labour a good deal." In another letter he says that, "had it not been for "the weather cloths, the sea would have broken "regularly over the top of the turrets." The turret was up in the position necessary for fighting it, and, owing to the difficulty of raising and lowering it, it defied all their efforts to get it down. The ship took in water rapidly round the turret's base, and at one time the water had covered the fire hearths to within three inches of the fires, and the splashing had nearly quenched three of them. The captain of the 'Weehawken' reports that she behaved admirably in a storm, but says that she made so much water that at one time the ash-pits were covered. The captain of the 'Montauk' observes "that on the whole she has "behaved very well with the moderate test she has "had, but she gives positive indications that, if forced "end on into a sea, she will strain both overhangs "greatly, and if she gets into the trough of the sea, she "will wallow very heavily—to such an extent, indeed, "as to render the breaking of a tolerably high sea over "the turret almost certain." The captain of the 'Nahant' reports that the decks leaked badly, and that a considerable quantity of water forced its way under the turret, wetting the belts of the blowers, putting everybody to serious inconvenience for want of air below, and causing instant depression of the steam by stopping the draught, because of the constant necessity to stop the blowers to repair damages to the belting. The other ships were of nearly the same size and class as those to which I have referred, and although we have no details of their behaviour, we are bound to conclude that it did not differ much from theirs.

When ordered to employ the monitors on blockading duty outside the bar at Charleston, Admiral Du Pont reported "that they are totally unfit for the duty, and "particularly in the hot season. In even a slight sea "the hatches must be battened down, and the effect "upon the crew, if continued for a brief period in hot "weather, would be most deleterious, indeed in such "weather they are not habitable." The commanding officers in a joint report on the same subject say "that "the hatches would have to be battened down the "whole time, and the vessel could not fail to be disabled "from loss of health to the crew."

If anything more were necessary, I would refer to the reports upon the original 'Monitor.' Captain Worden reports of her that "she would be unable to work her "guns at sea, as the ports are obliged to be kept closed "and caulked, they being but five feet above the water." Commander Bankhead reports that on her passage from Hampton Roads, northward (the passage on which she was lost), "she plunged heavily, completely "submerging her pilot-house, the sea washing over and "into the turret, and at times into the blower pipes" (she was then in tow of the 'Rhode Island'). Continuing, he says—"when the 'Rhode Island' was "stopped to see if that would cause the 'Monitor' to ride "easier, the latter fell off immediately into the trough "of the sea, *and rolled heavily*." She let in water round the base of the turret, and, as the captain believes, at leaks caused by the heavy shocks received by the projecting armour as she came down upon the sea, and she went down, in spite of pumps capable of throwing 2,000 gallons a minute, which were in good order and working constantly.

It may be mentioned also that, although the 'Weehawken,' as we have seen, weathered out a storm, she afterwards sank at her moorings in Charleston harbour at midday, with a large number of her crew, her loss being caused by a wave having passed over the deck when the fore-hatch was open for ventilation. This brought her down by the head, and caused her to take in water through the hawse-holes, and although the pumps were immediately set to work, the ship could not be saved. Three minutes elapsed from the time of flying the signal of distress to the time when she went down. The rush of the men up through the turret prevented anyone going down in time to warn those in the engine-room, and of the whole crew about thirty went down in her. As further instances of the suddenness with which these vessels sink when injured in their hulls, we have information of the 'Tecumseh' having gone down in four minutes with all hands, after being struck by a torpedo, and of the 'Patapsco' in one minute, by the same means, with the supposed loss of sixty-two men.

A very great point has been made of the supposed smallness of the American monitors as compared with English ships, and the sizes of the American monitors have been given as follows:—The 'Passaic' class, 844 tons; the 'Monadnock' class, 1564 tons; the 'Kalamazoo' and 'Dictator' classes, 3250 tons. But the fact is that these American tonnages are measured in a way very different to ours, and consequently people have entirely mistaken the relative sizes of English and American vessels—of the 'Pallas' and 'Monadnock' for example —as the following table of dimensions will show:—

	Pallas.		Research.		Enterprise.		Monadnock.		Dictator.		Kalamazoo.	
Tonnage B. O. M., including extra breadth in wake of armour ..	2372		1253		993		3345		3777		5260	
Ditto, excluding extra breadth in wake of armour	2372		1253		993		2796		2668		4308	
	Feet.	In.	Feet.	In.	Feet.	In.	Feet.	In.	Feet.	In.	Feet.	In.
Length at water-line ..	225	0	195	0	180	0	257	0	314	0	342	0
Extreme breadth	50	0	38	6	36	0½	52	10	50	0	56	8

The 'Pallas,' 'Research,' and 'Enterprise,' are English iron-clads; the 'Monadnock,' 'Dictator,' and 'Kalamazoo,' are American monitors.

It is evident from the above particulars that the 'Pallas' is not a larger, but a very much smaller, ship than even the 'Monadnock,' and only about half the size of the 'Kalamazoo.' Any remarks based on the supposed smallness of these American vessels therefore fall to the ground.

Several passages in the reports of the Commodore respecting the passage of the 'Monadnock' round Cape Horn have been referred to. It should, however, be borne in mind that this was not in the nature of an ocean cruise, but was a passage from one coasting station to another, calling at several points on the coast to take in coals, the vessel being fitted with temporary wooden pilot-houses, &c., and with coats round the bases of the turrets to keep them water-tight, but which would have to be slackened if the ship had to prepare for an engagement. There are many points, however, in the passage of this ship with which I was impressed at the time the reports reached us, even after carefully eliminating any little exaggeration. For instance, in a quotation from this report, we find it stated that, "in a "gale off Point Conception on the coast of California, "two successive waves rose which interposed between "my ship and the mast-head light of the 'Monadnock.' "Upon enquiry I found that the light was elevated 75 "feet above the water, my own eye being about 25 feet "above the sea level. In this sea, according to the "testimony of her officers, she was very easy."

I remember being struck with this passage in the report on considering that Scoresby's ocean storm-wave is only 30 feet high. The following questions also suggested themselves:—How high were the crests of these waves above the top of the turret of the monitor at the time? Could the monitor work her guns? And if so, what kind of practice would she make at an enemy on the other side of these waves? In the same report we find it stated that "in the long seas of the Pacific to "the southward of Valparaiso, I observed that the 'Monadnock' took very little water upon her decks, rising "over the waves easily and buoyantly." Dry decks under these circumstances are hardly compatible with a steady gun platform.

The following extracts from the report of Mr. Fox, Assistant Secretary of the American Navy, on the passage of the 'Miantonomoh,' have been much commented on :—" The extreme lurch observed when lying " broadside to a heavy sea and moderate gale was seven " degrees to windward and four degrees to leeward." These angles I assume to be from the vertical, but I would remark that the danger to a monitor is measured more by her inclination to the wave surface than to the vertical. With respect to the alleged steadiness of these monitors, I may add that the general steadiness has never been disputed; but we have sufficient evidence in the foregoing extracts from the reports of their commanders to show that it would be a great mistake to suppose that they are exempt at all times from considerable rolling. It is, however, unnecessary to enlarge here upon this aspect of the question, which has already been considered in Chapter VII.

When Mr. Fox is quoted as having said—" The " monitor type of iron-clad is superior to the broadside, " not only for fighting purposes at sea, but also for " cruising," it is quite clear from the report that he uses the term cruiser in the sense in which the 'Miantonomoh' is a cruiser, viz. a ship able to steam as far as her coals will allow her, which in the American ships is a very small distance. Mr. Fox in the same report says :—" In the trough of the sea her ports will be liable " to be flooded if required to use her guns to windward. " This, therefore, would be the position selected by an " antagonist who desired to fight a monitor in a sea- " way." He might have added that, when the waves rose higher than the ports (6 feet 6 inches), even when the ship rose over them sufficiently to prevent her ports being flooded, she would only be able to fire her guns when she mounted the crest. He would then have had to face the further consideration whether there was time, before sinking again into the hollow, to train and fire a turret gun. This view of the case of guns near the water in a heavy sea is supported by the official report of Admiral Yelverton, after encountering heavy weather in the Atlantic, in which he recommends a turret-ship 12 or 14 feet out of the water. Guns in such a ship would, in other than very exceptional circumstances, be enabled to keep an enemy constantly in view, or, if it were a monitor, the places where she disappeared, and where she would be likely to appear again.

Another passage from the same report says :—" The " comforts of this monitor to the officers and men are " superior to those of any other class of vessels in the " navy." This, in so far as it is accurate, may be accounted for in this case by the smallness of the crew ; it would be very different if the monitor had to carry the number of men necessary to work a sailing cruiser. We have, however, abundance of evidence from the reports of officers, after a long experience with the American monitors, to prove that they are not well ventilated or comfortable. I have already given the opinions of Admiral Du Pont and the commanders of the monitor fleet at Charleston on their ventilation, if kept on outside blockading duty. The 'Monitor,' when engaged against Drew's Bluff batteries, had to drop down the river out of action, because of the exhaustion of the crew. The thermometer in the turret stood at 140 degrees, and the commander says that at the time of writing the letter one-third of his crew were suffering from debility. We have instances of the blowing apparatus becoming deranged, stopping the draught, and driving the crew on deck, and of great discomfort to the crew from leaks in the deck. In the officers' reports of the passage of the 'Monadnock,' we find the following passages:—"Sixteen of the firemen and coalheavers "have been removed from the fire-room in a state of "insensibility." And again, from another place, we find the commander writes:—"Seven men have been "removed from the fire-room in an insensible condition "from the effects of the heat."

A few facts respecting the fighting qualities of the American monitors, drawn from the reports of officers who served in them during the late war, will doubtless prove interesting, and will serve to illustrate some of the preceding remarks on the advantages and disadvantages of the turret system. I need hardly say that most of the services of these vessels consisted in blockading harbours and the mouths of rivers, and in attacking land forts. There were only two or three occasions on which monitors had to compete with Confederate ironclads of any pretensions. The first action fought by the original 'Monitor' in Hampton Roads has again and again been referred to as an incontestable proof of the superiority of the 'Monitor' to the 'Merrimac;' but the official accounts show that the 'Monitor' received considerable assistance from the wooden frigate 'Minnesota,' and that the 'Merrimac' only withdrew when her bow had been injured by ramming. These facts are the more remarkable when it is remembered that the 'Merrimac' was only an improvised and hastily constructed iron-clad, her armour being said to consist of railway bars, while the 'Monitor' was, with a few minor exceptions, in all respects a pattern vessel of the type to which she gave her name. The only other engagement to which I shall refer is that between the monitor 'Weehawken' and the Confederate casemated ship 'Atalanta;' and this certainly afforded no better information respecting the real merits of monitors as compared with broadside iron-clads. The 'Atalanta' was originally an iron merchant-ship, and when converted into an iron-clad, she was cut down to a foot or two above the water, and upon the low hull a casemated battery was built, armoured with two layers of bar iron, 2 or 2¼ inches thick, and 6 or 7 inches wide; in fact, it has been stated that the bars were made of English railroad iron rolled out flat. It is surely no wonder that such a structure should have been smashed in by the blows of the 15-inch shot from the 'Weehawken's' guns, especially when it is considered that the 'Atalanta' had unfortunately got aground on her way down to the Federal squadron; nor is it surprising that, under such circumstances, the fire from the 'Atalanta's' guns should have been almost ineffective against the 'Weehawken's' deck and turret.

Although our information respecting the capabilities of monitors as compared with other iron-clads is so meagre, the reports give full accounts of the engagements of these ships with the land fortifications at Charleston and elsewhere; and from these accounts it is, I think, possible to infer, with considerable accuracy, what effects would be produced on an American monitor by heavy guns well mounted, and worked on board an iron-clad engaging her. In the first attack on Charleston, seven monitors were engaged, and Admiral Du Pont, who commanded, states that in 40 minutes four of these ships were disabled either wholly or partially. In two ships—the 'Nahant' and 'Passaic'—the turrets became jammed, although in the latter it was got in motion again after some delay; in the 'Nantucket' the port-stopper became jammed, several shots striking very near the port, and driving in the plates, preventing the further use of the 15-inch gun during the action; and in the 'Patapsco,' the rifled gun could not be used after the fifth fire. In their joint report on this attack, the commanding officers of the monitors stated that, in their opinion, "it had been proved that any heavy "blow on the turret was very apt to disorder and stop "it," and "that the side armour and decks were pene-"trable." They also give a summary of the injuries received by the various ships, in order to justify their opinion that "it would have been out of the question to "renew the action the next day." I shall not go through this summary in order, but shall simply state that it entirely supports the views I have previously expressed regarding the danger of turrets being jammed by the driving inwards of base-rings or glacis-plates, and the liability to injury from shot entering or striking close to the turret ports.

In his report on the attack on Fort McAllister, Captain Drayton confirms the accuracy of the latter opinion, stating that "the gunners in the fort never "exposed themselves to the fire of the monitors; they "usually discharged their pieces either while the moni-"tors were loading or just as the port came in line, "and before the guns were quite ready; the turrets "being painted black not deceiving them any more "than a different colour had done on the first attack." This extract also shows the want of force in the statement that has been so often made respecting the great advantages resulting from being able to turn away the turret ports from an enemy while the guns are being loaded. Of course, this turning away of the ports does prevent the possibility of shot entering the turret through them; but at the same time the monitor's offensive powers entirely disappear, and an enemy can, if he chooses, pour upon her an unopposed fire while the turret ports are turned away; or he can reserve his fire, as the Confederate gunners did, until the turret has just been brought round into line, but while the guns are still unprepared to fire. This report also bears testimony to the vulnerability of the low decks.

One other report will suffice to show how American monitors can stand the fire of forts, armed, be it remembered, with nothing heavier than 10-inch and 7-inch guns. The second attack on the batteries at Charleston was made at night; but notwithstanding this fact, the monitors were often hit and badly injured, particularly on the decks, which in many cases were penetrated. Several of the turrets were more or less jammed; and in one case the turret-spindle was so deranged as to carry the pilot-house—which ought to have remained fixed—around with the turret, thus destroying the ship's steering apparatus, and disabling her. The opinion of American officers seems to be that turrets like those of the monitors are especially liable to be driven out of their proper position, which is perpendicular to the deck, by the spindles becoming bent when the turrets are struck by heavy shot.

Very similar consequences seem to result from the straining unavoidable in a seaway; and Mr. Eads, to whom I have before referred, says on this point:—"Experience has shown that the rotation of the turret is "greatly interfered with by the straining of the vessel "in a seaway; the slightest deviation from a perfect "plane in the form of the base-ring on which it rests "being sufficient to create enough friction to check and "sometimes prevent rotation altogether. The 'Mian-"tonomoh,' on her late cruise, is a case in point." I may add that, in some of the monitor turret-ships built in this country for foreign governments, similar accidents have occurred through the spindle of the turret becoming strained by the ship's rolling at sea, those in charge not having lowered the turret down upon its bed, as they ought to have done. The liability to such accidents has, as I have shown, the effect of practically destroying the fighting powers of monitors at sea, when the turrets are thus mounted on central spindles. With Captain Coles' arrangement there is not the same danger, as the turret is carried on a set of rollers fixed in a band at the circumference of the turret-base, and is simply centred on a spindle.

I will not further extend these remarks upon turret-ships. I have said sufficient, I hope, to indicate that if we have made a mistake with reference to the introduction into the British Navy of turret-ships, and especially of monitors, that mistake has consisted in adopting them too rapidly, rather than too slowly. At least there has been ample cause for the exercise of prudence and caution in introducing them.

CHAPTER XII.

IRON-CLAD RAMS.

SIMULTANEOUSLY with the introduction of armour-plating, numerous proposals were made for reviving the ancient method of naval warfare—that of disabling or sinking an enemy by ramming. It is true that some years before, when our wooden steam fleet was being constructed, some naval officers had turned their attention to the subject, and had insisted on the possibility of using our line-of-battle ships and frigates as rams; but for various reasons the idea was not worked out, and had passed out of consideration at the time when the iron-clad reconstruction was commenced. As soon, however, as the 'Warrior's' design was determined on, the matter again came into prominence, and that ship was, as I have said in another chapter, built in such a manner—with a ram stem inside the knee-of-the-head, and with internal strengthenings—as to render her capable of being employed as a ram. In all succeeding iron-clads, also, more or less efficient provisions have been made to strengthen the bows for the same purpose; and in this chapter I propose to consider briefly what, as far as our experience enables us to judge, are the best means for securing efficiency in iron-clad rams. I shall, as far as possible, inform the reader also of the conclusions at which naval officers in our own Navy, and in the navies of other countries, have arrived, giving special prominence, as is but right, to the opinions entertained by Austrian and American officers, both of whom have seen actual service.

It may be interesting to state, before passing on, that the greater weight was at first given to efficiency in ramming power on account of the fact that the $4\frac{1}{2}$-inch armour, carried by the earlier ships, was practically impenetrable to the 68-pounder gun, then the heaviest carried on the broadside. On this account the advocates of ramming contended that it was an absolute necessity to avail ourselves of the attacking power possessed by a ship in virtue of her weight and speed—a power which, when effectually employed, would suffice to cut down and sink even the most formidable adversary. Since that time, the power of the armaments of iron-clads has, as I have shown, been greatly increased; and it is only our most recent ships that are practically impenetrable to our 25-ton and 30-ton 600-pounder guns. But even now the argument in favour of making use of a ship's momentum, as one of the most important features in her powers of attack, remains in full force; and in all our recent ships care has been taken to provide such bows and bow-strengthenings as will enable them to inflict the greatest damage on an enemy without themselves receiving, it is hoped, any serious injury. The French have also fitted their iron-clads for similar services; but the fact that most of their ships are wood-built prevents the bows being so effectually strengthened as they can be in iron ships. In both our own and the French navies also, within the last few years, ships have been included which are designed specially for ramming, and therefore carry only one or two of the most powerful guns. The French led the way in this direction by constructing the 'Taureau;' and they have since put four more rams on the stocks, one of which, the 'Cerbère,' is now fitting, and the other three are still building. We have two such vessels now building —the 'Hotspur' and the 'Rupert'—which bear some general resemblance to the French rams, although they are differently constructed, and are of a less unusual form. All these ships depend upon their powers of ramming for the main strength of their attack, but are by no means incapable of fighting with their heavy guns at long ranges, and of engaging an enemy while steaming up to attack him. They are not to be rigged as sailing ships, although they will carry a small spread of canvas, but will really be steam war-engines capable either of delivering a tremendous blow or of manœuvring and fighting with their heavy guns. Ships like these attached to a squadron of iron-clads, or lying under easy steam in the Channel, or off one of our naval stations—say, off Gibraltar—would undoubtedly be of great value in time of war.

During the late American war, both sides availed themselves of this method of attack; and from official reports of Federal officers it appears that the Confederates produced some of the most extraordinarily shaped vessels for ramming that could possibly be devised, and which could only be used for service in rivers or harbours. Most, if not all, of the monitors also were strengthened for ramming purposes, and many of the engagements, particularly those that took place on the western rivers, were decided, not by artillery, but by ramming. The fact that the vessels used

in this contest, especially the Confederate ships, were comparatively weak, very slow, and not at all handy, prepares us for the conclusion to which a study of the reports of the war conducts, viz. that in most cases where such a ship was fairly struck by a ram she sank. It cannot, of course be assumed that with stronger, swifter, and handier ships similar results would be obtained; and American officers have been among the first to point this out; but the conviction of these officers with regard to ramming, after their experience in the war, may be fairly summed up in the words of Admiral Goldsborough :—
" Every iron-clad, as a matter of course, should be an
" unexceptionable ram; or, in other words, susceptible
" herself of being used as a projectile."

The engagement at Lissa affords more conclusive evidence of the great results that may be achieved by the proper use of this method of attack, especially in actions between sea-going ships. This engagement, as is well known, resulted in the total defeat of the Italian fleet, that defeat being in a great measure due to the excellent performances of the Austrian ship 'Ferdinand Max,' which rammed and sank the 'Re d'Italia,' and damaged other ships severely. The lessons to be learnt from these results I shall hereafter attempt to set forth.

In dealing with the question of ramming efficiency, it is most natural to consider the subject under two aspects: first, how best to construct and prepare a ship for inflicting the greatest damage upon an enemy with the least possible injury to herself; second, how best to manœuvre and work such a ship when in action. The first of these points is, of course, as much a matter of interest to the naval architect as it is to the naval officer; the second is peculiarly the business of the naval officer. I shall refer to both, treating the former at some length, and the latter only briefly, and shall strive to set forth, and to weigh fairly, the various opinions entertained on the subject.

In order that a ship may be efficient as a ram, it is obvious, first of all, that she must be *handy under steam.* The effect of the blow she can deliver is in a large measure dependent on the directness of her attack, and an oblique or glancing blow on an enemy's side might sometimes do as much damage to the ram herself as to the ship she attacks. When a vessel steams directly down upon a ship at rest, as the 'Merrimac' did upon the 'Cumberland' at Newport News, or upon a vessel which can only manœuvre sluggishly, as the 'Ferdinand Max' did upon the 'Re d' Italia' at Lissa, the attack by ramming can scarcely fail to be successful. But when an enemy is under way, and is perfectly under command of the steersman, there is much opportunity for her either entirely or partially to evade the attack of a ram, unless the latter is capable of being manœuvred much more rapidly.

All naval officers, and others who have written upon the subject, have recognised these facts. Admiral Warden, in his Report on the Channel Fleet for 1868, says:—"It is as clear as anything can be that, so long as "a ship has good way on her, and a good command of "steam to increase her steam at pleasure, that ship "cannot be what is called 'rammed;' she cannot even be "struck to any purpose so long as she has room, and is "properly handled. The use of ships as rams, it appears "to me, will only be called into play after an action has "commenced, when ships, of necessity, are reduced to a "low rate of speed—probably their lowest." It should be stated that Admiral Warden does not look so favourably on attack by ramming as some other officers, so that his remarks on the difficulty of effectually ramming a steamship are of great weight, inasmuch as they indirectly bring handiness in rams into the most prominent position. In his accompanying Report, Admiral Ryder goes fully into the discussion of this point in his answer to the question—"What class, in your opinion, "presents the greatest advantage for giving effect to "ramming or otherwise?" He decidedly prefers the short class exemplified in the 'Bellerophon' to the long class of which the 'Warrior' and 'Minotaur' are examples, and, in justifying this preference, says:—"The "short class is the handiest, and is therefore more likely "to hit the enemy if she is moving; to hit that part of "her which it is desired to penetrate; to hit her at "about the desired angle, so as to injure our own stem "as little as possible; to minimise the wrenching strain "on her stem, as this short class is more easily turned." This able summary requires, I think, no further remarks in order to enforce its important bearing on the point now under discussion.

It may be interesting if, to these opinions of English naval officers, I add an extract from the Report of the American Admiral Goldsborough. In speaking of the elements of efficiency in iron-clads, he says:—"Among these elements is that of celerity in turning, "and as it is a point to which sufficient attention has "not been given hitherto, I wish to impress my con-"victions in regard to it." Then, applying this to rams, he adds, respecting their success:—"This, how-"ever, cannot be the case unless they can be directed "with a great degree of promptness to any desired "quarter, or turned with every degree of quickness "necessary." Farther on he says:—"But to return to "the point of celerity in turning, no practical means, "in my judgment, should be neglected, more par-"ticularly in an iron-clad, to secure this cardinal "quality."

These are a few specimens of the opinions entertained by naval men respecting the necessity for handiness in iron-clad rams; the means of obtaining this facility of manœuvring next claim attention. The chief of these consists, as I have shown in preceding chapters, in the adoption of moderate dimensions and proportions, in combination with improved means of steering, and more especially with the use of balanced rudders. Having so fully illustrated the superiority in steering power of our short ships as compared with the 'Warrior' and 'Minotaur' classes, I need not do more than refer the reader to Chapter VIII., as he will there find the results of trials of turning, and some criticisms on the opinions which have been expressed respecting them. Without doubt, I am correct in saying that a large majority of the officers in our Navy are in favour of the change, which was inaugurated in the 'Bellerophon,' to shorter and smaller ships than had previously been in vogue as the types of first-class iron-clads, and that their preference is based upon the fact that recent ships are so much more manageable. If we compare the 'Warrior,' taking 9 minutes 10 seconds at full speed to go round a circle of 1050 yards diameter, with the 'Hercules,' which when turning to starboard at full speed took only 4 minutes —considerably less than half the time taken by the 'Warrior'—to go round a circle of only 527 yards diameter, it must appear that the shorter ship has a much better chance of striking an enemy fairly, or of avoiding a charge, than the long ship.

The reduction in dimensions here alluded to, of course, leads to a reduction in the force of the blow which the ship can deliver, supposing the attack to be made at the same speed and with equal directness, and it may be thought that this fact tells in favour of the longer and larger ships. No doubt there is some truth in this opinion, but there are one or two points requiring notice which considerably modify an estimate of its importance. For instance, it is scarcely reasonable to suppose that the longer ship could in general attack an enemy with a directness equal to that of the shorter ship, seeing that the latter is so much more readily handled. On this account oblique attacks are much more likely to result in the diminished force of the blows delivered by long ships than in those by short ships; so that on this account there will be much less difference, if there be any, in favour of the larger ships than their greater weight would lead one to anticipate. Besides this it is quite unnecessary to compare the attacking powers of two rams when the smaller one is able at a moderate speed to deliver a blow far heavier than is required to smash in the armoured side of any ship yet built or likely to be built. Taking, for example, a ship like the 'Rupert,' of about 5000 tons weight, and supposing her to charge an enemy at a fair speed, say at 10 knots per hour, the "energy" of the blow she can strike is measured by about 22,300 foot-tons; and we know from the trials at Shoeburyness that the 600-lb. shot from a 25-ton gun is capable of penetrating all the French iron-clads, for example, at a short range, although its "energy," when it leaves the muzzle of the gun, is only a little over 6000 foot-tons. What then must be the effect of the 'Rupert's' attack? and what would be gained by doubling her size and making her of 10,000 tons displacement, like the 'Minotaur,' even if the larger ship could be made to strike as fairly, which is, as a rule, out of the question? The blow struck by the heavier ship would obviously be heavier, but then it must be evident from the preceding figures that the smaller ship has a very large reserve of power, and that it is quite unnecessary to add to it, especially as in doing so we take away from her handiness. Admiral Ryder, in the Report from which I have already quoted, says with respect to the long and short iron-clads, represented by the 'Minotaur' and 'Warrior' on the one hand and the 'Bellerophon' on the other:—"Speed and "weight are, no doubt, of great importance in ramming, "but both classes have speed enough and weight "enough for the purpose."

The reader will, I think, be inclined to believe that this is really less than might be said on the subject; and that smaller ships than the 'Bellerophon' may be, and are, thoroughly efficient as rams. The Admiralty and the French authorities have both acted on these considerations, in designing ships like the 'Hotspur' and the 'Taureau,' which are essentially steam-rams, and which have ample ramming power in combination with good manœuvring power.

Among other means of obtaining increased handiness in iron-clad rams, the chief is the adoption of twin-screws, which increase a ship's manœuvring power considerably, and give her special facilities for turning in a small space—a matter of the highest moment in an action where many ships are crowded together. As far as our experience goes, it appears that the single screw has some advantage over twin-screws in point of speed attained, but it has the disadvantage of requiring greater draught of water, and giving less power to turn a ship upon her own centre without change of place. For these and other reasons, it has been considered desirable to give iron-clad rams twin-screws. In these ships—such as the 'Rupert' and 'Hotspur' in our own Navy, and the 'Bélier' class in the French navy—specially designed for ramming and but lightly rigged, there is another and most weighty reason for adopting twin-screws, viz. that the probability of their being disabled through accidents to their engines is much reduced. These ships, as I have said, are not capable of proceeding under sail alone, and, depending, as they do, on their steam-power for propulsion, it would obviously be bad policy to entrust their safety to one engine and one screw, when it is possible to have the separate engines and screws of the twin-screw plan. Even if one of the screws were disabled, the ship would still be manageable, and could proceed at a fair speed, as is shown by the fact that twin-screw ships often perform the greater portion of distant voyages with only one screw working, and are then perfectly under control. There can, I think, be no reasonable doubt, therefore, that, in adopting twin-screws to the extent they have, the Admiralty have acted wisely, in so far as the efficiency of our iron-clad rams is concerned.

Handiness being secured in an iron-clad ram, the next great object of the naval architect is to adopt the form and structural arrangements of bow best fitted for dealing a deadly blow on an enemy's side without itself receiving too serious damage. It is generally agreed that, at least in iron-built ships, ram-bows can be efficiently strengthened, and I shall revert to the arrangements made for this purpose in another part of this chapter. As to the proper form for ram-bows, there is not, however, the same unanimity of opinion. Some persons are in favour of a contour of stem which reaches forward above water, something like the knee-of-the-head in our wooden frigates and line-of-battle ships; others have expressed their preference for an upright or nearly upright ram-stem; but the majority are decidedly in favour of the under-water prow, spur, or *éperon*, which has been adopted to a greater or less extent in the iron-clads both of our own and of foreign navies.

The advocates of the overhanging, or fore-reaching, stem think that there is an advantage in delivering the blow above rather than under water; and that in ramming low-decked monitors, or ships having a small height of armour belt above water, there is a probability of over-running the enemy and making the weight of the attacking ship aid in sinking her. They also hold that there is not the same liability to danger by the bow becoming more or less "locked" in an enemy's side when ramming has taken place, as exists in a ship with a projecting under-water prow. I shall again refer to these opinions almost immediately, but may add for the reader's information that a statement of the advantages claimed for the fore-reaching stem will be found in a paper on "Naval Construction" read by Sir Edward Belcher before the Institution of Naval Architects in 1868, and since published in their 'Transactions.'

Those who advocate the upright, or nearly upright, ram-stem contend that the blow it is capable of delivering is not so local in its character as that delivered either by the fore-reaching or the *éperon* bow, and that on this account the smashing or damaging effect on an enemy's side is sure to be increased. The upright bow is also thought to be more readily disengaged from an enemy's side after ramming than the under-water prow, and to be less liable to twisting or wrenching. The latter is the consideration to which most weight has been attached, and I shall, therefore, direct particular attention to it hereafter. Amongst those who are in favour of the upright bow, I may mention Admiral Warden, who expresses his preference in the Report on the Channel Fleet for 1868, to which I referred above.

The *éperon*, or spur-bow, is intended to deliver a strictly local blow, the aim kept in view being rather to sink an enemy by penetrating the weak side below water than to smash in or otherwise damage the strong armoured side above water. In fact, in comparing this form of bow with either of the others, its great advantage consists in the greater penetrating power which it undoubtedly possesses. The armour of even the strongest iron-clads does not extend much more than 6 feet below water, and below this depth the ship's safety depends upon the comparatively weak planking, or plating of the bottom, remaining intact. The foremost point of the projecting prow, in ships with spur-bows, is situated about 7 or 8 feet below water, and is consequently in the best possible position for penetrating the weak side below the armour, before meeting with much, if any, resistance from the stronger armoured portions. It must, then, be obvious that the force required in order to make this kind of bow effective in sinking or severely injuring an enemy will be much less than is required to make either of the other forms equally effective, supposing such a result to be possible. This is an important feature, for a ram may be so situated as to be unable to gather much speed before the attack, or to avoid attacking obliquely, instead of directly, but may still have power enough to break through the side below the armour, while powerless, or almost powerless, against the armoured side. A large hole below water in a ship's side must inevitably lead to her loss, unless some special provisions, in the way of water-tight divisions or compartments in the hold, have been made; and I need hardly say that adequate provisions have not been made in most iron-clads, while the shock of a collision may be expected to greatly disarrange and damage any but the best arrangements of the kind. It is not unreasonable to expect, therefore, that a well-executed charge by a ship with a spur-bow must prove a source of great, if not fatal, damage to the ship attacked, and that very serious results will follow even from a blow possessed of but moderate force.

Another advantage which the spur-bow has is its extreme adaptation for damaging an enemy's rudder, or screw. Both rudder and screw are perfectly secure, in modern ships with full pink sterns and overhanging counters sheathed with armour, against injury from an upright or fore-reaching stem; but even a light touch of the under-water spur, which is exactly adapted for passing in under the counter, would suffice to disable the finest single-screw iron-clad in the world, and place her at the mercy of her foe.

The other forms of ram-bow do not, I repeat, possess the foregoing advantages. A fore-reaching stem, whether striking amidships or abaft, must encounter resistance from the armoured portion of the side, and the ram must be moving directly down upon her enemy at a good speed in order to inflict serious damage. The unarmoured upper works of a ship with an armour belt may, it is true, be swept away by a moderate blow; but the loss of these will not at all affect the ship's safety, and but little interfere with her fighting efficiency. The over-running of an enemy, to which so much importance is attached, would certainly require a rapid attack, except perhaps in the case of monitors of the American type, with extremely low freeboard; but even in the case of these vessels it seems a much more certain means of destruction to penetrate the thin side, and to trust to the in-rush of water to sink the ship, than to rely mainly upon the super-position of the weight of the ship upon the monitor for that purpose. The margin of buoyancy is so small in these ships that a leak of only moderate amount becomes important, and the cases of the 'Weehawken' and other monitors prove that a comparatively small hole in the side below water would suffice to sink them. The 'Weehawken,' in spite of the efforts made to save her, went down at her moorings in a few minutes; the 'Tecumseh' was sunk by a torpedo in about four minutes; and the 'Patapsco' is said to have sunk one minute after being struck; while the original 'Monitor' went down in consequence of the sea washing over and into the turrets, and through the junction of the turret with the deck. These losses, resulting from the admission of the sea into the ship, I think, leave no doubt as to the efficacy of the spur-bow as compared with the fore-reaching bow even when monitors are the objects of attack. I am aware that it has been stated that the overhang of the armour and backing on the sides of monitors would prevent the spur from reaching and striking the thin sides of the ship. There can, I think, be little doubt, however, that, in most cases, a charge by a ship with a spur-bow against a monitor would tend to lift the side of the latter somewhat, and thus render the penetration of the weak portions possible; and the bows of our recent ram-vessels are of such a form as to entirely do away with this objection, as they can pierce the side of any monitor afloat without coming in contact with the overhanging armour. It will also be clear, from the drawings and description of American ships given in Chapter II. (on Armour), that their customary mode of greatly reducing the thickness of the armour at a very small depth below water, tends to render it still more probable that the spur-bow would be most effective.

The upright, or nearly upright, bow has more numerous supporters than the fore-reaching bow, and it has been adopted in several of our iron-clads, such as the 'Achilles,' the 'Minotaur' class, and the converted ships of the 'Caledonia' class. The French also adopted it in their earlier iron-clads, but, like ourselves, have since deserted it in favour of the spur-bow. The reasons for this desertion will, I think, be regarded by the reader as amply sufficient when he considers the merits of the two forms. The very advantage claimed for the upright bow—the non-local character of the blow it delivers—is undoubtedly a serious disadvantage; for an attack concentrated upon a limited area must, with a given attacking force, be more effective than one distributed over a considerable area. Nor should it be forgotten that the force of the blow delivered by an upright bow is, for the most part, distributed over an area of the armoured side; whereas the spur-bow, as I have said, inflicts injury upon a smaller area of much less strength. The proportion of the force of the blow struck to the strength of the side which resists it is, therefore, enormously greater in the latter than in the former kind of bow. If it be true, as I think most persons will admit, that the *ne plus ultra* of ramming efficiency consists in the capacity to sink an enemy, there seems to be no good ground for maintaining the equality, much less the superiority, of the upright bow as compared with the spur. There can be no doubt that, if a powerful iron-clad ram, with an upright bow, came down at a good speed directly upon the broadside of an enemy, she would inflict injury of so terrible a character as usually to occasion the loss of the ship attacked; but in action it might well happen that a ram could not ensure either a swift or a direct charge, and on this account the form of bow which does the greatest damage with the least force must be considered the best.

The experience of the Americans may be referred to as proof of the efficiency of the upright ram-bow, and a few words on this point may be of interest. In most of their monitors the ram consists of a wedge-shaped prolongation of the overhanging side armour and backing beyond the hull proper, the structural arrangements being made to conform as much as possible to the necessity for unusual strength. This was the readiest means of making these vessels available as rams, and in them had special advantages connected with raising the anchors, &c.; but it must not therefore be regarded as the best means, and was not so regarded by the Americans themselves, who, in the 'Keokuk,' 'Dunderberg,' and other vessels, adopted bows approximating more or less closely to the spur shape. That the monitors did good service is not for a moment disputed, but it is necessary to remark that little or nothing respecting the merits of their form of ram-bow can be applied to the present discussion. The monitor ram was upright, and it struck an enemy's side on the armour close to the water-line, the blow being distributed over a depth of five or six feet; so far, therefore, the conditions resembled those we have been considering. But the ships which were attacked in this manner, and in most cases sank, were not to be compared in structural strength with most European ironclads; and from the effect produced upon them by a ram of any form whatever it is impossible to infer anything respecting the damage that would be done to such ships as the 'Minotaur,' 'Bellerophon,' and 'Hercules.' One point appears clear, however, from the reports of the losses of ships by ramming, viz. that in many cases the hulls were so weakly built as to be made to leak seriously by the vibration caused by the shock, even when the parts struck were not penetrated, nor seriously injured. We know that in some of the monitors themselves the strains of a coasting voyage were sufficient to cause leaks of great magnitude, and it requires no argument to show that ships thus weak themselves, and moving at such low speeds, could not have been formidable as rams against any but hastily constructed ships like those of the Confederates. I need only add that the latter in many of their rams adopted the under-water prow, but so imperfectly were these vessels constructed and strengthened, owing to their hurried building and the limited means possessed by their builders, that they often sustained serious damages in inflicting injury on an enemy. The 'Merrimac,' for example, with a wrought-iron or metal cleaver upon her bow, did good execution among the Federal fleet at Hampton Roads, but was at length obliged to retire on account of the injury sustained by the ram-bow. On the whole, then, I do not think American experience can be regarded as affording any evidence of the merits of any form of bow.

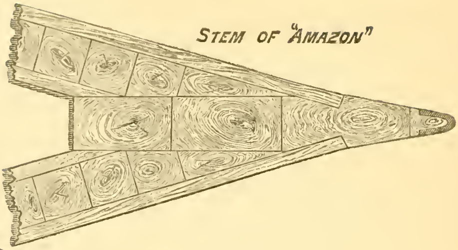
Having contrasted the merits of the spur-bow with those of the other two forms, I pass on to notice the disadvantages which have been said to be connected with this form. The chief of these assumed disadvantages consists in the difficulty that would be experienced in disengaging a spur-bow after ramming an enemy, and the danger that would exist of such a bow being twisted or wrenched off. Both of these points have been brought very prominently forward by the opponents of this bow, and have been considered by some sufficiently weighty to justify its rejection. I shall therefore attempt to show how far these opinions are justified by the few facts in our possession. With respect to the difficulty of disengaging this bow from an enemy's side, I may remark that, so far as my information extends, no such difficulty has ever been experienced in actual warfare; in fact, judging from the action at Lissa, this difficulty does not exist. The 'Ferdinand Max,' which has a bow of this form, sustained no serious injury from the effect of her four collisions, one of which had caused the loss of the 'Re d' Italia,' which went down so rapidly as to test most thoroughly the capacity of the ram to disengage herself from the sinking ship. It is, of course, within the bounds of probability to suppose that a ship may by some extraordinary combination of circumstances become locked to the vessel she has rammed, and be endangered; but experience warrants us rather in believing that, when an iron-clad ram is properly handled, her engines being reversed as soon as the blow has been delivered, no difficulty will be experienced in clearing the sinking ship.

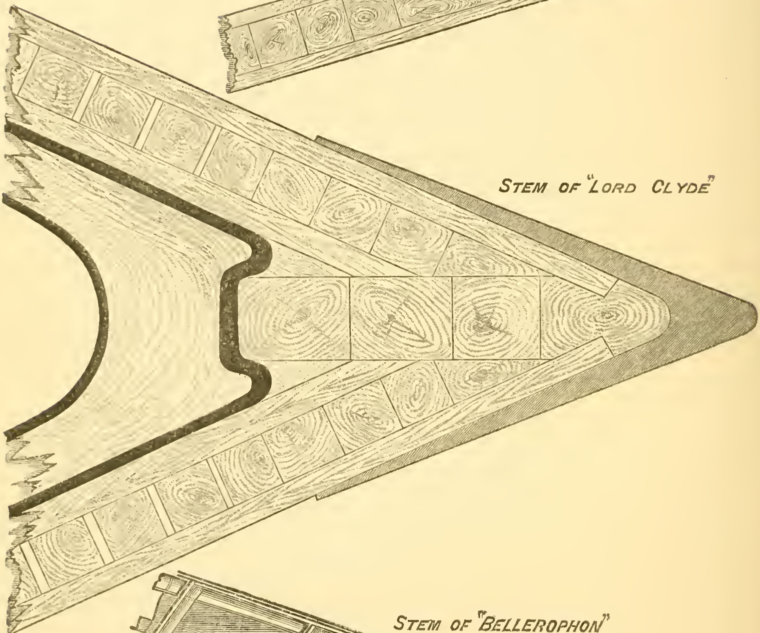
Next, as to the danger of injury to a spur-bow by twisting or wrenching taking place. Those who consider such danger probable have supported their opinion by reference to the loss of the unarmoured wood sloop

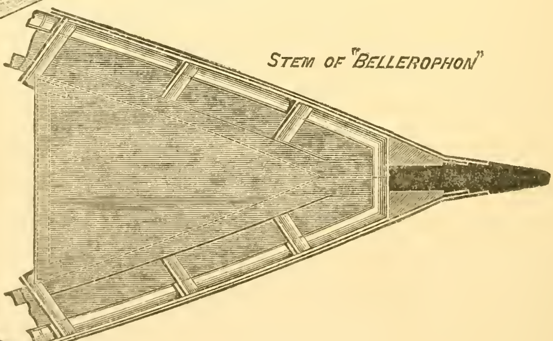
'Amazon,' which sank after coming into collision with the merchant steam-ship 'Osprey'—an example which, I shall proceed to show, has really no bearing on the matter. In order to do this, I must state a few facts respecting the 'Amazon,' and this is the more needed as statements of a most mistaken character have been repeatedly put forward as the bases of arguments on the proper forms of ram-bows. This ship had a stem very similar in its contour to that adopted in our iron-clads of recent date, but without any actual point or spur, being merely curved like a swan's breast. This form was not in any way connected with an intention to use the ship as a ram, nor was such an idea ever entertained. The profile of the stem was really adopted because it favoured the use of fine horizontal sections, or water-lines, in combination with U-shaped transverse sections at the bow, by which combination the fineness of form requisite for good speed was associated with the amount of buoyancy required to render the ship's pitching and 'scending motions easy. The intentions of the designers in both these respects were more than realised in the actual performance of the ship, but as the idea of employing her as a ram was, as I have said, never entertained, no means whatever were employed to specially strengthen the bow, which was constructed just in the same way as it would have been in another wood ship with the ordinary contour of stem; in fact, I have in my possession the original memorandum upon the authority of which I designed this vessel, directing the adoption of the form of bow, *not* for ramming purposes. One other fact requires to be mentioned, viz. that, in order to prevent the projecting wood prow from being chafed by the cables when the ship was riding at anchor, it was thought desirable to put on a thin metal casing on the front of the wood stem. This casing, I need hardly say, added nothing to the strength of the bow.

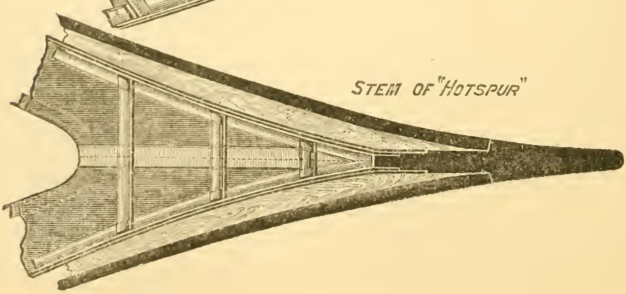
It is on the loss of a small lightly-built sloop of this kind—neither built nor strengthened for ramming purposes—by the twisting of her light false stem, and the opening of her bow planks through collision with an iron vessel moving across her bows at a good speed (said to be 9 or 10 knots per hour), that the very decided condemnations of the spur-bow to which I have referred have been based. On the face of the matter, however, it must appear that it is absurd to argue from the 'Amazon's' case to that of a bow built for ramming, and to consider that case as more conclusive of the merits of the spur-bow than the experience had with the real ram-vessel 'Ferdinand Max,' not in an accidental collision, but in actual warfare. There can be absolutely no sort of comparison made between the strength of ram-bows like the 'Lord Clyde's' and the 'Bellerophon's,' or the 'Hotspur's,' and the weak bow of a small wood sloop, even though the contours of the stems may be somewhat similar. That this is so will be evident even to the non-professional reader if he refers to the accompanying drawings, which show sections, on the same scale, of the bow of the 'Amazon' and the ram-bows of the three ships just named. No remarks are needed to give additional force to the comparison.

It is only necessary to observe that the parts shown in black are of *solid iron*.


STEM OF "AMAZON"


STEM OF "LORD CLYDE"


STEM OF "BELLEROPHON"


STEM OF "HOTSPUR"

No doubt it is the fact that the 'Amazon' had the swan-shaped contour of stem given to her for the reasons assigned above which has misled many critics, and particularly those foreign writers who have referred to the subject. Admiral Paris, for example, who is so well known as a writer on naval architecture and the associated sciences, says of the 'Amazon's' bow:—"The most remarkable part of this ship is the "bow, which, although the vessel is unarmed, is of "the same form as that adopted in the English iron-clad "frigates, and projects forward under water like the "prow of the 'Bellerophon,' and is doubtless intended "for ramming ships of equal size with the 'Amazon.'"* The assumption here made is, I need hardly say, an altogether mistaken one, as is also another which the same writer makes soon after, that "the iron-clads have "not stronger prows (than the 'Amazon'), since they "are placed below their armour, and consequently are "similarly constructed whether there is or is not "armour." To compare the 'Amazon's' bow with the 'Lord Clyde's' is not more reasonable than to compare a walking-cane with the pike of one of Cromwell's Ironsides.

A still more striking instance of the mistakes made respecting the 'Amazon's' bow is found in the Report, on "Munitions of War," of the United States' Commissioners at the Paris Exhibition in 1867. Speaking of the 'Amazon,' they say †:—"Here, *en passant*, let us for "a moment consider the loss of this vessel in connection

* 'L'Art naval à l'Exposition universelle de Paris en 1867.' Paris, Arthus Bertrand. *See* page 134.

† *See* page 249 of the Report. London, E. & F. N. Spon, 1868.

"with the ram principle of attack. The 'Amazon,' it "is true, was a wooden ship, but she was fitted with a "projecting prow, *armed with a strong cleaver of cast* "*brass for the purpose of being used as a ram if occasion* "*required.** If she was, comparatively speaking, a small "ship of war, the vessel she ran into was only a small "coasting steamer of less than half her tonnage. Hence "it is reasonable to conclude that the projecting prow "of the 'Amazon' was as formidable to the 'Osprey' "as that of the 'Bellerophon' would be to the 'Mian-"tonomoh,' and that it would, in proportion to the "weight of the ship, be as strong as the prows of iron-"built and iron-plated ships generally." After the brief statement of the real facts of the case given previously, I feel sure that no further remarks are necessary in order to demonstrate the errors of description and deduction contained in this quotation; but I cannot forbear noticing the ingenuity which converts the thin metal casing, which protected the wood stem from the chafing of the cables, into "a strong cleaver of cast "brass," and the bold assertion that the ship was intended to be "used as a ram if occasion required." Such remarks are, however, beneath further notice, having absolutely no relation to the practical construction of iron-clad rams.

Not only have foreign writers fallen into these mistakes, but there are a few English naval officers and shipbuilders who have also joined in the belief that the loss of the 'Amazon' finally settles the merits of the projecting prow for ramming; and the phrase "Amazon

* The italics are mine.

"fashion" has been employed more than once to give full expression to the probable effect of a collision upon the strengthened ram-bows of our recent iron-clads. All such opinions obviously rest on fundamental misconceptions with respect to the purposes intended to be served by the 'Amazon,' and the construction of her bow, and require no answer additional to that given above. While maintaining, as I have done, that the 'Amazon's' loss does not render it in the least likely that a similar accident would happen to an iron-clad ram with a spur-bow, I admit most freely that, if a ram attacks a ship which is moving ahead at a good speed, there will be some danger of the ram-bow becoming twisted. It is also evident that in a prow which projects forward under water for a very considerable distance, the liability to twisting is increased, especially when this contour of stem is associated with very fine water-lines. In our iron-clads, however, the prow does not project to anything like a dangerous extent, nor is there such fineness of form as to prevent a proper amount of lateral strength being given to the bow. When ships are engaged in a general action, they are nearly sure to be moving at only moderate speeds, and on that account also the danger to the ram-bow is rendered less; in fact, with proper care there seems no reason to suppose that the danger is at all considerable. At Lissa, on one occasion, the 'Ferdinand Max' is said to have struck a ship at an angle of nearly 50 degrees in consequence of the attempt made by the enemy to avoid the charge; but, as I have said, no serious injuries were inflicted on the ram-bow. This satisfactory result was no doubt due to the great care taken on board the Austrian vessels throughout the engagement to put the helm in such a position at the moment of striking an enemy as would prevent the ram from turning to port or starboard and wrenching or twisting her bow. This simple precaution would not, I am sure, be overlooked by any naval men under similar circumstances, while the experience had at Lissa shows it to be amply sufficient.

One other point in connection with the spur-bow demands brief notice, viz. the now notorious bow-wave which it causes, and which some persons consider to be so prejudicial to a ship's steaming capability, and to the power of fighting her bow guns, as to make it desirable to do away with this form of bow even if it were the best adapted for ramming. It is the great stress laid upon these points which has led me to mention the subject, for obviously they are quite independent of the merits or demerits of the bow as far as ramming only is concerned. I shall therefore content myself with stating that, in view of the steam trials made with ships having spur-bows, it may be asserted that no serious falling-off in performance has been caused by the bow-wave. When a ship is steaming at great speed against a head-sea, the bow-wave may, no doubt, at times, render it difficult or even impossible to fight chase guns in bow batteries on the main deck, but the upper-deck guns would never be similarly affected. At moderate speeds in rough water, or at full speeds in smooth water, the bow-wave is not at all likely to reach such a height as to interfere with the working of the main-deck guns, and as general actions are sure to be fought at low speeds, there is no reason to anticipate that the fighting efficiency of ships with spur-bows will be at all affected by the wave at the bow. In heavy seas, with any form of stem, main-deck bow-guns will be swamped if the ports are kept open, but under such circumstances the form of the stem has but little effect.

These remarks on the proper form for ram-bows have unavoidably run to some length; but I shall be very brief in my statements respecting the almost equally important subject of the proper modes of constructing and strengthening such bows. This is a subject to which great attention has been paid by both French and English shipbuilders, all of whose efforts and plans may be said to have, in the main, two objects: first, to provide such longitudinal strength at the bow as to prevent its deformation by being driven inwards in the direction of the vessel's length; second, to provide such lateral strength as to prevent the bow from being twisted or wrenched. Besides these objects, there has also been kept in view, especially in iron ships, the desirability of adding to the ship's safety by dividing the bow into numerous watertight compartments.

Wood-built iron-clads can be made very efficient as rams by bolting strong timbers and iron straps, placed in a longitudinal direction, upon the inside of the hull proper, and thus supporting the bow; while the stem in such cases is usually armed with an iron or metal "cleaver" strongly bolted to the outside of the ship. This is the kind of arrangement carried out in the 'Lord Warden,' 'Lord Clyde,' and some other wood ships in our own Navy; and it has been adopted also in many of the French iron-clads. In fact, all the French vessels specially intended for ramming, such as the 'Bélier,' 'Boule-dogue,' and 'Taureau,' are wood-built, their efficiency as rams consequently depending mainly upon the solidity of the timbering used to strengthen the bows and the massive spurs or cleavers on the stems. Whatever degree of efficiency may be attained in such bows by means of elaborate and weighty strengthenings, it cannot be expected that they will equal the ram-bows of iron-built ships, and I shall attempt to show why this is so. First of all, the materials and fastenings in a wood-built bow are of such a character that some amount of injury—as, for instance, the starting of bolts, opening of butts of plank, tearing of stem, &c.—is nearly sure to be caused by ramming, and more or less extensive leaks will often result, against which it is scarcely possible to make sufficient provision. On the other hand, an iron-built bow has a solid mass of wrought iron for a stem, which is well backed up by the armour, the sides, and the longitudinal frames (of which the strength is immense), so that the only damage to be apprehended is that the comparatively thin side plating will be broken through; but even then the space inside is so cut up by watertight partitions, which also contribute to the strength of the bow, as to render the liability to danger from the inflow of water very small indeed. Any one who has studied the construction of the bow in such a ship as the 'Bellerophon'* will, I am sure, agree with me in the opinion that either the force required to drive the bow in and to fold up the immensely strong

* Full particulars and detailed drawings of the bow of this ship are to be found at pages 117 and 118 of my work on 'Shipbuilding in Iron and Steel.'

longitudinal girders that abut against the stem, or that required to twist or wrench off these same girders in the manner described above, would be immense; and that, even if a part of the bow were torn away by a collision, the ship's safety would remain almost untouched. In such a bow the great principle of combining lightness with strength is fully exemplified; for instead of having the heavy wood logs and the iron braces required to strengthen the bow of a wood ship inside the framing of the hull proper, we have the framing of the hull itself made to give longitudinal and lateral strength to the bow of the iron ship. Hence, although weaker, the wood ship's bow is heavier than that of the iron ship, and I need hardly say that excessive weights at the extremities are very objectionable, since they tend to produce both pitching and straining. This is another aspect of the advantages resulting from the use of iron for the hulls of iron-clads instead of wood, and one which gives additional force to the remarks made in Chapter IV.

The preceding summary, brief though it be, will, I think, convince the reader that in strength of bow our iron-clad rams are not deficient, and that our iron-built ships such as the 'Bellerophon,' 'Hercules,' 'Hotspur,' and 'Rupert,' would probably stand the shock of a collision very satisfactorily. In ramming, as in artillery, the force spent in breaking up or injuring the projectile is so much lost from the amount that should be expended on the object of attack. To render the attack most effective, therefore, the ram-bow must approximate most nearly to a weapon little liable to injury, and this condition is best attained by adopting the arrangements possible in an iron structure. It may happen that the thin side plating below the armour will receive some damage and be broken through, but this is no cause for anxiety; and in our recent ships, the 'Hotspur' and 'Rupert,' the armour has been carried down over the bow to such a depth as renders accidents of this kind very improbable, while it admits of enormous support being given to the ram-stem.

Hitherto I have almost exclusively dealt with the provisions made to secure offensive power in iron-clad rams; but it is obvious that provisions also have to be made in these ships in order to render them capable either of avoiding the charge of another ram, or of being but little endangered by it. Under this aspect also handiness is the great essential, and all the means of securing it referred to in the earlier portions of this chapter are, as I have said, quite as applicable to avoiding a charge as they are to delivering an effective blow. In fact, there can be little doubt that a ship possessing good manœuvring power, and being well handled, could, as long as she kept moving at a moderate speed, at least avoid being dangerously injured by ramming. But even if she were struck, unless the blow were delivered directly, and at a very high speed, one of our iron-built iron-clads would still, in all probability, remain comparatively efficient, as the penetration of the side and the entrance of water into the ship would not involve anything like the serious consequences which would result in a wood ship, or in iron ships built on the ordinary plan. This superiority in our iron-built ships is due to the fact that, with one or two exceptions, they have a strong longitudinal watertight skin of iron, situated at a few feet inside the bottom plating, and extending from the ship's bilge up to a considerable height above water. In fact, this longitudinal partition, or bulkhead, shuts in a space on each side of the ship into which the water may enter freely when the outside plating is broken through by a ram, but the passage of the water into the hold of the ship is rendered impossible so long as the partition remains intact. The watertight space, or "wing," on each side of the ship is also subdivided by numerous transverse partitions so that the water which enters through a hole in the side is really limited to a space about 20 or 25 feet long, and can therefore be of but inconsiderable amount. The situation of the inner plating here referred to (usually styled in technical language the "wing bulkheads") is such as to give special protection to the ship "between wind and water," just where the attack of a spur-shaped bow would be made. This is a point worth notice, especially as there is not a corresponding provision in the iron-built ships belonging to other navies, except in some of those built in this country, nor can there be so satisfactory a provision in wood-built ships. It is this fact which gives special weight to the remarks previously made on the advantages of the projecting underwater prow as applied in our ships.

The direct and swift attack of an iron-clad ram on the broadside of one of our iron-clad frigates would undoubtedly smash in not only the outside plating but the "wing bulkhead" also, and then the water would have free access to the hold. Such a result is scarcely probable, unless the iron-clad attacked became unmanageable by the loss of her steering power, or was charged by a much handier ship, with a very projecting prow; but since it is possible, it is only proper to consider the consequences. Even if the side were thus broken through, any one of our iron-built ships would most probably remain afloat, although her efficiency would be considerably impaired, the water which would enter being confined to the watertight compartment of the hold, enclosed by bulkheads crossing the ship at a moderate distance before and abaft the part broken through. In fact, under these circumstances, the ship struck would be in exactly the same condition as an ordinary iron ship which by any accident has had the bottom plating broken, and one of the hold-compartments filled with water, so that we have good reason to believe that her safety need not be despaired of, unless, by the blow being delivered at, or very near, a bulkhead, more than one compartment should be injured and filled. All iron ships can thus be protected to some extent against being sunk by a single blow of a ram, and our own vessels have the further and important protection of the watertight wings just described; but wood ships are not similarly safe. One hole in the side of the 'Re d' Italia' sufficed to sink her; but this would scarcely have been possible in an iron ship with properly arranged watertight compartments. The French, in their latest iron-clads, have become alive to this danger, and have fitted transverse iron bulkheads in the holds of wood-built ships in order to add to their safety. No doubt this is an improvement, but our experience with wood ships leads us to have grave doubts whether these bulkheads can be made efficient watertight divisions in the hold, on account of the working that is sure to take place in a wood hull. This fact adds another to the arguments previously advanced in favour of iron hulls for armoured ships; for it appears that an iron-built ship, constructed on the system of our recent iron-clads, is comparatively safe against destruction by a ram, unless she is repeatedly attacked when in a disabled state, while a wood-built ship may, and most likely will, be totally lost in consequence of one well-delivered heavy blow.

Before concluding this chapter, I desire to touch briefly upon the subject of the manœuvring and working of iron-clad rams in time of action, a subject which is of special interest to the naval officer, and which really belongs to him mainly, but in which the naval architect and the marine engineer also have a share. The officer in command of a ram would undoubtedly require to exercise his judgment as to the best speed, direction, and place of attack upon an enemy's ship, and success would for the most part be dependent upon the correctness of his decision. There are, however, some points of importance which are sure to require notice in all, or nearly all, attacks by ramming, however different the circumstances attending the attacks may be, and to some of those it may be of interest to refer.

The first of these matters is the necessity for arranging and securing everything on board liable to derangement by the shock, in such a manner as to prevent serious injury. Most of our iron-clad rams are, it will be remembered, rigged, and in them it would consequently be proper to take precautions, such as running in the bowsprit (which can be done in all the ships) and clearing the head-gear, sending down the topgallant masts and as many of the upper yards as possible, and securing the spars which remain aloft in the best possible manner by preventer stays, &c. In the 'Hotspur' and 'Rupert,' these preparations would not be required, as they are only lightly rigged, and it is hardly necessary to repeat that these ships may be regarded as steam war-engines, always cleared for action. I may mention in this connection, as a proof of the necessity for these preparations in a full-rigged ship, that the Austrian line-of-battle ship 'Kaiser,' which went into action at Lissa without having been prepared for ramming, but which did resort to that mode of attack, lost her foremast and bowsprit in attacking some Italian vessels. Besides these preparations, it is also necessary to look well to the stowage of anchors, boats, and other heavy articles on board; to train the guns in such a manner as to render them least liable to being dismounted when the shock comes; to secure the engines and boilers against displacement (arrangements for which are made in the original construction and equipment of our ships) or injury by the shock; and to take such precautions as to prevent any temporary derangement or stoppage of the machinery being caused by the water in the boilers being forced by the shock into the steam passages and cylinders. These are a few of the principal precautions which would have to be taken in all cases before an attack is made, and I may add that the crew should be so placed as to feel the shock as little as possible—either by lying on the deck, or swinging by their hands from the beams of the deck above, as was done by the Austrians—and to be out of the way of any heavy stores that may be dislodged by the blow.

So much for the preparations on board the ram-vessel; a few words will suffice respecting the mode of attack likely to prove most efficient. A fair speed is necessary for two reasons: first, in most cases an attack to be most effective must be direct, and, when charging an enemy not disabled, a direct attack must partake somewhat of the nature of a surprise; second, a fair speed is requisite to give proper effect to the blow. With a spur-bow which strikes an enemy's side below the armour, it is possible, as I have shown, to inflict great damage with a very moderate force, and in such cases it might be thought desirable to attack at a low speed; but it must not be overlooked that a direct attack should be the great aim kept in view, and that a very slow rate of approach would usually militate against the attainment of this object. On the other hand, it must be confessed that there is great truth in Admiral Ryder's remark,* that "any more momentum "than is necessary to pierce to a vital point only tends "to more seriously injure the bow of the rammer;" and it appears from Austrian accounts that the 'Ferdinand Max' was not steaming 8 knots per hour when she delivered the blow that sunk the 'Re d' Italia.' On this point of speed, as I said before, the officer in command of the ram is by far the best judge, and its decision must be left in his hands. At whatever speed the ram attacks, however, it is obvious—and the experi-

* Report on Channel Fleet for 1868, page 13.

ence of Lissa shows it to be true—that the engines should be kept going up to a very short time before the blow is delivered, but that at the time of striking they should be stopped; while they should be reversed directly after striking an enemy in order to disengage the ram-bow. Reference has previously been made also to the care required at the ship's helm at the moment of impact, in order to prevent the bow from being twisted or wrenched violently, and this constitutes the only other feature of importance to which I shall here draw attention.

Up to the present time our experience with rams is but limited, but this is almost equally true of all iron-clad ships of the European types, the action at Lissa forming the only reliable evidence we have of both the fighting and ramming powers of these ships when engaged in a general action. Whether or not ramming power will eventually take rank before armament in our iron-clads it is impossible to foretell. Very decided opinions have been expressed on both sides of this question, but a series of real engagements between well equipped and efficient iron-clads can alone afford a proper solution; and in the absence of such a solution—which no one can desire—we cannot, I think, do better than perpetuate the policy that has guided the Admiralty thus far. If so, the greater number of our ships will remain well armed fighting ships possessing ramming power, so to speak, as an auxiliary; and a less number will be built in which the ramming efficiency is the main feature, but which, like the 'Hotspur' and 'Rupert,' will be armed also with a small number of very heavy guns. Even now, it may with justice be asserted that some of our iron-built broadside iron-clads are the most formidable ram-ships afloat, and there need be no fear that our specially constructed rams will require to avoid the presence of any other vessels of the kind either building or built. Much remains to be learnt, no doubt, on this subject, and many improvements may be made in the course of a few years, especially if our experience is added to by any naval war; for the present, however, we may rest assured that in ramming power our iron-clad fleet is, to say the least, more than equal to that of any other navy in the world.

CHAPTER XIII.

CONVERSION OF WOODEN LINE-OF-BATTLE SHIPS INTO IRON-CLADS.

WHEN the reconstruction of our Navy was commenced about ten years ago on the introduction of armour-plating, our wooden steam fleet had been brought to a very efficient state, and in all the dockyards line-of-battle ships and frigates of the most improved type were in process of construction. The Admiralty, recognising the importance of quickly creating a considerable iron-clad fleet, ordered that several of the line-of-battle ships, then building, should be modified and converted into iron-clad frigates. As the result we have the class of ship to which I have given the name 'Caledonia' class in the preceding chapters, and which can well compare with the 'Gloire' and 'Flandre' classes in the French navy. Having in various parts of the preceding chapters had occasion to refer to the construction and performances of these ships, I need add nothing here beyond the statement that, considering the exigencies of the time when they were produced, and the great success which has attended their conversion, there can be no doubt that the course adopted was, on the whole, the best.

But though the partly built line-of-battle ships were thus, with a few exceptions, economically utilised as iron-clads, the large number of line-of-battle ships completed and afloat could not with economy be similarly treated. The 'Caledonia' class were considerably lengthened and otherwise altered from their original designs as two-deckers, besides having their upper decks omitted, and being thus turned into frigates. Similar changes would have been very costly if carried out in ships that had already been completely built and finished. Hence arose the question, Would it not be advisable to devise some scheme by which the wooden steam ships, having their machinery on board, could be turned into iron-clads? Of course, on the face of the matter it was evident that such a conversion could be made by removing more or less of the top weight of these ships, reducing their height out of the water, and putting the weight thus saved into armour for the whole or part of the exposed portions of the hull that would remain. Such conversions might be carried out either in accordance with the broadside or turret systems of armament; in fact, we have in our Navy examples of both methods, the 'Zealous' having been converted as she stood into a broadside iron-clad, and the 'Royal Sovereign' being a converted turret-ship. Either of these conversions could be repeated, of course, in other line-of-battle ships, and it is highly probable that, if a prolonged war should occur, many of these ships would be razeed and plated with a few strakes of armour. It is, however, in connection with the turret armament that public opinion has mostly been drawn to schemes for conversion, since that system can, it is supposed, be well associated with extremely low free-board; and most of these schemes have been intended to produce a class of vessels specially fitted for coast defence. In the following remarks, therefore, I shall for the most part confine attention to the feasibility and propriety of turning our line-of-battle ships into monitors; but it must be clearly understood that these ships could, if it were thought fit, be turned into broadside iron-clads, and that most of the arguments advanced will apply with equal force to both classes of converted ships.

The 'Royal Sovereign,' to which I have just referred, was originally a three-decked line-of-battle ship, but in 1862 was cut down to a height of about 7 feet above the water, her upper, main, and middle decks being removed, and the weights thus saved, together with those due to the very large reductions made in masts, sails, anchors, cables, coals, and general equipment, were replaced by the side armour, the plating on the deck, and the turrets. This conversion, allowing 12½ per cent. on actual expenditure for incidental charges, cost about 150,000*l.* in addition to the first cost of the vessel, and as the result a ship was obtained which, while valuable for coast defence, is not fitted for anything but Channel service. In this ship, it is true, Captain Coles' system of turrets received its first trial; it may therefore be proper to assume that the cost of conversion was much greater than it would have been if the work had not been of an unusual character; but the wisdom of repeating such an experiment may well be doubted when for very little, if any, more expense it would be possible to construct, of iron, a new armour-plated monitor, better defended, drawing much less water, and more durable and efficient in every respect.

This view of the matter leads me to refer more fully to some of the reasons which have hitherto prevented the carrying out of any general scheme for converting our wooden line-of-battle ships into iron-clads. We have, it is true, a considerable number of such ships, which could be thus treated, and if necessity should arise, doubtless many would be converted by ready and inexpensive methods; but the question may well be asked, Whether the money that would be required for such conversions could not be better spent, especially at a time like the present, when saving of time is not imperative or pressing? My own opinion is that our money could be and has been better employed, and I shall almost immediately show why I hold this opinion. Before doing so, however, I may remark that the capability of our old line-of-battle ships for rapid conversion into either armoured broadside ships or monitors has been fully recognised by the Constructive Department of the Admiralty, and detailed designs have been prepared which would enable the conversions to be immediately carried out if there should ever be a great and sudden demand for such vessels. It is only due to the officers of the Admiralty to make this statement, as it has frequently been assumed, and stated, that they were entirely opposed to any scheme of conversion. I may add that the experience obtained with the hastily built and improvised iron-clads used by the Confederates during the late war shows the importance which, under some circumstances, might attach to the possession by this country of a wooden steam fleet, and of the resources in public and private ironworks and dockyards which would enable us to turn it into a fleet of iron-clads in a very short time. If need were, the Channel might within a brief space be held, and every English port of importance be defended, by ships beside which the much-talked-of 'Merrimac,' 'Atalanta,' and 'Tennessee' would appear contemptible, and which would be stronger in both offensive and defensive powers than most, if not all, of the American monitors.

Reverting, however, to the reasons why our armoured fleet has not yet been thus developed, it is necessary to observe that there are many strong reasons for not expending large sums of money upon the conversion of our wooden line-of-battle ships in a period of peace, and when no prospect of naval war exists. In the first place, the development of our wooden steam fleet was so sudden that many of our line-of-battle ships were built with timber not thoroughly seasoned, and decay has consequently been more rapid in them than is usual in wood ships. Again, it must be remembered that even the newest of these ships are now eight or ten years old, and many of them are considerably older; so that their condition is on that account the less satisfactory. If these ships were taken in hand for conversion, therefore, extensive repairs would be required in the hulls, and it would be necessary to greatly renew and strengthen them in order to adapt them for armour. But, supposing for the moment that the hulls did not require to be repaired and strengthened, and were likely to last a reasonable time after conversion, there would still remain the extremely important fact that the weights of these wooden hulls are much greater than those of iron hulls, and that the weight of armour they would carry would be consequently much smaller than could be carried by iron-built ships. It may be well to take the cases of a few ships in order to illustrate this fact. In the converted broadside ship 'Zealous,' a hull weighing 3067 tons carries only 3055 tons (as nearly as possible its own weight) of armour, armament, engines, coals, and equipment of all kinds; while in the new iron-built broadside ship 'Audacious,' a hull weighing 2675 tons—nearly 400 tons less than that of the 'Zealous'—carries 3224 tons of armour, &c., or nearly 200 tons more than are carried in the 'Zealous.' In fact, had the 'Zealous' been built of iron on the same system as the 'Audacious,' the weight saved on the hull would have sufficed to increase the armour from its present thickness of 4½ inches to 6 inches. In the turret-ships this feature is even more striking, as the following comparison will show :—

	Weight of Hull.	Weights Carried.
	Tons.	Tons.
Royal Sovereign (converted ship)	3243	1837
Glatton (breastwork monitor) ..	2209 *	2975
Thunderer „ ..	3272 *	5790

This comparison need not be dwelt upon; the figures speak for themselves. It is but proper to state, however, that the 'Royal Sovereign' was the first and only ship so converted, and that the superiority of the new ships is to some extent the result of the difference of type. On the other hand, this superiority is mainly due to the material employed being iron instead of wood, and to the system adopted in the construction of the recent ships.

* Including very strong defensive deck plating, and plating on top of breastwork. The 'Glatton' is taken at her fighting draught.

Besides this, it must be remembered that these line-of-battle ships are comparatively slow, and have engines (in most cases more or less worn) which are deficient of modern appliances for reducing coal consumption, so that they would need to carry larger supplies of coal than ships with new engines, which is another reason for concluding that their armour must be thinner than that of a new ship. Finally, these ships all have a considerable draft of water, and on that account are less fitted for coast defence than shallower ships would be. For all these reasons, therefore, I think it must be admitted that the Admiralty have acted wisely in refraining from expending large sums on the conversion of our line-of-battle ships. To sum up, they are undoubtedly more or less decayed and weak; are of deeper draught than they should be for coast defence; are slow, and have comparatively wasteful engines; and could not carry nearly so great a weight or thickness of armour as new iron ships, the mere hulls of which can be very cheaply and quickly built by the great private firms of the country.

These are reasons for the comprehension of which no amount of technical knowledge is required; there are others which are no less weighty, but more technical, to which I shall briefly refer. The chief of these is the probable behaviour at sea of these ships if converted into monitors; for, although not sea-going ships in the usual sense of the term, such vessels ought to be capable of keeping in the Channel under most circumstances of wind and weather. It is—as I have before said when treating of rolling—natural at first sight to suppose that, when the lofty sides of a line-of-battle ship are cut down and the top-weights removed, the converted ship should be steadier than the line-of-battle ship; but I have shown that this is not so, and that, in general, the reverse is to be expected. I have also called attention to the fact that a wood ship with her heavy hull, and great weights of engines, boilers, &c., low down, is much more likely to roll heavily than an iron ship with the improved structural arrangements introduced into the iron-clad ships of the Navy. In the converted ships, then, it must be expected that the rolling would be considerable, and the only good means of reducing the rolling somewhat would be the carrying out of the breastwork monitor system in combination with a low free-board, as has been provided for in the designs for converting these ships prepared at the Admiralty. It would of course be true that the waves would wash over the decks of these converted monitors, and that the tendency to roll would on this account be somewhat checked; but in any but breastwork monitors this would also cause inability to fight the turret-guns. These considerations render it still more apparent that the conversion would not place very satisfactory ships at the service of the country.

So far I have dealt chiefly with the proposals for turning our line-of-battle ships into coast defence vessels, or monitors which would not be rigged so as to be capable of proceeding under sail, but would closely resemble in this respect the 'Royal Sovereign' and the 'Prince Albert.' Proposals have, however, been made for converting them into sea-going monitors, in which lowness of free-board is retained, but associated with the masts and sails of a full-rigged ship. All that has been said previously (except the remarks relating to draught of water) applies to these proposals also; but there are many special objections to the latter class which I consider it desirable to indicate, as the Admiralty and their professional officers have been subjected to some strictures for declining to entertain proposals of the kind. In an Appendix at the end of this volume, I have considered theoretically the question of "The Stability of Monitors under Canvas," and have pointed out some of the dangers to which such vessels are liable. I need only say here, therefore, that the chief of these dangers consists in the risk of overturning, or upsetting, which results from the fact that in a monitor a moderate inclination puts a portion of the lee-side of the deck under water, and that the stability is thus diminished, especially in other than breastwork monitors. This danger is at its greatest when the ship is at sea, when the actual amount of heel is often virtually increased by the slope of the wave-surface. That this is no phantom danger will, I think, be seen by all my readers from the preceding brief statement, but the reality of the danger will perhaps be best understood by naval officers and naval architects.

Leaving this most serious feature out of consideration for the present, there are, however, several other points of importance which, in my estimation, render the plans unsuited for practical application. For example, a sea-going full-rigged ship requires a large complement of men, a great weight of stores and equipment, and a good coal supply. Now I venture to assert that in no proposal yet made for converting the line-of-battle ships into sea-going iron-clads has adequate provision been made in these respects, in association with a sufficient thickness of armour. At the present time it would, without doubt, be worse than folly to construct an armoured ship for general sea-going purposes that should not have a reasonable prospect of being able to meet at least most of the existing iron-clads on equal terms as regards defensive armour; and if armour of the thickness required for this purpose be carried on a converted ship, she cannot carry besides the weights of coal, stores, and equipment necessary in a full-rigged ship, nor provide proper accommodation for her numerous crew. On paper it may be possible to meet all these requirements; in practice it is impossible. Of the plans that have been put forward for the purpose, it may without exception be said that they all fail to allow sufficient weights and space—in other words, far too much has been attempted to be done on the dimensions. As an example of this, I may mention that on one occasion the Secretary of the Admiralty stated in his place in Parliament that, had one of these schemes for conversion been carried out, instead of having a free-board of between 3 and 4 feet, as was estimated, the upper decks of some ships would have been only a few inches above water, when all the weights intended to be carried were on board. The result of careful examination of such schemes and of calculations connected with them may be briefly summed up as follows:—None of our screw line-of-battle ships can be converted into efficient sea-going iron-clad monitors, having the necessary sail-power and the crews required to work them under sail, together with the weights of stores and equipment required in a full-rigged ship. They may be converted as partially-armoured broadside ships like the 'Zealous' and 'Repulse;' or, by giving up masts, spars, sea-stores, and a large weight of equipment, such ships can, as I have said, be turned into formidable coast-defence monitors; but even such conversions would not be justifiable except in the emergencies of a war.

Before concluding this chapter I may observe that the question of the policy of carrying out these conversions has been often argued from false premises. Statements have repeatedly been made respecting the loss to the nation involved in the non-conversion of the line-of-battle ships, which are not only mistaken but positively absurd. We hear of ships representing a money value little short of 10,000,000*l.* lying in harbour and rotting, when they might, by the expenditure of a moderate sum, be converted into useful iron-clads. The truth is, however, that a considerable number of those ships have been in service, and that, although many of them have not been completed, they have really constituted a reserve force that would have been drawn upon if occasion had arisen. The transition from wood to iron-clad war-ships has undoubtedly been rapid, and the Admiralty acted wisely in suspending the construction of wooden line-of-battle ships and frigates when the expediency of building iron-clads became apparent; but the action at Lissa shows that wooden ships are far from ineffective in engagements where iron-clads are present, and there can be little doubt that the value of such ships as a reserve would be very great, since the first iron-clad action would greatly cripple the armoured ships of the enemy, and give scope for the operations of the wooden fleet.

For these reasons, then, I hold that it is a very wrong assumption that is made when the wooden steam fleet of this country is put down as virtually powerless for purposes of war, and the money locked up in it is represented as being worse than useless. To convert the line-of-battle ships into iron-clads would be to incur considerable expense, as is proved beyond doubt by the case of the 'Royal Sovereign;' and the class of ship that would be produced would undoubtedly be less durable and efficient for coast defence than the new monitors which could be built of iron for about the same money.* In war time the rapidity with which these ships might be converted into iron-clads would probably outweigh these considerations, important though they be, although it may fairly be questioned whether even this advantage would exist in presence of our enormous resources for building quickly in iron. In time of peace there is not the same urgency, and it would certainly be false policy to devote any considerable part of the sums annually voted for the construction of iron-built iron-clads to the production of such inferior and short-lived ships as the converted vessels must undoubtedly prove.

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* We have seen that the conversion of the 'Royal Sovereign's' hull, with 560 tons of armour, cost about 150,000*l.*, whereas the contract price of the hull of the iron-built 'Cerberus,' with 670 tons of armour, is but 99,000*l.*, and the estimated cost of the hull of the powerful monitor 'Glatton,' with no less than 1065 tons of armour is (including 12½ per cent. for establishment expenses) but 163,000*l.*

APPENDIX.

ON THE STABILITY OF MONITORS UNDER CANVAS.

Read at the Ninth Session of the Institution of Naval Architects, April 4th, 1868, *the Rev.* JOSEPH WOOLLEY, LL.D., F.R.A.S., *Vice-President, in the Chair.*

THE proposal to mast monitors and to send them to sea as full-rigged sailing ships has been so often made, and urged upon the public with so much zeal, even by persons claiming to speak with weight upon questions of naval construction, that I have deemed it desirable to lay before the members and friends of this Institution a few considerations which will exhibit some of the dangers of such a course, and which will at the same time present a few examples of what are certainly very interesting and exceptional cases of "stability."

Permit me, at the outset, to say that I employ the term stability in the sense in which it has hitherto been used in scientific works upon naval architecture. In nautical parlance the word is often employed as the synonym of *steadiness;* the 'Achilles,' for instance, being in this way pronounced the most "stable" ironclad in the Channel Squadron. This, however, is not at all the scientific sense of the term stability; for, in that sense, the 'Achilles' is (for her size) the least stable of the iron-clads, and, in point of fact, owes her superior steadiness to the very circumstance of her stability being so small. The 'Bellerophon,' which is, I believe, next to the 'Achilles' in *steadiness*, is next to her also in the smallness of her *stability*, while the 'Lord Clyde' and other ships of much larger stability are correspondingly deficient in the quality of steadiness. It is to be regretted that this discrepancy exists between the scientific and the nautical use of the term; but the fact of its existence should incite both seamen and naval architects to cultivate a mutual understanding of both uses of the word.

In naval architecture—forgive me for detaining you a moment while I reiterate an elementary fact or two which may help this mutual understanding—the word stability is applied to the effort which a ship makes, when inclined, to return to the upright position. If she is urgent to return to it, she has great stability; if slow to return, she has small stability; and the fact to be chiefly observed—for it exhibits the cause of the discrepancy in question—is this, viz. that a ship which is reluctant to move out of the upright position in still water, and urgent to return to it, is usually the most urgent to obey the fluctuations and impulses of waves. We naval architects say such a ship is too stable; seamen say she is not stable enough; and I must say that our use of the word is a mere fair-weather use of it, and that we must forgive naval officers if they laugh at us for pronouncing a ship stable in proportion as she rolls about in waves at sea. Still, our use of the word is a perfectly legitimate one; it is too firmly built into our scientific terminology to be removed, and all we can do is to endeavour to make it as well and widely understood as possible.

Strictly speaking, stability, in our sense, is of two kinds—statical and dynamical. Permit me to explain both briefly.

FIG. 1

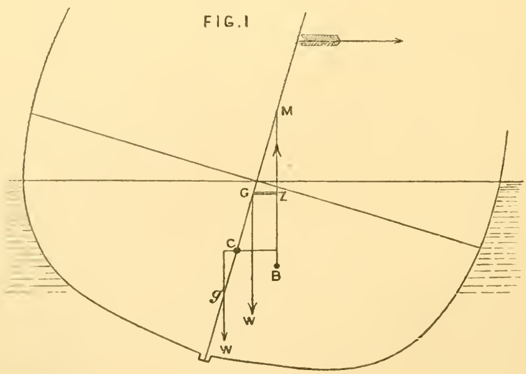


Fig. 1 represents the section of a ship heeled over to a certain angle; G is the position of the centre of gravity of the ship; C and B are the centres of buoyancy in the upright and inclined positions respectively; B M is a vertical line along which the buoyancy of the ship acts upwards; G W, a vertical line along which the weight of the ship acts downwards. These two forces form a couple, the arm of which is G Z, tending to restore the ship to the upright position. The moment of this couple is called the moment of statical stability; and since the weight and buoyancy are constant whatever the angle of heel may be, the length of the arm, G Z, will be a measure of the statical stability.

The dynamical stability is the mechanical *work* necessary to heel the ship over to any angle. It may be measured in two ways. Either by taking the sum of the distances through which the centre of gravity ascends, and the centre of buoyancy descends, in moving from their vertical into their inclined positions, and multiplying it by the weight of the ship. Or, by means of the formula:—

Dynamical stability $= \int M d\,\theta = W \int r d\,\theta$; where $M =$ the moment of statical stability, $r =$ the length of the arm G Z of the couple, at an inclination θ, and $W =$ the weight of the ship.

Now I think it will be seen upon consideration that the security of ships of the ordinary form, when under canvas, or when rolling in a seaway, against being turned over by a sudden gust of wind, or by a deep roll, depends in a great measure upon the fact that the moment of statical stability increases with the angle of inclination, which it generally does, nearly in proportion to the angle of heel. In the case of a ship under sail, in smooth water, the angle of heel increases until the moment of statical stability is equal to the moment of the wind upon the sails; and this becomes a position of equilibrium if the force of the wind remains constant. In order that this inclined position may be one of stable equilibrium, it is necessary that, when the ship is moved from this position towards the vertical, the moment of stability should decrease and become less than the moment of sails; and that, when she is heeled over farther from the vertical, the moment of stability should increase, so as to exceed that of the sails. Or, in other words, in the neighbourhood of this inclined position of equilibrium, the moment of statical stability should increase as the angle of heel increases.

The conditions are the same for a ship carrying canvas in a seaway. But, since the rolling, caused by the variation of the wave surface, and the variation of the force of the wind, takes place about the inclined position of equilibrium, and is more likely to be considerable than the effect of the variation of the wind alone in still water, it becomes necessary that the conditions, above stated, should not be confined to the neighbourhood of the inclined position, but should extend on both sides of it to a safe distance beyond the probable extreme inclination of the ship to the wave surface.

If, however, the stability—and by stability I must be understood to mean the moment of statical stability when not otherwise stated—of any class of ships increases as the ship heels over, until, when she reaches a certain angle, it becomes a maximum, and then decreases as she still continues to heel over until it passes through zero and becomes negative, there will be three positions of equilibrium of the vessel; one of stable equilibrium in the upright position, and one of unstable equilibrium on each side of it at a certain angle of inclination. And if these positions of unstable equilibrium occur within the limits of roll of an ocean steamer when not under canvas, the ship will evidently be unsafe for sea-going purposes. It will also be shown that, although the positions of unstable equilibrium fall beyond the limit of rolling, if they fall near that limit, the ship may be safe under steam, but may be totally unfit to carry sail.

The first condition to be fulfilled to enable a ship of the latter class to carry sail will evidently be that the moment of sails at any time shall not be greater than the maximum statical stability of the ship. Now, suppose this condition fulfilled, and the ship heeled over, under the influence of the wind, to some finite angle, less than that of greatest stability. It will be seen that, if by any disturbing cause, such as the alteration of the wave slope, the ship were inclined beyond her position of maximum stability, the resistance to heeling would become less the farther she went, until she reached a position at which her moment of stability would be the same as before the disturbing force began to act. And in this position she would remain in unstable equilibrium if the disturbing forces were removed. But if she should pass this position before the disturbing forces, and the angular velocity caused by them, cease, the ordinary moment of the sails will then be greater than the resistance offered by the stability in any other position through which she will pass, and she will be turned over. General considerations led us, of course, to foresee that the above critical state would be likely to occur in low-decked turret-ships, with great weights concentrated upon and above their decks; but in order to find out more definitely how the stability did vary in this class of ship as compared with that of ships of a high freeboard, two ships were taken, viz. the 'Duncan' cut down to a freeboard of 3 feet 6 inches, and fitted with three heavy turrets, and a ship with the same displacement and immersed body as the 'Duncan' when so cut down, but whose sides were continued up like those of an ordinary ship, observing that the centre of gravity was estimated to be in the water-line in the latter case, and ·2 of a foot below it in the former case. The moment of statical stability and the length of G Z were calculated in each case at every 5° of inclination, and the results are laid down on the diagram shown in Fig. 4. In this diagram, the angles of inclination of the ships are marked along the base line, and the corresponding ordinates of the curves represent the lengths (on the scale marked in the left-hand column) of the arm (G Z, Fig. 1) of the couple, at the ends of which the weight and buoyancy of the ship act, tending to restore her to the upright position.

The line, A *a* B, Fig. 4, shows how the stability of the 'Duncan' monitor varies for the different angles of heel. Her moment of statical stability increases nearly in proportion to the angle of heel through an inclination of 7°; the deck then begins to be immersed, as shown in Fig. 2, and the stability increases less rapidly, until the ship reaches about $10\frac{1}{2}$°, as in Fig 3, at which inclination the stability is a maximum. It then begins to decrease as the angle of heel increases, and she loses all stability before she is inclined to 25°, arriving there at a position of unstable equilibrium, and past this position her tendency is to turn over still farther.

The line A C, Fig. 4, shows how the stability varies in the ship of ordinary form. And it will be seen that the moment of stability goes on increasing through very large angles of heel nearly in proportion to the inclination.

FIG. 2

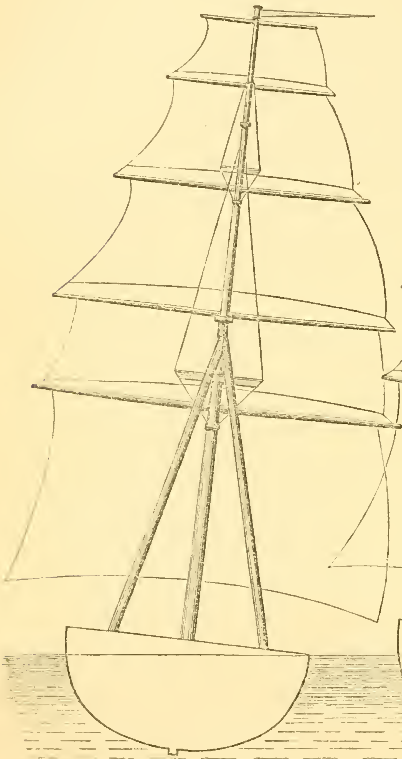
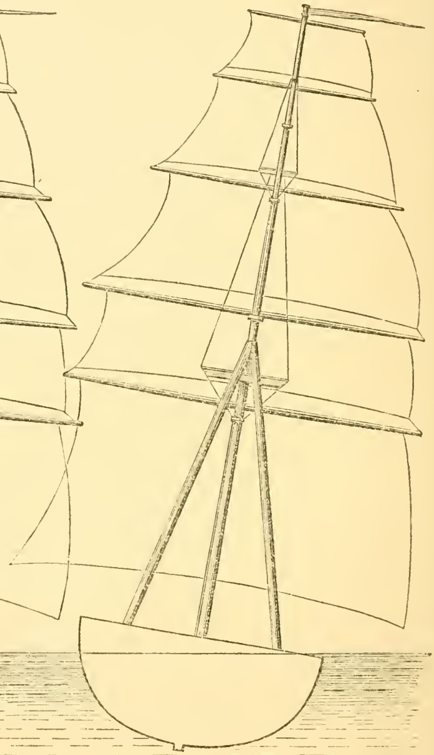
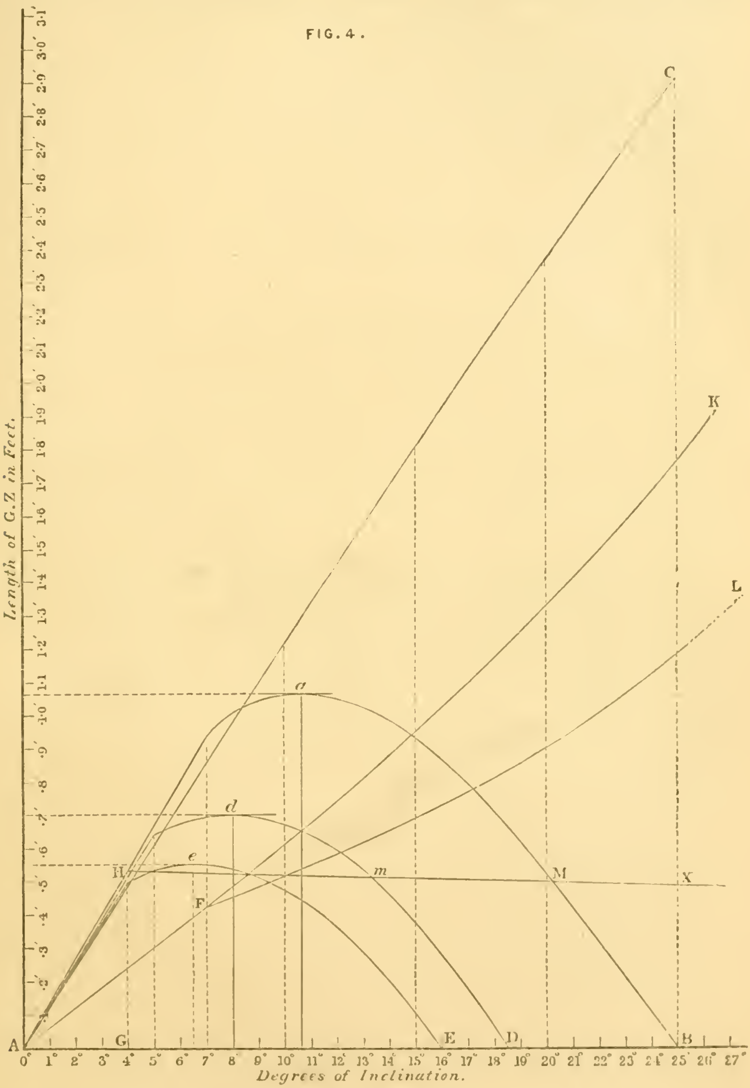


FIG. 3



Hitherto I have referred to the case of a monitor with a freeboard of 3 feet 6 inches, which is far more than the American monitors have possessed, and much more than has been contemplated by many persons who have proposed the adoption of sailing monitors in this country. It is also certainly a greater freeboard than most of our line-of-battle ships would possess if cut down and weighted with armour and turrets to the extent which has sometimes been recommended, and especially more than we could depend upon getting if they were placed for conversion into the hands of any one not capable of resisting the temptation to produce a formidable-looking ship on paper by adding armour regardless of weight. I have therefore taken the

FIG. 4.



case of the 'Duncan' monitor with increased draught so as to give a freeboard of 2 feet 6 inches, and also with a freeboard of 2 feet, and have shown, by means of the curves, A *d* D, and

A e E, Fig. 4, how their stabilities vary. I assume the centre of gravity to remain in the same position as before relative to the ship, and therefore to be 1·2 feet below the water-line in the former case, and 1·7 feet below it in the latter case. In the former case, viz. with the freeboard of 2 feet 6 inches, the stability increases until the ship is inclined to an angle of 5°. The edge of the deck is then immersed, and as the ship goes on increasing her angle of heel, the stability increases very slowly, until it reaches a maximum at 8°; it then decreases, and the ship reaches a position of unstable equilibrium at 18½° inclination.

In the case where the freeboard is 2 feet, the edge of the deck is just immersed when the ship is inclined to 4°; up to this point the stability increases nearly the same as in the other cases, and it will be seen that it has then almost reached its maximum value; it increases slightly until the angle of heel reaches 6½°, and then decreases as the angle increases until the ship becomes unstable, which takes place before she has reached 16° inclination.

I will here explain what seems at first sight to be an anomaly in Fig. 4. We see that the curve A C lies inside of the curve A a B at the small angles of inclination, thus showing that in these two cases, and in these positions, the monitor has the greater stability. This is, of course, due to the fact of her centre of gravity being the lower, while both the displacement and load-water section are the same in each case. But the curves A d D and A e E also fall inside of A a B at first, although the centre of gravity in the two former cases is much farther below the water than in the latter. This apparent anomaly may be explained in the following way:—The moment of inertia of the water-line remaining nearly constant as the ship sinks in the water, while the displacement increases, causes the distance between the metacentre and centre of buoyancy to diminish; at the same time the centre of gravity descends faster than the centre of buoyancy, and consequently approaches it. Now if the metacentre approaches the centre of buoyancy faster than the centre of gravity approaches it, the distance of the metacentre from the centre of gravity, and with it the arm of the lever, G Z (Fig. 1), will be diminishing, and this is just what occurs here.

It is interesting also to compare the dynamical stabilities, or mechanical work necessary to heel these ships through equal angles. This may be done by comparing the areas enclosed (Fig. 4.) between the base line, the curves, and the ordinates drawn to the curves at the particular angles of heel. That these areas are proportional to the dynamical stabilities may be seen from the formula given before, viz. :—

$$\text{Dynamical stability} = W \int r \, d\,\theta.$$

If we take the case of the first monitor being heeled over to the position H G, Fig. 4 (4°), under the pressure of sail, and draw the line H *m* M, so that it shall represent the variation of the moment of sails, due to their inclination; and suppose the line H *m* M also to represent the effect of the sail upon the other ships, it will then divide each of the areas A C B, A *a* B, A *d* D, and A *e* E into two parts, the lower of which will represent the work which the wind (at a constant pressure) would be capable of doing in overturning them, and the areas above the line H M will represent the whole of the energy which the ship could put forth to withstand any additional impulse, such as the effect of waves, or a sudden gust of wind. We thus see, by comparing the areas, H C X, H *a* M, H *d m*, and the small part of A *e* E above H M, the relative amounts of energy stored up in the ships when sailing at the given inclinations, and this energy it is which chiefly constitutes their safety. Comparisons may be made in the same way at any other angles of heel under sail.

It must be obvious from this that the danger to be apprehended to these monitors, when under canvas, is very great.. And when we think that they are liable at any moment to be overtaken by sudden gusts of wind, and that, if they are heeled over beyond 8° or 10°, the farther they go the less resistance they offer to being capsized, their unfitness to carry sail must be quite evident.

If it should occur to any one to consider that the case of an ordinary barge is both an illustration and a refutation of the subject as I am here stating it, I would beg leave to remind him that the two cases differ in a most essential respect—the barge usually has nearly the whole weight, both of her hull and of her cargo, below the water, and therefore comparatively low down;

whereas it is the object of these monitors to carry a large weight of armour, guns, and turrets, mainly above water, so that the centre of gravity—the position of which is so important to the stability—cannot well be got low down. Any one who will take the trouble to closely compare the two cases will find that they differ exceedingly, and that, although barges sometimes carry a deck cargo, it is always of comparatively light material, and, when unbalanced by weights in the hold, leaves a considerable height of freeboard; and this leads me to observe that the state of the monitor which I have been describing would become very materially modified if the centre of gravity of the vessel could be greatly lowered, say to the extent of many feet. If, for example, it could be brought down to the depth of the centre of buoyancy, or beyond it. On reverting to Fig. 1, it will be seen that, when the ship heels over in the direction of the arrow, the centre of buoyancy, C, moves out in the same direction. This is the case, more or less, however low the freeboard. We also see that, if the centre of gravity, G, of the ship is above C, the vertical line, G W, through G, in the inclined position moves in the same direction. In other words, the vertical lines, G W and B M, both move outwards in the direction of the arrow; and we have seen that in the case of the monitors which we have been considering, owing to the low freeboard, B M moves slowly, so to speak, and is soon overtaken by G W, and the ship then capsizes; but if we suppose the centre of gravity to be below the centre of buoyancy, say at *g*, and and draw the vertical line *g* W, then it is obvious that, as the ship is inclined, B M and *g* W move off from the middle line in opposite directions, and the distance between them, and consequently the statical stability, increases as the ship heels over. This case, no doubt, corresponds to that of the sailing barges, loaded deep with hold-cargoes, before referred to; and it is a good illustration of the fact that vessels which may seem to a casual observer alike in principle may, nevertheless, be seen by the naval architect to possess totally opposite qualities.

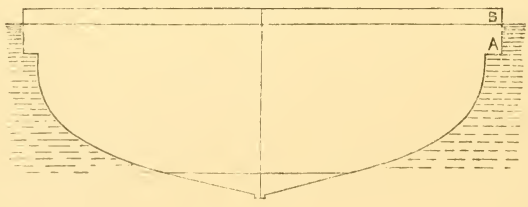
A very little reflection will suffice to show that we cannot as a rule avail ourselves of this last exhibited principle in the construction of armoured monitors. The tendency of things is to increase the upper weights, that is to say, the weights of the deck, the turrets, and the guns, and to lighten the construction of the hull below water as much as possible; and although the resort to great engine-power and coal supply would tend to correct this tendency and to lower the centre of gravity, it is extremely improbable that in future iron-built ships we shall ever have a very low centre of gravity associated with the monitor type of vessel.

I do not, however, wish to use the present paper as a bar to future developments of the monitor system; its sole object is to show that monitors having their centres of gravity situated approximately like the centres of gravity of other ships would be quite unfit to carry a press of canvas.

Before closing this paper, I may make a few observations on the behaviour of these monitors as influenced by wave motion. I have already referred to the fact that the steadiness at sea of some of our iron-clads is due to their want of stiffness or stability, and their consequent increased time of oscillation in still water; and, I may add, that it is a very well-established fact that ships which have great stiffness in still water are very uneasy rollers. Now, it will be seen that these monitors converted from line-of-battle ships, as before mentioned, have great stiffness for small angles of inclination, and they would consequently start rolling under the same influences as ordinary ships which are very stiff and have a lofty freeboard. This would, but for another consideration, be a very dangerous feature in the monitors, because it would cause them to roll quickly until the range of roll became large, and they would then get into positions where their stabilities would be small and decreasing, and from which, if under canvas, they might not be able to right themselves. Suppose, for instance, a ship of this kind rolling among waves of the same periodic time as her small oscillations. Should she roll beyond her position of maximum stability, she would have her time of roll increased, and the following circumstances would then occur:—When reaching the hollow, she would not have finished her oscillation, and might be still rolling towards the approaching wave; the alteration of the direction of the water surface caused by the front of the approaching wave—instead of developing in the ship a greater moment of stability tending to right her, as is the case with all ships which have a high freeboard—would diminish what stability there was remaining, and the danger of her being blown over, if she carried sail, would be very great. The stability of these ships, in fact, would appear to vary in the worst manner possible for safety. They would have all the characteristics of very uneasy ships until they rolled deeply, and not have the advantage of an increasing stability to prevent their rolling too far. The consideration which modifies this state of things materially is, that the very absence of free-board, which deprives them of the necessary stability at great inclinations, would usually operate in the early stages of rolling to mitigate the impulses which the waves impress.

And besides this, the amplitude of rolling is undoubtedly much diminished by the disturbance of the water, which the immersed angle between the deck and the side causes, and is still further diminished by the plan adopted in America of allowing the armour and backing to project from the side, instead of their being imbedded in the side as proposed in the cases which we have been considering. In fact, this projection of the armour beyond the side must play an important part in the alleged steadiness of the American monitors. Its action is like that of an immense bilge keel, and is very effective in diminishing the angle of roll. For instance, if a ship of the form of Fig. 5 were set rolling, the resistance caused by the

FIG. 5



action of the projection at A on the surrounding water would be very great, and would tend to diminish the amplitude of roll. The action of the angle B, when immersed, which would be of the same kind in all monitors, whether the armour projected or not, would be as follows:—If the ship were rolling towards the side A B, the angle B would have very little effect on the amplitude of roll, but as soon as the ship commenced to return to the upright, it would act to prevent her, and thus tend to increase her time of roll; and, by diminishing the force with which she returns to the upright, would indirectly tend to decrease the amplitude of the next roll. It will thus be seen that the action on the water by the angle at A is always in the right direction, while the action of the angle at B may be against the ship when she is in the most critical positions, viz. when she has rolled over to an inclination where her stability is very small—and with decks as low as the American monitors this would be the case at very moderate angles of roll—so that by losing A while retaining B, which we do if we put the armour in a recessed side, we give up a really valuable feature, while we retain one which, under certain circumstances, may prove a disadvantage. I need hardly add that I am here speaking only of monitors which have to serve at sea, and not at all of mere harbour defence ships.

I have recently had occasion to consider two other cases of a somewhat similar kind. We are building for the Government at Melbourne an iron-clad monitor with a height of deck above the water of 3 feet, and with an armour-plated breastwork surrounding the bases of the turrets, and enclosing the hatchways, as in Figs. 6 and 7. This monitor has to be navigated to Melbourne, and for this purpose is to be fitted with a temporary side and upper deck. I have shown in Fig. 4., by means of the curves A F K and A F L, the variation of the stability of this vessel with different conditions of freeboard, observing that, as this is a very much smaller vessel than the 'Duncan,' the actual stability is much less than in her case. The curve A F K shows how her stability would increase if the side were continued up as an ordinary ship, the whole length fore and aft. The curve A F L shows how it varies when the side runs up before and abaft the breastwork only, as in Figs. 8 and 9. The difference between these two curves is caused by the break in the ship's side in wake of the breastwork, and shows how the stability is influenced by a departure of this kind from the usual continuous side. In neither case, however, have we that alarming decrease and loss of stability which the monitor proper would undoubtedly possess, especially with a very low freeboard.

In conclusion, I will only add that it will be no answer to the doctrines of this paper to say that the rolling of ships is affected by the lateral distribution of weights as well as by their vertical

FIG. 6.

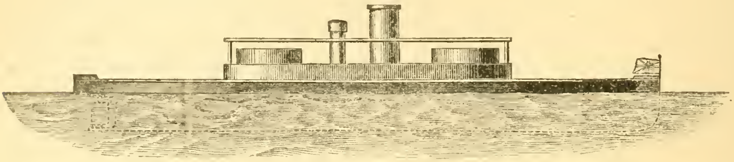


FIG. 7.

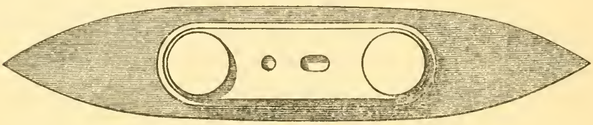


FIG. 8.

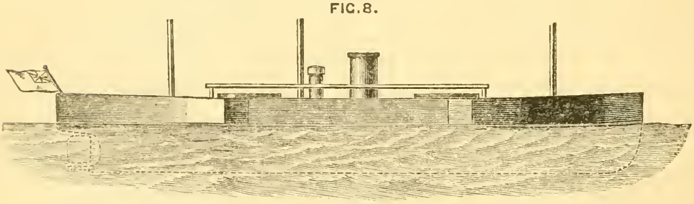
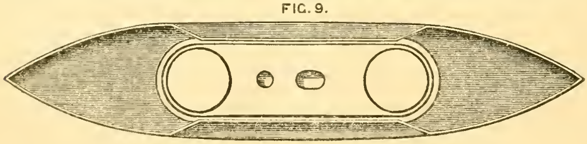


FIG. 9.



heights. That is undoubtedly true, and would deserve great attention in a discussion upon rolling. But my ruling argument is that the monitors we have considered would be dangerously deficient of statical stability, and this argument would hold equally with their weights either distributed or concentrated.

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