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LECTURE.

Friday, February 4th, 1876.

ADMIRAL SIR HASTINGS R. YELVERTON, G.C.B., in the Chair.

ON CIRCULAR IRONCLADS.

By E. J. REED, Esq., C.B., M.P.

I HOPE I may be excused for saying at the commencement of this paper that I have undertaken to write it at the request of the Council of this Institution, and not from any desire on my part to add at present to the public statements which I have already made concerning circular ironclads. Nevertheless, as the desire of the Council was based, I presume, upon the remarks upon this class of vessel, made in certain letters which I wrote from Russia last autumn, and as those remarks have since been subjected—as I at the time feared they would be—to much misconception and much misrepresentation, I ought to feel, and do feel, grateful to the Council for having voluntarily afforded me this opportunity of stating more fully my views upon the subject.

Whatever may be the merits or demerits of circular ironclads, it will be admitted by all present that their construction by the Russian Government for service in the south is a noteworthy fact, and that I should have been wanting to myself, and perhaps to others, if I had failed to avail myself of a very favourable opportunity for inspecting these vessels and witnessing their performance at sea. That was the object of my recent visit to Russia, and the opinions which I formed of them were stated with considerable care in my letters to *The Times*. On the present occasion, I propose to discuss the question in an essentially different manner.

But let us at the outset get as clearly as possible into our minds an idea of what the circular ironclads of Russia are. In the first place they are circular only in one sense, *i.e.*, their horizontal sections only are circular, or, in other words, they have circular water-lines. The only departure from a circle is a small extension or protuberance at the stern for the purpose of facilitating the arrangement and working of the rudder and steering apparatus. It follows as a consequence, from the circular form of water line, that all the radial sections are alike. In the earlier proposals for circular ironclads, for example, such as those suggested by the late Mr. John Elder,¹ and, if I remember rightly, by Sir Samuel Baker, the midship section of the vessel was an arc of a circle, and therefore, in order to get the requisite displacement, the depth or draught of water of the vessel had to bear a considerable proportion to the diameter at the water line, and this involved, in the case of vessels carrying heavy armour, a draught of water which would be too great for heavily-armoured coast defence vessels. The

¹ See Journal of the Institution, No. 52, Vol. xii, page 529, *et seq.*

circular ironclads of Russia, or Popoffkas, have quite a different form of section, the bottom of the vessel being an extended plane surface, which is connected with the edge of the deck by a quadrant of a small circle. With this form of section great displacement is obtained on moderate draught of water. The deck of the circular ship is formed in section with such curvature as to give in a ship of 100 feet in diameter a round-up of about four feet. There are two Popoffkas already built, named respectively the "Novgorod," Fig. 1, and the "Admiral Popoff," Fig. 2, of which the following are the dimensions and other particulars:—

	"Novgorod."	"Admiral Popoff."
	Ft. ins.	Ft. ins.
Extreme diameter	101 0	121 0
Diameter of flat bottom	76 0	96 0
Depth in hold at centre, from underside of beam to top of the frames of the double bottom ..	13 9	14 0
Draught of water	Forward ..	12 0
	Aft ..	14 0
	Mean ..	13 0
Height of barbette tower from load water-line ..	12 0	13 3
Diameter of barbette tower, outside	30 0	34 0
Height of upper deck at side, from load water line amidships	1 6	1 6
Displacement, in tons	2,490	3,550
Area of midship section in square feet	1,170	1,416
Engines, nominal horse-power	430	640
Coal supply, in tons	200	250
Propellers, screw, in number	6	6
Complement of Officers and men	110	120
Armament, breech-loading guns:		
Two in number, each weighing, in tons ..	23	40
Smaller guns in unarmoured breastwork ..	—	4
	Ft. ins.	Ft. ins.
Height of armour on side above water	1 6	1 6
Depth of ditto below load water line amidships ..	4 6	4 6
Thickness of armour on sides (including equivalent thickness for the hollow iron girders behind armour)	0 11	1 6
" Lower strake	0 9	1 4
Ditto on barbette tower	0 11	1 6
Thickness of deck plating	0 2½	0 2½

It is but fair to the distinguished designer of these vessels, carefully to bear in mind that, in so far as the "Novgorod" and "Admiral Popoff" are concerned, they have been designed and built purely for service in shallow waters and near the land. You will all remember that during our great war with Russia in the Black Sea and Crimea, the coasts of the Sea of Azof were ravaged by the small and weak unarmoured vessels of our Navy, and that the defences of Kinburn were destroyed by English and French floating batteries which were protected by armour of only four inches thick. The impunity with

which we thus assailed the Russian coasts on the Azof and at the mouth of the Dnieper, suggested to the Russian Government the necessity of providing sufficiently-armoured floating defences for protection in the future; and whatever we may think of the suitability of the circular vessels for sea-going purposes, we shall all, I presume, agree that in the two ships above described, the Russian Government has put itself into possession of light draught vessels of unexampled power, both offensive and defensive, as compared with the armoured vessels of equally light draught belonging to any and every other country. In this country it must be acknowledged that the problem of producing armour-clad vessels, subject only to the conditions of 13 feet draught, 8 knots speed, thick armour, and heavy guns, has never been put by the administrators of the Navy to the constructors of the Navy. During the seven years that I filled the office of Chief Constructor of the Navy, the only light draught armoured vessels that I was called upon to design were certain very small vessels, the breadth or beam of which was limited to a comparatively small amount, to make them fit for service on the inland waters of North America, and a vessel or two for colonial use, under conditions imposed by colonial requirements. The administrators of the Navy have usually considered—and for my part I have concurred with them—that the necessity for ships capable of performing service abroad is, in our Navy, so much more urgent than that for purely coast-defence vessels, that sea-going qualities at least sufficient to make the ships safe at sea, have been for the most part of primary importance. It is quite open to me, therefore, and to every one, to admit the great qualities of these circular ships, without in any way depreciating our own work as English constructors; and it would be well if those persons who have endeavoured to find in such praise as I have accorded to the circular ships, a condemnation of English vessels, would bear this very important consideration carefully in mind.

With reference to the performance of these circular coast defence ironclads of Russia, I cannot, I fear, do much more than simply repeat what I wrote to *The Times* on the subject. As regards speed, only a low speed was required for the object in view, and with engines of 480 nominal horse-power, manufactured in Russia, a speed of $8\frac{1}{2}$ knots has been obtained in the "Novgorod." She has steamed long distances at an average speed of $7\frac{1}{2}$ knots, and when I was on board we easily averaged over $6\frac{1}{2}$ knots, although the machinery was out of order, and much steam was wasted. I cannot give the indicated power developed, for we had not on board the means of determining it; 2,270 indicated horse-power has subsequently been given to me as the fullest power developed in this vessel. If we consider only the displacement of the vessel, this will no doubt be thought a large power to employ in obtaining a speed of only about 8 knots; but displacement only is a very delusive standard to judge by; the true standard is the offensive and defensive power of the vessel, and I do not believe any other vessel exists, equal to the "Novgorod" in these respects, in which a like speed is obtained with like power. Our

colonial defence vessels of the "Cerberus" class, of my own design, come nearest to the "Novgorod" of any vessels I know, and they certainly steam a knot faster with two-thirds of the power. They also carry 72 tons weight of guns against the "Novgorod's" 56 tons, although this discrepancy is partly compensated in the "Novgorod" by a larger coal supply, after allowing for the increase of fuel required by the larger power. But the "Cerberus" draws 2 feet more water than the "Novgorod," and her defensive powers are not nearly so great as the "Novgorod's," owing to so much of the armour being of less thickness.

With regard to the behaviour of the "Novgorod" at sea, I must say that it was remarkably good. We left the roadstead of Theodosia when a night's gale of wind, blowing across the full extent of the Black Sea from the S.W., had raised a considerable sea, and when a strong breeze was still blowing. The motions of the vessel, both rolling and pitching, were very moderate, never, according to the best measures I could take, reaching as much as 7 degrees. The vertical rise and fall of the centre of the vessel seemed absolutely nil, and the guns could have been fired at any time with excellent aim, and in any direction whatever, excepting only in the line of the funnels, and of the steering deck-house aft. I, who seldom escape some sensation of sickness at sea, felt perfectly at home and comfortable in the "Novgorod" throughout the voyage.

It was impossible to avoid observing how much more efficiently a vessel of this form is protected by her armour than is a vessel of the usual form. In ordinary ships, as you well know, great exposure results from pitching, from rolling, and from the alternation of wave hollows and crests along the ships' sides. No one who has anxiously considered the circumstances of ironclads in an engagement at sea can doubt, I think, that with armour stopping as it has hitherto stopped some five, six, or at the most seven feet under the water—and at much less than these depths at the bow and stern—much of the bottom of the ship below armour is in a sea-way exposed occasionally and repeatedly to the fire of the enemies guns. From the first day of my connection with ironclad ships I felt the force of this consideration, and fondly hoped to carry the armour continually lower upon the sides of our ironclad frigates as we made progress in other ways. But in a service like the Royal Navy, and where the constructor is but a humble servant of the Admiralty in so many things, I never was able, I think, to get beyond the depth to which the armour of the "Bellerophon" and the "Hercules" was carried, and undoubtedly the length even of our shortest ships occasions so great a demand for armour that it has not been possible, consistently with other conditions which were thought more important, to carry the armour lower than it was carried in the vessels just named. For you will see at a glance that in the case of all vessels where the belt extends from bow to stern an increased depth of armour if uniformly carried means increased depth and weight over the whole length of the vessel. The result is, as I say, that at sea the armour-belt is frequently abandoned by the waves, and the bottom below armour becomes thus subjected to occasional

and even frequent exposure. I know that this consideration has weighed with many naval officers, and it was greatly urged in the case of the "Devastation" by two Officers with whom I do not at all times agree, viz., Admirals Elliot and Ryder; and some devices were resorted to in that ship and in similar vessels with the sanction of the Admiralty for compensating in some degree for the exposure of the ship at the ends when in a sea-way. It is no doubt true that the largest part of this exposure is at the ends, and is occasioned by the ship pitching, and by the hollowing of the sea between the waves. But rolling also is, of course, a great cause of exposure likewise, and I have considered that in securing great steadiness for modern ironclads in comparison with the early ones, by diminishing the stability (even to the extent of occasionally incurring undue crankness, afterwards compensated by ballast), we have materially mitigated the danger of this kind of exposure. But after all is done that can be done to check rolling, ships will roll at times, and may have to engage enemies when rolling; and if it be true that the circular form of vessel involves less exposure of the hull below water than the ordinary form, there is in that fact a great and valuable element of increased safety (see Figs. 3, 4 and 5). As regards pitching it will be readily admitted, I presume, that ships which are no longer than they are broad, will at the bow and stern be in all probability very much less subjected to exposure of the kind we have considered than ships of the ordinary form. In both respects, therefore, and on the whole, we may confidently expect that circular ships if approximately like the "Novgorod," will be found to expose the bottom of the vessel below armour very much less than ordinary vessels. Certainly the tendency to roll in the Black Sea, when the waves were of ample size to roll an ordinary vessel of her displacement, seemed to me to be singularly small; and as the circular form wherever adopted would no doubt be accompanied, as in the "Novgorod," by low freeboard for at least a considerable part of the vessel's length, all circular vessels will probably always be found to possess great advantages in these respects.

Presuming that all circular armour-clads are to resemble the "Novgorod," we may confidently predict for them a second very important advantage in point of defence. I allude to the fact that in the "Novgorod" and "Admiral Popoff" the armour is of uniform depth and uniform thickness at equal depths throughout the whole extent of the vessel's circumference. Now, in vessels of the ordinary form and proportions there is, and I am afraid always will be, a very grave deficiency in this respect. I believe I may say that every ironclad frigate in existence is characterised by the fact that the armour is greatly reduced in thickness as we pass from the midship portion towards the ends; and in some ships the reduction towards and at the ends is so great that the armour there is little more than nominal. We have been driven, by the length of the ship, to the use of tapering belts—tapering, not only as regards breadth, but much more as regards thickness. Of course, this subject will bear looking at from the other side, and it may be said, with truth, that it has been most wise to give to the engine and boiler spaces and to the magazines a greater measure

of protection than could be allowed to the ends of the vessel, the contents of which were of less vital moment. Still, looking to all the contingencies and risks of a naval engagement, I think every man who takes an ironclad ship into action would be glad to know that his armour tapered neither in breadth nor in thickness, and that a shot or shell fired squarely at him, wherever it might strike, would be equally resisted by his armoured defence. Now, when at sea in the "Novgorod" I felt strongly that this object is attained in her, and I think the simplicity and efficiency of the defensive armour of such a vessel will commend itself strongly to most practical naval Officers.

Those who have thought much of the construction of ironclad ships will have observed that hitherto the decks have been subject to comparative weakness, and that, but for the great comparative height of freeboard which ordinary ships possess, the decks must of necessity have been made a great deal stronger still. Of course, deck attack does not play, and probably never will play, a very important part in naval actions at sea, for obvious reasons; but, even at sea, there are times when weakness of the deck might prove very serious, and whenever ironclad ships are required to attack or to defy land fortresses, they are liable to considerable deck attack from elevated guns. I think I am right in saying that, when a year or two since Admiral Sir Hastings Yelverton was called upon to take by force two Spanish frigates from the harbour of Carthagena, he had to perform that service with the knowledge that there were guns of $12\frac{1}{2}$ tons situated in elevated batteries commanding his decks, and the risk of having to withstand the fire of these guns, as well as of many other powerful ones situated both ashore and afloat, had to be encountered on that occasion—an occasion which, in my humble opinion, is deservedly considered to have elicited from the gallant Officer whom I have named a display of coolness, courage, and determination which effectually proved that we may, with confidence, look in the future, as in the past, to our naval Officers for the full possession of these high qualities. Now, as against deck attack, the "Novgorod" seems very fairly defended, after due allowance is made for the lowness and the upward slope of the deck. In so far as I have investigated the subject, I am also led to believe that on the whole, and speaking generally, the circular ship would have a decided advantage over others, in lending itself to complete armour protection, including that of the deck.

It will be seen from the foregoing that I am strongly disposed to credit circular vessels with great advantages as regards their defensive capabilities against the fire of guns. They possess further advantages, in my opinion, in the facility they afford for protection against the attack of torpedoes. I confess myself much astonished when I found that a gentleman writing to *The Times* declared that this form of vessel was more exposed to the attack of torpedoes than the ordinary form. I cannot see that this is true, even in case of the attack of fixed torpedoes in harbour entrances, or other like places, because the area of the bottom of a circular ship is much smaller than the area of the bottom of an ordinary ship, even when we make allowances for the rise of the bottom of an ordinary ship as the sides and ends are

approached, as compared with the flatness of the bottom of a circular vessel. In making a comparison of this kind we must adopt some standard; I think the standard should be equal power to carry a given weight of battery armour and of protected guns in the vessels compared. Let us, then, take the case of two vessels about equal in this respect, and compare them by simply taking the areas of the load water section in each case. The "Glatton" and "Novgorod" are sufficiently near each other for our purpose, and we find that, while the area of the "Glatton's" water section is about 11,300 square feet, that of the "Novgorod" is about 8,000 square feet, thus showing a difference of 3,300 square feet, or, in other words, the "Glatton's" area of water section is 41 per cent. greater than that of the circular ship. After making due allowance for the greater flatness of the "Novgorod's" bottom, she would still possess the advantage.

But if we pass from the case of ground or anchored torpedoes to the case of moving torpedoes, whether of the Harvey or the Whitehead types, it will be obvious that the circular vessel has much the advantage of the other, as regards liability to be struck. I think we may say that as such attacks will usually be directed to the broadside of the vessel, and will have for their object the destruction of the engine or boiler-room compartments, the relative exposures of the vessels will be approximately as are the areas of their longitudinal sections. Now, taking the two vessels just compared, we find the area of the "Glatton's" longitudinal vertical section, when at the ordinary designed load-draught, is 4,579 square feet, and at the fighting draught, 4,820 square feet, while that of the "Novgorod," at load draught, is about 1,170 square feet. Thus showing a proportion of about 4 to 1 in favour of the circular ship. Without dwelling longer upon the point, I must express my opinion that the advantage is greatly with the circular vessel as regards the chances of escaping the blow of the horizontal torpedo.

But the advantage of the circular vessel does not end here. With such a vessel it is obviously practicable to concentrate your steam power and your magazines at and near the centre of the ship sufficiently to leave around them all a clear space many feet in width, which may be divided and sub-divided into very many compartments so as to limit the extent of the injury when struck by a torpedo, to a degree that is not possible with a long and narrow vessel (see Fig. 6). If Admiral Popoff's system of largely multiplying the propelling engines and screw propellers be adopted, we may say more, for we may isolate each set of engines and boilers from the neighbouring set, and thus largely increase the chances of preserving both the flotation and the propelling power after a torpedo blow had been struck. While on this point, I may admit that I consider for sea-going purposes the arrangement of the screw-propellers, and of the form of the vessel aft, would require to be modified somewhat from the arrangements and form of the "Popoffkas," in order to prevent the screws from protruding largely beyond the circumference of the vessel. As the "Novgorod" and the "Admiral Popoff" are to fight from shallow waters, the projection of their screw propellers is of but little moment,

but in a sea-going ship it would not do to allow the screws so to project that an enemy, by simply steaming past the stern in contact with it, would destroy or injure several of the propellers at once. There will be no difficulty, however, in making the necessary modifications, so that I need not here dwell upon the point. I may conclude my remarks on the defensive powers of circular vessels, by stating that I am unable to see how vessels of the usual form, can, by possibility, be made as secure as circular vessels from the blows of torpedoes and rams, and from the destructive effects of such blows.

It has been confidently stated that circular ships cannot be efficiently steered. That they answer their helm with promptness and certainty is to me, after my experiences in the "Novgorod," absolutely certain. But, in point of fact, the objection is really based on the circumstance, that while in a long ship, when she is turning round under her helm, her length comes athwart her course and takes the momentum out of her; a round ship, as she turns, has no such increased surface to oppose, and will therefore lose momentum less rapidly. This is no doubt perfectly true, but surely it is a matter of extremely small importance, and one entirely unworthy of consideration as a substantial objection to the employment of circular vessels. In every ship the steam power which gives onward momentum to her, is always at hand to take it out of her by the reversal of the engines. This is therefore, merely a question of manœuvring, which our naval Officers are fully capable of solving.

You will expect me to say a few words about the low freeboard of these vessels. In ships of ordinary form and proportion there are many objections to low freeboard, but the chief of these is reduced more and more as the length of the ship is diminished and the breadth increased, and they become of comparatively small importance in circular ships, in which the length is of course very short and the breadth very great. I will here advert only to two of the more serious objections to low freeboard ships of usual form: they would be deficient of stability, and the margin of surplus buoyancy which they would possess would be too small for purposes of safety. A collision, or an accident much less serious than a collision, would suffice to send them quickly to the bottom. More than one of the American "Monitors" were, if I remember rightly, sunk from the mere accident of a hatch in the deck being left open. But with the circular form of ship, and with a greatly rounded deck like the decks of Admiral Popoff's vessels, both these objections are very materially diminished. In fact it is quite possible in a circular ship to adopt a very low freeboard and yet to have, with a well rounded deck, ample security for all purposes, and good surplus buoyancy likewise. For example suppose we take a circular ship of 150 feet in diameter and 12 feet draught, and therefore with a displacement of about 6,000 tons. With 2 feet 6 inches freeboard, and a good round up of the deck, we can have a surplus buoyancy of 3,000 tons. A ship 280 feet long and 54 broad, with about the same displacement (6,000 tons) would have surplus buoyancy of about 300 or 320 tons per foot, and therefore, with the ordinary round up of deck, would require a freeboard of about

9 feet to bring her surplus buoyancy up to an equality with that of the circular vessel with $2\frac{1}{2}$ feet of freeboard. It is hardly necessary to remark upon the relative stabilities of two such vessels, because in either case it would be ample for all the uses to which the circular ship could be put. You will observe, therefore, that the circular form sweeps away some of the gravest objections to low freeboard. With reference to the sea flooding the low upper deck, much less of this takes place than would ordinarily be expected, and I am inclined to believe that the trials of large circular ironclads, even in channel or Atlantic waves, would develop very unexpected and satisfactory features.

In this connection I ought, nevertheless, to make it quite clear that the "Novgorod," and "Admiral Popoff," have, like the "Devastation," very extensive unarmoured houses erected above the armoured deck. The chief of these is a spacious forecastle, which of course adds greatly to the buoyancy forward when the sea rises there upon the vessel, and I do not think even circular vessels of very low freeboard could be steamed against a heavy head sea without such a forecastle, more especially, as we shall see hereafter, when driven at a high speed. The forecastle, and other deckhouses, add very greatly to the accommodation and comfort of a circular ironclad.

In coming now to consider more generally the qualities of circular vessels, and especially of fast sea-going vessels, I think it right to say most distinctly that the great value which I attach to Admiral Popoff's labours in this connection, springs from the stimulus they exert in favour of reduced length and increased breadth in ironclads. The circular ships exhibit the limit of reduced length and increased breadth, and it is in this aspect that I wish to discuss the subject. I do not profess to be able to discuss it at all exhaustively; my investigations have not gone nearly far enough for this, and it is upon investigation only that strong opinions in such a matter as this should be based. To say that circular ships can, or even to suggest that they possibly may, have high speed given to them is a startling thing, for we all know that the resistance of such a form of ship must be very great indeed. We all know that great steam-power must be needed to overcome that resistance. Still, having come to plate our ships with very thick armour, and to carry tremendously heavy concentrated armaments, we have now to ask whether the adoption of ordinary forms and proportions does not entail upon us greater disadvantages than an increase of steam power? In order to place the subject into due relation to the broad question of ironclad construction, I have to ask you to look at it from this new point of view: Hitherto the problem has been, how best to armour-plate ships? The problem to which I now invite your attention is, how best to adapt armour-plated fortresses for being sent to sea, and steaming there at sufficient speed?

This aspect of the subject is for all practical purposes a new one, and one which the progress of events has first made possible and then forced upon us. No doubt many persons—myself among the number—years ago conceived forms of floating fortresses capable of being sent to sea. But in a country like this there are many checks to rapid

progress, and in dealing with a great service like the Navy it is unavoidable that improvement should—

“Slowly broaden down
From precedent to precedent.”

It was most natural, and on the whole I think most proper, that when the use of shell guns drove the Navy to the use of shell-proof armour, the application of such armour to something like existing ships was first resorted to. It must be remembered that steam itself was only introduced into the Navy as an auxiliary to masts and sails; and although it has been continually assuming more and more importance, it is in extremely few vessels only that the use of canvas has been dispensed with. If we may believe what we read in the newspapers, the “Inflexible” herself, with her 2-feet thick armour, her 85-ton guns, and her twin engines of 8,500 horse-power is to be furnished with mast and sails. As she is to carry, however, but 18,000 feet of canvas to 11,000 tons of displacement (or less than one-half the proportion of the “Hercules”), it is clear that the sail has become completely subordinated to the steam in this ship, while from the “Devastation” and some similar ships sail has disappeared altogether. I think we may safely say that when the steam power comes to be distributed over a greater number of engines, so that all danger is removed of the ship becoming disabled by a loss of all her engine-power at once, masts and sails will finally disappear from heavily-armoured vessels. We may believe this the more confidently when we note that Naval Officers themselves, and more especially those who have commanded ironclads, or squadrons of ironclads, now cease to demand the use of sail-power in such ships, and consider that very heavily-armoured vessels should not be allowed in any way to depend upon sail for safety.

With the abandonment of masts and sails in such vessels disappears the necessity of adhering in their construction to the ordinary forms and proportions of ships; and we are now free, as I say, to consider in future what is the best form of battery, citadel, or fortress we can adopt, and what are the best means of sending it to sea under steam. I expect to have the general concurrence of thoughtful officers in saying that with armour already 2 feet thick in the “Inflexible,” and a hull to carry it made larger than any previous ship except the “Great Eastern,” it is time that we ceased to armour mere *ships*, and set about subordinating ship-shapeness and the use of sails to more momentous considerations.

Seven years ago I wrote and published a work on “Our Ironclad Ships,” in the Introduction to which I said:—“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 basis of that remark was that, I had then foreseen, that as armour increased in thickness and guns in weight, their requirements would more and more overpower the requirements of mere steam and sailing ships, and that ironclad ships would have to be made first and foremost armoured and armed sea citadels. Starting with this idea, and desiring to preserve as many of the qualities of a ship as were consistent with it, I projected at the Admiralty a number of tentative designs on the general principle exhibited in the annexed diagram, Fig. 7, the citadel having sufficient buoyancy and stability to maintain the vessel afloat at her fighting draught, and with the necessary stability, even when the ends were filled with water as shown. By the desire of Lord Dufferin, I explained my views on the subject to the Admiralty Committee of Designs, in April, 1871; and, at the request of the Committee, Mr. Barnaby, the present able Director of Naval Construction, was good enough, at a later period, to furnish certain additional observations on the subject. Between ships of this class, and those subsequently advocated by Admirals Elliot and Ryder, or the "Inflexible" herself, I cannot discern any difference of principle whatever. It has been proposed, I believe, in those cases to place cork, stow coal, &c., in the water spaces, but these are details that do not affect the general principle. It must be understood, however, that beyond claiming to have laid down this general principle of the plan I do not go; the "Inflexible's" design in all other respects being solely due, I believe, to the Construction Staff of the Admiralty.

I have dwelt upon this type of design for a reason which you will now discern. The object in originating it was, as you will see, to build a very strongly armour-plated citadel carrying very heavy guns, and to add as little additional armour as possible to that which the citadel demanded. All the armour I proposed to employ apart from the citadel was, as you will observe, that of an under-water deck 3 or 4 inches thick, and that deck I sought to make very short. Still, in time of battle, the water must be let in at the ends, and that water took the place of a belt of armour of about equal weight, and to that extent the citadel was further encumbered.

Two years after the publication of the book above referred to, I went to Russia, and there I found that Admiral Popoff had designed, and the Imperial Government had ordered to be built, iron-plated vessels of circular form for the defence of the Dnieper and of the Sea of Azof. I saw the keel of the first vessel laid, and during last autumn I had the privilege of inspecting her at Nicholaieff, and of steaming in her from Sevastopol to Theodosia and back to Yalta. I wrote my impressions of the vessel to *The Times*, and as the editor has permitted me to republish my letters, what I there said is now accessible to all.

Now the chief characteristic of these circular ironclads is that they are purely and simply sea-citadels, propelled by steam, and without

any attempt whatever to make them conform to the shape of an ordinary ship.

The question to be determined hereafter is, is this form of vessel, thus originated for coast defence purposes, and proved eminently successful for that purpose, available under proper modifications, for sea-going citadels.

I think we may fairly say that for a sea-citadel, viewed as a citadel only, apart from other features, the circular form is best, because it requires a minimum amount of armour to protect a given area or volume; or, in other words, with a given amount of armour secures the greatest amount of buoyancy. For special purposes some modified form might be preferable, but speaking generally, the circular form is the best for floating armour to protect an included space, and also for giving that equal all-round command with your guns which is so desirable at sea. Starting then with this circular armoured citadel, and wishing to propel it at speed at sea, there are several ways in which we can deal with it.

1. We can put engine-power in it just as it stands, without modification; or,

2. We can build ends to it like those of an ordinary ship, protecting those ends by a belt of armour, as in the "Bellerophon," "Hercules," and many other ships; or,

3. We can build such ends to it, and protect the lower parts of them by an under-water deck of armour, as in the "Inflexible"; or,

4. We can build around it an outer circle of thin iron, with a mere narrow belt of armour, analogous to the belt of ordinary ironclads; or,

5. We can build around it such an outer circle of thin iron, with an under-water deck of armour, analogous to that of the "Inflexible," or

6. We can build short ends to it, with either belts or under-water armour decks, but of greatly reduced length as compared with the ends of ordinary ships of large beam.

The "Novgorod" is the only actual example of the first of these cases that has yet been tried, and we may state roughly that in her, 750 tons of armour, and 56 tons of guns, are carried on a displacement of 2,500 tons, and driven at about $8\frac{1}{2}$ knots with 2,270 indicated horse-power. This confirms what we already knew, viz., that such ships will require great power in proportion to displacement. But taking not the false standard of displacement, but the better (although not perfect) standard of weight of armour and guns as our guide, we shall find nothing very extraordinary in the power required. In the "Warrior," our first ironclad, the armour and the guns protected by it weighed 1,100 tons, and 5,470 indicated horse-power was required to propel it. In our next ironclad, the "Defence," the armour and protected guns weighed about 700 tons, and the indicated horse-power employed at full speed was 2,500. Grouping these figures we have—

	"Norgorod."	"Warrior."	"Defence."
Weight of armour and of guns protected	806 tons	1,100 tons	700 tons
Indicated horse power at full speed ..	2,270	5,470	2,500
Proportion of power to weight driven ..	2·8 to 1	4·9 to 1	3·5 to 1

It will of course be said that the "Warrior" was driven at 14 knots, and the "Defence" at nearly 12, "while the "Norgorod's" speed was only 8½. But on the other hand, not only was the steam power required in the "Warrior" so much greater as we see, but even with this power an enormously long and costly vessel was constructed solely with the object of promoting speed; and when speed was by these means attained, we still had a ship with only about one-half of her protected, with exposed steering apparatus, and with other very serious defects as a fighting engine. In the "Defence" analogous sacrifices were made, but on a length proportioned, of course, to the reduced speed.

If we take a fully armoured ship, say the "Prince Consort," for comparison, we shall have the following figures—

	"Norgorod."	"Prince Consort."
Weight of armour and guns protected ..	806 tons	1,080 tons.
Indicated horse-power at full speed ..	2,270	4,234
Proportion of power to weight driven ..	2·8 to 1	3·9 to 1

Here the vessel was fully armoured, but the armour was thin, and could be extended over the whole length of a hull of pretty bluff form of moderate length. But as armour progressed in thickness, to extend it over the whole length would have been to increase greatly the size, power, and cost of the ship, and therefore we were obliged to resort to central batteries or citadels, the water-line armour alone extending from stem to stern. This of course involved a still greater proportion of power to weight of citadel and guns, although it enabled us to keep down the size, power, and cost.

We may start, therefore, by saying that the circular ironclads have started with a much less proportion of steam power to citadel armour and guns than has usually been given to ironclads, and not with an enormously greater power as many persons have been too ready to suppose; and I must say that before resorting to the adoption of enormous ends, whether armoured or unarmoured, as a means of fining the lines, it is incumbent upon us to investigate how far it is possible, or otherwise, to get high speed by merely increasing the power. As compared with ordinary forms the power required to drive at high speed a circular ship of equal displacement, will probably be from two to three times that required for an equal displacement obtained on ordinary lines, or even more; but then displacement, as we have seen, is no sufficient basis, and the problem is to find out the true basis, and to proceed upon that.

I feel persuaded that the circular ship or citadel will hereafter be

taken at least as the point of departure, if I may so speak, of our investigations. It is idle to say, as has been said, that it is impossible to put engine-power enough in it to drive it at high speed, because the engine-carrying and coal-carrying power can be enormously increased, while preserving the circular form by the plans suggested in cases 4 and 5 before given. We are just as free to extend our unarmoured hull, or our belt-protected hull, or our under-water-deck-protected hull all round a circular armoured citadel, as we have been to extend our rectangular citadel ships to great length by means of long fine ends protected either as in the "Hercules" or in the "Inflexible;" and I can see many advantages in doing so.

But there is one consideration which strongly tends, in my opinion, to favour the adoption of a short bow and stern in these vessels of extreme breadth, and that is, that the power of the vessel to steam against a head-sea would thereby be improved. This opinion is in some small degree based upon my observations in the "Novgorod," but as her speed is so small, no marked features were in this respect developed. But there are considerations, based upon the relations between wave-periods and a ship's period of longitudinal oscillation, and of the changes in these relations effected by great speed, which point strongly to the value of some elongation of the form especially at the bow in order to facilitate steaming against a head sea at speed. I have had the advantage of a conversation on this subject with that very eminent investigator of naval science, Mr. Froude, and I think I may venture to say that he fully concurs with this view, and attaches to it even more importance than I at first did. The accompanying diagram, Plate III, fig. 8, shows that, with a comparatively small increase of armour, the circle may be developed into an approximately ship-shape form of short length and great breadth.

But knowing as I do much of the mind of Admiral Popoff on this matter, I think I may safely say that he is quite as ready as you or I would be to make any modifications of the circular form which either high speed or any other special object may require. He has, as I have intimated, added even to his coast defence vessels a protrusion from the strict circular form at the stern to assist in housing the rudder-head; and for sea-going ships, he has before now suggested the prolongation of the bow into a ram. He has taken so much pains to assert and reiterate that his great object is to promote economy and efficiency by extreme shortening and broadening of ships, and has achieved, as I believe, so distinguished a success, that although he has taken the circular form as his emblem and battle-flag, so to speak, his great object would be accomplished and his victory won—and mine with his—if the present proportions of heavily-armoured ships were superseded, even though the circular form were stretched to an oval, or made pointed at the bow and stern, or even modelled into something like a ship-shape, provided only that the full benefit of extreme breadth and shortness are secured. It would be presumptuous in me, at the present stage of the inquiry, to assign perfection and finality either to the true circle, or to any one particular modification of purely circular lines. I repeat now, what I said before in *The Times*,

that I believe the circular form is itself quite compatible with high speed, and certainly it possesses very great and numerous advantages in other respects. I do not, however, refuse to bring it under the closest scientific scrutiny; I do not say that some modifications of it may not be beneficial; what I suggest is, that you, and especially those of you who influence the Admiralty, should secure for the whole subject impartial and exhaustive investigation. I am glad to say the Admiralty are having it investigated; on their behalf Mr. Froude is applying his splendid apparatus and his remarkable faculties to the resistance part of the question. But inquiry must not stop there; Mr. Froude himself, and the Construction Staff of the Admiralty, are well qualified to pursue it much further than that, and I hope they will pursue it to the end. I have myself thought the matter out sufficiently to be quite sure that many unexpected advantages will be found to gather around the principle of making even fast sea-going ironclads extremely broad and extremely short.

The CHAIRMAN: We have now had a full description of these vessels, and we find them favoured, if not backed, by the opinion of Mr. Reed, the originator and constructor of that ironclad fleet, of which we are justly proud. Therefore, if any officer or gentleman has anything to say on this subject, I hope he will be good enough to favour us with his observations.

Mr. SCOTT RUSSELL: Mr. Chairman and Gentlemen,—As no one else rises, perhaps I may be permitted to offer an observation or two. It so happens that I was one of the designers of the "Warrior," that I had something to do with the "Great Eastern," and had also to build one of the first so-called ironclad batteries; therefore I may be said to have even a little personal interest in this matter. But I come here to-day merely with the feeling that we are very much obliged to Mr. Reed for having brought this subject so clearly and so thoroughly before us, and for having added his own observations and opinions to those of the inventors of this circular system. Mr. Elder is the gentleman who first developed the great value of circular vessels for steam purposes. He was an old friend of mine, and I was very much struck by the great originality of the system, and by the great wisdom with which Mr. Elder never thought of making it a substitute for ship-shape ships; but merely brought it forward as an instrument for accomplishing certain peculiar ends for which it happened to be peculiarly adapted. For example, he meant it to be, not a substitute for sea-going ships, but to be applied to the purposes of a ferry-boat between Liverpool and Birkenhead; and he showed me that as a ferry-boat he could by this means carry far more in proportion to its mass of weight and given draught of water than by any other form, and also that it could be propelled at slow velocities with moderate power. Let me say one word on that subject, in order to be rid of it once for all. At slow velocities allow me to assure you this circular form is propelled nearly as easily as any other ordinary form, and therefore let us draw a clear distinction between talking of low velocities, like 6 or 7 miles an hour, and high velocities, such as we think necessary for our steam navy—namely, 14 knots an hour. There is no resemblance between them; and this is an admirable shape for one of the purposes, and is totally out of question for the other. With regard to the merits of Admiral Popoff in this matter, allow me to say that I esteem it quite as highly, if not higher, than that of Mr. Elder. Though Mr. Elder may have adopted the circular form, we are indebted to Admiral Popoff for having adopted this circular form and propelled it for the special purpose of naval warfare. Admiral Popoff four or six years ago was kind enough to explain to me all his views on that subject. I entirely coincided with those views, and I think this vessel a very admirable thing, so long as you do not call it a ship. Now this floating battery—for it deserves the name—of a circular form is most admirably adapted for carrying the heaviest armaments and the heaviest armour, and for the special purpose of local defence, for which it was designed. Admiral Popoff is entitled not only to our thanks, but

to our admiration. Permit me to say here confidentially that it so happened that I served professionally on several of the Commissions for Coast Defence. I had the pleasure of sitting there with some of the most distinguished Admirals and Generals whom I see here, and we discussed among other things the whole question of fixed fortresses, of floating fortresses, of self-moving fortresses, of elongated fortresses, and of circular fortresses, and we arrived at a great many conclusions which I dare not tell you here. The question which Admiral Popoff's invention raises is this—"What are the particular places in England where you think that floating batteries are wanted as coast defences?" And if you know of such places, allow me to say that his experiments show that you can make excellent vessels for local defence most economically and most conveniently of the circular form. There is another question which he raises: whether it is more expedient to propel these vessels by power within themselves, or to anchor them where they are wanted, or to shift them by tug vessels from the outside? You will find if you only settle the circumstances in which you want these defences, the circumstances will settle for you which plan is the best. In the one place you will find the fixed circular battery is the best; in another, the anchored circular battery is the best; and in another you will find that vessels conveniently moved by other vessels towing them are the best; and, finally, you will find that there are other circumstances in which it is most desirable, at great sacrifice of cost, of machinery, of complication of construction, and so on, to have steam engines to enable you to transport them from the place where they are stored to the place where they are required.

I come next to the question whether, according to a suggestion made in the paper, you ought to consider the sea-going qualities of a ship of war as qualities of the second or third rank, and whether you should place the armour or the other points in the ship in the foreground, and leave her seaworthy ship-shapeness as a secondary point. On that I will endeavour to say all I think in two or three sentences. In the first place, I call your attention to the fact that in all those qualities and quantities quoted by Mr. Reed with reference to this subject he has left out of sight the real question of a sea-going ship—namely, how long a voyage has it got to make, how much coal has it got to take for that length of voyage, and at what rate is it to steam on that voyage? Now those, allow me to tell you, as sea-going qualities and quantities are elements which, I trust, will rule our future navies, and not the question how the utmost performance can be got out of a short ship of this or that shape. I think it is most unwise to set up any theoretical notions of what the best possible shape is, and it is most necessary that for every ship, when it is about to be constructed, you should take into consideration the practical purposes for which that particular ship is wanted. If you do that, you may get a good ship, and if you are only to have a grand ship in general, without any particular duty, you will get a bad ship. If you settle what the speed of your ship is to be, that will give you the length of the ship—the minimum length. If you settle, secondly, what the depth of water is into which she must go, that settles for you the draught of water of your ship. If you then ask me what settles the breadth, I answer the weights to be carried and the sea-going qualities settle the breadth? You then say, "Having settled the minimum length, what increases the length?" I answer you in a moment, what increases the length is the length of the voyage of the ship. A small quantity of coal in a given ship will certainly let that ship go at a given speed; but it will not maintain the speed, and will not make the voyage. The ship grows in length according to the length of the voyage she has to make; therefore, I say, lay down the conditions of your ship—first of all, then make it a principle that above all things she shall be a seaworthy, sea-going ship. Thirdly, make it a condition that she shall have the power of remaining long at sea, and that implies her carrying large stores; and if you will then add the particular nature of the service she has to perform, you will find all the rest will settle itself. The last observation I have to make is an observation practically upon my old pet the "Warrior," and practically on this diagram, which Mr. Reed has given you, of a vessel with a central fortress. You all know the "Warrior" was the first vessel of this class. I think you all rather liked the "Warrior," as a sea-going, sea-worthy ship. I think also you all remember that the "Warrior" had the principle of a central battery, and that that principle of a central battery has been followed, and must be followed. Allow me, however, to differ entirely from

Mr. Reed on a point he has put forward—namely, that you cannot, without this enormous deck which he has given, and this mode which he has given of filling the fore and aft part of the ship with water, make that a good, seaworthy ship. Allow me to say that you can; that there are ample means with a central fortress of having your ship beautifully shaped, perfectly like a seaworthy ship, and with all the qualities you require of speed, stability, and endurance, without making an ugly shape of that kind. If you will permit me to entreat you, it is not to give up your old sea-going prejudices of having a handsome, ship-shape, seaworthy ship. And if you will take my word for it, neither ugly ships, nor ugly proportions, nor any of these things you have lately been used to, which have offended the eye, and have disgusted so many sailors with their profession,—I say, if you will only get rid of such prejudices as these are, you will find that you may to-day have a perfect central fort, have an unsinkable ship, have the best guns and most powerful armour, have a convenient, comfortable, and wholesome dwelling, and still have all the beautiful form and sea-going qualities which you had before. Only you must *first will it*, and then you must give those people to whom you confide its construction *full power* to carry out your purpose in the design and in the execution of the work.

MR. WILLIAM SMITH, O.E.: I wish to correct an error which Mr. Reed seems to have fallen into. He speaks of this circular shape as being merely a suggestion of the late Mr. John Elder's. Now I think the transactions of this Institution will carry you back to a period when Mr. Elder read a paper here upon the subject of circular ironclads and other vessels, and you will find he referred not simply to the ferry-boats, to which Mr. Scott Russell has alluded, but also to circular turret-ships and floating fortifications, of which he gave a variety of diagrams. There is one point also to which Mr. Reed has given considerable prominence: he says the suggestion of Mr. Elder was, that the mid-ship section of the vessel should in every case be the arc of a circle. That is a very great error; and you have only to refer to the Transactions of this Institution, published some years ago, to find that it is so. In fact, if I look at the diagrams Mr. Reed has placed upon the wall, I see there is little or no difference between them and those which Mr. Elder brought before this Institution. I think it was in 1860 or 1861, during the time the British Association Committee on steam-ship performance were sitting, Mr. Henry Wright, now Secretary to His Grace the Duke of Sutherland, was then preparing a collection of facts and materials sent in from time to time to be recorded in the proceedings of the Association; and at that time Mr. Elder described to Mr. Reed, in my presence, the idea he had in his mind, and I advised him to make a series of experiments, to ascertain the difference of resistance of that particular form which he described. He had a series of models made and experimented with them, and the results were recorded. I think he called upon Mr. Reed, who was not then the Chief Constructor of the Navy, and described his invention to him, accompanying his description by diagrams. And I am sorry to say that Mr. Reed did not at that time so fully appreciate the merits and advantages of the form of vessel then described to him by Mr. Elder as he has since had occasion to do. Under these circumstances, I think it hardly fair to give Admiral Popoff the full credit for this circular design; and that this occasion ought not to pass without my putting on record that Mr. Elder certainly was the first designer of these circular ironclads, not with their mid-ship section, a portion of a sphere, but according to diagrams exactly identical with those which we see before us.

Major-General Sir JOHN ADYE: Although this question is a naval rather than a military one, still I hope you will allow me as an artilleryman to make a few remarks, not upon the general construction of these circular ironclads, but upon the arrangements which have been made for mounting and fighting their guns. According to the description which Mr. Reed has given us, the circular ironclad has in the centre an open-topped fixed turret, that is, an iron martello tower on a floating platform, capable of moving at slow speed. The guns are *en barbette*, with a slight command over the water. Now we all know that the barbette principle affords great lateral range; but the disadvantages are, that it leaves the guns and their detachments fully exposed. These circular ironclads, therefore, if attacked from more points than one at the same time, offer no defence at all to lateral fire. And there is another danger of mounting guns in this way so close to the water, namely,

that they are liable to be commanded, and the guns and men therefore exposed to great danger. On shore we rarely, if ever, contemplate mounting guns *en barbette* near the level of the water, where serious and close action is expected. We rather seek for a high and a somewhat distant position, where the advantages of an all-round, lateral, and plunging fire are available, and where the exposure of the men and the guns is reduced to a minimum. Those are the principles upon which we construct *barbette* batteries on shore, and they do not appear to me to be carried out in the present instance. I am quite aware the reply will be, that you may get greater speed, and you may get the disadvantages of *barbette* remedied by the disappearing principle. It is true; but in the circular ships which have as yet been built that principle has not been adopted; therefore, I presume that the distinguished Officer who designed them did not find his way to mounting guns except *en barbette*. Even if that system were established, you would still have an open-topped turret, and therefore, in my opinion, the guns as now mounted, and their detachments, being fully exposed to flank and plunging fire, are not well adapted for close and serious action.

Commander W. DAWSON, R.N. : In a naval discussion upon circular vessels it does seem very extraordinary that, surrounded as we are by a great number of most experienced naval Officers, the whole discussion of such a nautical subject should be left in the hands of military men and of civil engineers. A great deal that I should have myself said has been anticipated by Mr. Scott Russell, and by what has just fallen from Sir John Adye. We are invited to consider the use of this vessel, not in its local and limited application, but as a sea-keeping ship. One point to which I wish to draw attention as to its sea-keeping qualities is this, that if the ignorant prejudices of naval Officers against a novel construction of this kind are to be met, it must be given a special name, and not be called a "ship." The very first requirement of a ship in a sailor's estimation is, that it should constitute a comfortable home, a permanent habitation, in which he can spend his life from boyhood until he leaves the Service. It is quite true that in these saucer-shaped diving-bells, or whatever you choose to call them, air will be pumped in in very large quantities; but I should recommend those who advocate this vessel as a sea-keeping residence, to ask the manager of the Polytechnic Institution to allow him to go into the diving-bell there for ten minutes. He would find abundance of air pumped in, and perhaps for that length of time he would not suffer inconvenience; but let him stop there a month, and when he has been in a diving-bell for a month, he would get a very fair idea of what a life-long residence in a sea-keeping thing of this kind means. With a very diminutive amount of light, and with air pumped in at high pressure, he will thus be able to judge of the effect which permanently living under water will have upon the spirits as well as upon the health of the fighting men. If it is desired to reconcile sailors to the adoption of a vessel of this kind for sea-keeping purposes, it must be called by some other name than a "ship." Coming to the point of the special use of such a semi-submerged residence as a vessel of war in the Atlantic: This is a point which involves considerations of fleet manœuvres which many naval Officers present are far more capable of discussing than I am, and which ought to be discussed from all sides, if vessels of this class are to be opposed or defended in the open sea. It must be remembered that this broad, exposed, and unprotected deck may be met by high-sided vessels of various classes. What would be the relative positions of the high-sided "Sultan's" and "Hercules" and the low and broad-decked vessel when they meet in hostile conflict? In dealing with such questions, we ought to regard the proposed employment of such a vessel in open water as critics; and therefore I am now looking at this vessel solely from a hostile point of view, and trying to find out its weak points, putting aside for the moment the many advantages it may have in a large area of shallow water like the Sea of Azov, and its possible advantages even in the open sea. If a sailor in a high-sided ship had to attack a broad vessel of that kind with an unprotected wide expanse of deck, what would be the natural tactics that he ought to adopt? Why, he should try to bring his armoured side as close to the exposed low-lying deck as possible, and to keep his guns depressed as close to that low, wide deck as possible. It might not be safe to lay the high-sided ship actually alongside, because, I suppose, the enemy would not be so foolish as to trust the defence of his circular

vessel entirely to guns and armour, but would have torpedoes bristling round the circumference as additional means of defence. But supposing he had such other means of torpedo defence as would make it dangerous to go alongside, the high-sided ironclad should still keep as close as it was safe to get, and the closer the better. A very few shells planted through the broad, low decks and bottom of the circular vessel, would suffice to dispose of it. We must remember that that deck presents a very large and wide target. It presents exactly what a gunner wants, not only for close firing, but also for distant firing. What a gunner likes to aim at in distant firing is not a target of great breadth, but a target of great depth—depth being to him akin to height. An ordinary ship is more easily hit when at an unknown distance, when presented end on to the gunner, than when broadside on, because a shot may, by a mis-judgment of the distance, go over the ship when broadside on, which might possibly hit the decks when she is end on. Therefore, a broad circular vessel would be far more likely to be hit than a narrow vessel. That a circular vessel would present a much smaller area for the hostile action of torpedoes is evident. But once struck by a proper torpedo charge, the advantage to be derived from cellular construction and water-tight compartments is small. A proper torpedo charge should make a hole through the bottom large enough for a coach and six to be driven through. I do not think any vessel could float with such a hole in her bottom even with all the water-tight compartments described, and torpedo charges should be so regulated that the smallest hole they ought to make would be one of that size. I do not, therefore, attach very much value to the extra amount of defence against torpedo gained from cellular construction by means of the circular principle. I find also that the armour of the circular vessel does not extend to the keel, but is the ordinary patch on the side, so that in this respect it is on an equality with high-sided ships. An artilleryman would not aim at that narrow patch, but he would try to avoid it, and there would be large deck surfaces above and bottom spaces below, which it would be quite possible to give a good account of. I have not spoken of the unquestionable advantages of the circular form, nor have I entered into the question from the naval architect's point of view; but, looking at it simply as a fighting vessel in open water, if I was given the choice of commanding either an ordinary high-sided ship with the same armament or this low-decked circular one, whether I consider the purpose of ramming or the resistance to torpedoes, or artillery purposes, I confess I should prefer the high-sided ship with its superior speed. Whatever advantage the short circular vessel might have in turning, it would have this disadvantage, that it could not possibly ram the broadside of any ship unless its own stern was very nearly at right angles to the side attacked, because the breadth of its own bow would in any angular approach keep the spear from touching the enemy, whilst the high-sided enemy aiming at any point whatever of the periphery might run at any part of the circular vessel, and would have only to keep his iron stem in a line with the centre of that saucer, with the certainty of always striking its side at right angles, so that he would most likely thrust his stem right into the heart of the citadel itself. With all its merits, there is a good deal to be said from a tactical point of view against the circular form of ironclad for deep-sea purposes, and I do not know any part of our coast which corresponds in expanse of shallow water to the Sea of Azov. I do not, therefore, see the necessity for vessels of that class being introduced for mere defensive purposes into this country. Even for the defence of the shallow banks which cover the entrance to the Thames, I would much prefer the same money's worth of Mr. Rendle's small gunboats to these costly circular ironclads, with very low freeboard, which offer very large deck targets to the enemy's fire.

Admiral Sir SPENCER ROBINSON, K.C.B.: The very late hour of the afternoon will prevent me troubling you with any but a very few remarks; indeed I should have risen a little sooner, but I thought there were others better qualified than myself to make various remarks on the very interesting lecture Mr. Reed has given us. My object is simply this, to bring back, if I could, the discussion to the point from which it started. The point Mr. Reed has very ably illustrated, and has given us a most interesting lecture upon is, whether for certain well defined purposes a circular ironclad was well designed, or whether it was not? A good many of the gentlemen who have spoken have diverged entirely from that subject. Some have gone into

æsthetic questions, and discussed with considerable blame, and no approbation whatever, the ugly ducks that have been launched upon the ocean, and that have done, and will do again, the work the country requires. I wish simply to say we have had in this lecture of Mr. Reed's a type of ship explained to us—no matter from what quarter it comes, whether the origin of this admirable ship for coast defence came from Russia, or came from Glasgow, or came from England—coupled with the fact that we have had the experience of one himself, a very eminent Naval architect, who has seen the performance of such a ship at sea, and is able to give us the whole particulars of her construction, and of the service for which she is likely to be employed, and apparently to be a master of the work she has to do. Therefore the question seems to me to be entirely this, is it not worth while for every person in the Naval profession, and for everybody who can influence the opinion of those authorities that govern the Navy, is it not worth while to consider every point of this new armoured vessel most carefully, and to see whether it does or does not contain the elements of that very great success which Mr. Reed has shown it possibly may contain? The question is certainly not as some have put it, whether a circular ship is in all respects the very best possible vessel you could put upon the ocean to make long voyages, or to fight your actions against other ships of different classes; but it is whether this circular ship is not capable of defending places which no other ship could defend, and not only capable of doing so but capable of assaulting places that no other ship could assault? Those are questions that Mr. Reed, without any dogmatism, has put before you as matters deserving the investigation the Admiralty is prepared to give it, and I think as matters not deserving the ridicule of any person connected with Naval architecture and Naval architects, and certainly not deserving the ridicule of any person who may some day or other be called upon to fight the battles of this country. Mr. Reed, having put before us the qualities of this circular ship and its adaptability for certain purposes of offence and defence, tells you that he sees no limit to its application, and that it is possible that hereafter the notorious and self-evident want of speed in these circular vessels might be cured by methods that he has not yet investigated, but that he has shown to any reasonable mind are capable of being investigated, and so that the problem may be ultimately solved. These are the points, therefore, which I think every Naval Officer and all the eminent artillerists and engineers here present should take into consideration:—Have we or not, a reason to suppose that for certain well defined purposes, men have in the circular ship the means of carrying out our purposes practically and fully? And is it not possible by further investigation to find whether the principle is not applicable still further, and whether that point of Naval architecture, that point in all ships which I should be the first to uphold, namely, excessive speed, whether that cannot be obtained in these forms as well as it can be obtained in the usual forms of ships? And notwithstanding what we have heard about their ugliness, notwithstanding that we have heard that sailors are disgusted with these ships and with recent types of war ships, we may depend upon this, if the principle is a sound one we shall never find any sailor objecting to go to sea in a circular ship or even in a square one if he is required to do so.

H. WRIGHT, Esq.: As my name has been mentioned in the course of this discussion, will you allow me to say that Mr. Elder explained to me that one of the chief features of his vessel was that high speed would be most certainly attained. The diagrams he showed to me years ago before ever the subject was brought before this Institution, agreed, so far as I can recollect, distinctly with these. I know also that he considered the revolution of the vessel would be one of the most important features in an attack upon an enemy's vessel.

Admiral W. HOUSTON STEWART, C.B.: I wish to say I had a great deal of conversation with Admiral Popoff as to the circular ironclad, and he gave me to understand he originally designed or intended it to protect certain localities in which he intended to place obstructions against the advance of ships. These obstructions owing to the draught of water could not be protected by ironclads or by fixed forts, and therefore could be readily removed by an enemy if unopposed; and it was for their protection he designed the circular ironclad. After he had proceeded with them he found that they were capable of being moved about with much greater facility, and of giving greater advantages as to their sea-going qualities, than he had

originally supposed, therefore the question was opened out to his mind and to many others in Russia, that this circular form which enabled him to carry very thick armour with a light draught of water might be used to a much greater extent than he had originally contemplated, which, as I have said, was to defend obstructed places where he could not place the usual sort of ironclads, and he could not place forts. Perhaps Mr. Reed will say if that was the idea that was in Admiral Popoff's mind—

Mr. REED : Quite so.

Admiral STEWART : It may be satisfactory if I mention a report I received the other day from the Commander-in-Chief in China, who commands one of our ironclads designed by Mr. Reed. Mr. Reed has touched on a subject that I am sure is often present to the minds of Naval Officers—the behaviour of ironclads in a sea-way. Admiral Ryder writes to me from the "Audacious" saying, "Whatever objections may have been raised to ships of the 'Audacious' class, the longer experience I have of them the more I am struck with their wonderful steadiness. I have just lately made (he says) a passage running before a heavy sea and strong wind, all my stern ports barred in, and to our great surprise the ship did not roll more than 2° to 1° each way. I half made my mind up to broach her to, to see what she would do in such a sea, but the helmsman did it for me. In giving the ship a yaw he brought her to the wind, and positively to our great surprise she declined to take any notice of the sea at all. An ironclad flag-ship of a first-class naval power accompanied me. We were both proceeding before the same sea. My flag-ship rolling 2° to 1°, the flag-ship of the other power rolling 20°. I am happy to say that we are on the most friendly terms: if the conditions were altered I think the steady platform would have decidedly a great advantage."

Admiral INGELFIELD : The words "ugly, unhealthy, and unwholesome" were applied just now to one of our principal ironclads. I have just returned from Malta, and I saw the "Devastation" having come into port from a long cruise. She went out with the Mediterranean squadron, and returned a month or six weeks after their cruise was over; and the Captain reported to me she had only two small defects, and those were put to rights in a couple of days. He spoke of the ship as being perfectly seaworthy, wholesome, and comfortable for the men and Officers, and everything he could wish. I think it is my duty to bear this testimony to the qualities of one of our special ironclads of the present day.

Admiral SELWYN : I think the points raised by Mr. Reed in his paper have scarcely received the discussion which he might well have expected. I have always myself been an advocate of Mr. Elder's ideas of marine construction, and I still hold to the same theory as far as it is a theory; but I am disappointed to see that in seeking for a less draught of water Admiral Popoff has thought it necessary to give a very abrupt turn-up to the side of the ship, and I think in this probably is to be found the secret of the extreme power required to drive that particular circular ship. Mr. Elder's models, although they did preserve a species of spherical form, yet provided quite sufficient capacity in tonnage to have carried all the provisions, stores, guns, and armour that we could possibly have wished to put into them; but he also did not ignore the fact that screws were a very awkward mode of propulsion in such a vessel, and he provided another form of internal propulsion which I am persuaded will one day take its place very high among the modes of propulsion, if indeed it does not supersede all others, namely, that of the hydraulic propeller, thus obviating the exposed situation of the screws, which is one of the chief defects of this vessel, and which might probably cause their destruction by the very smallest unarmoured vessel that could run against them, Mr. Reed says that by elongating the vessel better lines can be obtained, and therefore more speed; and those gentlemen who remember what the shape of the centreboard yacht is, or the form of a Chinese junk, would see what might be the elongation preserving the spherical outline. I do not exactly like the form Mr. Reed has shown, and an approach to the centreboard form would give additional advantages while it might preserve the sail power. I do not care how much power is put in a vessel, or how much coal if you tell me I must not use it until I go into action, for under such circumstances no Officer or crew can be properly trained in the use of their vessel. If it be necessary to go to sea and carefully preserve a very low rate of speed, and

to limit the use of the steam till even the engineers get rusty over their furnaces, I think decidedly sail power should not be ignored. If the centreboard boat with its single sail, or the Chinese junk with its three sails at the outside can obtain very high speed, I think there is no earthly reason, if we will consent to abandon all our traditions about the placing of masts and the description of yards, why we should not get sail power in these circular vessels quite sufficient to drive them about the ocean when steam is not allowed or available. But the question of armour carried on these vessels assumes a different complexion the instant the spherical outlines are preserved. It then becomes possible to carry a thickness almost unlimited as well eight feet as eight inches. I am not one of those who attach any very large importance to the sawing motion advocated by Mr. Elder, but I think ramming will have a great offensive effect in that as in every other ship; and neither am I one of those who mistake the question as to the surface presented by a circular vessel of this description considered as the area of a target. I think if you show me a target whose elevation is twenty feet above the water-line and some six hundred feet long, I shall be more likely to hit that than a circular vessel which exposes no height above the water-line and only half the length, for she can be sunk up to the edge of her armour in action, therefore I do not attach much weight to such objections. To the question of Artillery *en barbette* I do attach a certain weight; but it disappears before the fact that Admiral Popoff has seen that the barbette battery is not so applicable as it might be, and that the new ship is expressly designed for carrying disappearing carriages. My friend, Major Moncrieff, is in Scotland, or I am quite sure he would show you that his principle is particularly applicable to this form of ship. The question of a steady platform has been, since I can remember Artillery questions in this theatre, regarded as of the very highest importance, and considering that more defence must be given to our shores in the absence of our fleets at sea, it is no answer to say that a comparison may be drawn between the slightly sea-going ship and the unsightly sea-going ship in favour of the slightly ship if it be not proposed to put forward for that purpose any such ship. This is devised for a special purpose, and as it has answered beyond expectation is it not worth while to consider that principle as one to be discussed and provided for in our own Naval Estimates, instead of ships which have been said in the Houses of Parliament to be entirely unfit to defend the coast on account of their draught of water? I am not one of those who undervalue the comforts of a sailor's home, but I am one of those who do not fear to say that there will always be found sailors ready to go to sea in anything thought to be fit by the powers and authorities that be, for the defence of the nation. I believe the principle to be good, that it may be successfully developed so as to give high speed under steam and great carrying power whether of guns or armour, and that it is not at all impossible so to develop and mast it as to combine with those qualities great powers under sail and practical unsinkability.

Mr. E. J. REED: I am very much obliged to the Naval Officers who have spoken in this debate with the single exception of one, and that is my friend Captain Dawson, because I do not understand what object any thoughtful Naval Officer can have in view in introducing epithets like "diving bell," and phrases of that kind into what ought to be, and what I, to the best of my humble ability, endeavoured to make, a simple scientific discussion. I shall not answer Captain Dawson because I think he has been answered already, and certainly the spirit of his speech has been answered by other Naval Officers who have spoken. Nor shall I take very much pains to reply to my esteemed friend Mr. Scott Russell, because he has an advantage over me at all times, which is a very serious one, and with which I cannot compete, for if not omniscient he knows everything. And he has done a good deal too, because I always note in these discussions it is impossible to speak about the "Warrior" in never so incidental a manner without bringing Mr. Scott Russell to his feet to claim the design of her. Well, I have heard him claim that design a great many times, and I have heard him very justly claim for the design "great merit," and I am sure I have spoken of the "Warrior" on a thousand occasions with great consideration; but we are discussing to-day, Sir, how to send to sea very thick armour and very heavy guns, and I read in *The Times* newspaper a few days ago that the Chief Constructor of Portsmouth Dockyard had stated that the "Warrior" was relegated to harbour service, as a ship unfit to take her part in the fights of the future of our

Navy. Therefore I do not understand why we are to be debarred by continual harpings back upon the design of the "Warrior," from discussing the new phrases of the question as they arise. Mr. Scott Russell undertook to tell us all about these circular ships. At first he refused them the name of ships, as did Captain Dawson; and I am sure I refused them the name of ships also. I took very great pains to make it clear I was asking this Institution to consider not the construction of ordinary ships, but the construction of engines of war, the primary objects of which were to take to sea heavy guns protected by thick armour. And that observation, which I carefully abided by throughout my paper, answers a great deal that has been said in disparagement. Mr. Scott Russell undertook to tell us all about these circular vessels, but he seems to have been wrong in what he told us, because he told us they were introduced by Mr. Elder only for ferry purposes, and he was immediately succeeded by a gentleman who told us it was distinctly a mistake, that they were introduced for the kind of purpose we are here considering to-day.

MR. SCOTT RUSSELL: I said they were supplied by him to be used for that purpose.

MR. E. J. REED: I accept the correction, but I found Mr. Scott Russell's remarks went so wide of the various interesting points that I hoped they would be confined to, that I am obliged to track him into these very desultory observations which he made. Mr. William Smith remarked that Mr. Elder did design these vessels with flat bottoms. I should be sorry to say he did not. Mr. Smith also stated that Mr. Elder showed me the designs of these vessels. That is certainly most true. It is equally true Sir Samuel Baker showed me his, but in both cases I have spoken only from memory, for, as I have said, my object was not to press these views upon the public, but simply to comply with the request of the Council of the Institution to explain these vessels. I hope that that fact will be borne in mind, because I have not appeared here to-day for the purpose of thrusting and forcing circular ships upon anybody's adoption. I concluded my paper, as Sir Spencer Robinson kindly reminded you, by simply saying the subject seemed to me to be so important as to require the careful and close attention of the Admiralty, and I expressed my confident opinion that the Officers of the Admiralty associated with Mr. Froude were quite capable of working the thing out; and I am quite sure from the very proper spirit in which Admiral Stewart was good enough to address the meeting you will infer that this subject will receive full consideration.

ADMIRAL STEWART: I intended to say, though I omitted to do so, that the question did deserve and should receive the greatest consideration.

MR. E. J. REED: I am much obliged. I am sure that is all that I desire. I have no object whatever in view except seeing the principle of short lengths and great breadths made available to our Navy, in so far as it is consistent with other qualities. I must turn again to Mr. Scott Russell, and distinctly disclaim the strange imputation that he brought against this paper and myself, when he said I had asked you to treat as altogether a secondary thing the seaworthiness of the sort of vessels I was discussing. Why, I took a good deal of pains to explain the grounds upon which I thought such vessels could be made thoroughly seaworthy. I never put seaworthiness into any secondary position, because I take it for granted that every man who undertakes to design a ship in which the British sailor is to be sent to sea, will make the seaworthiness and safety of that ship his first consideration; and I may say more than that; I may say—and I am sure the distinguished Officer under whom I served, and who is present, and who has spoken, will bear witness to the fact—that so far as my humble influence in his office went, it was always against the adoption of contrivances and schemes for sacrificing the seaworthiness of British ships. Mr. Scott Russell further said, that the speed of a ship at once determines its length, and that is a doctrine I have heard him propound many times before. (MR. SCOTT RUSSELL: It is not quite accurate.) Well, perhaps a little inaccuracy will be excused in me as well as in others. I understood Mr. Scott Russell to say, and I have often thought I heard him say the same before, that when you have determined the speed it will give you the length. (MR. SCOTT RUSSELL: I added the word "minimum" length.) If I had heard that word I should have attached a different value to the observation. I think from Mr. Scott Russell's point of view, it is reasonable to suppose that the speed of the ship does determine the minimum

length. I do not myself believe it does anything of the kind. I believe, and that is precisely the point I want brought out in the investigation of this subject, that the length has so much to do with the quantity of armour you are obliged to carry in armoured vessels, that you must not make it the first consideration in determining the dimensions and form of your vessel. He says, and he finished with that, that you, gentlemen, can have all you want without departing from handsome forms and thoroughly sea-going ships. I do not suppose anyone ever doubted that proposition, and I should hardly think a meeting of cultivated gentlemen in the centre of London need to be told that all our plans and discussions are not based upon the assumption that you cannot have what you want if you choose to spend unlimited money in obtaining it; but our efforts are always directed to get economically, cheaply, and in conjunction with a number of other things, what we want. I think it would be perfect madness for the administrators of the Navy to set up an æsthetic standard, which, at the best, changes from day to day; for people who used to imagine every ironclad the ugliest thing possible, now consider some of the ironclads as amongst the handsomest productions of the modern epoch. I distinctly remember the Board of Admiralty, consisting of some of the most eminent naval Officers of the Service, requiring to steam several times round the bow of the "Hercules," because they thought it was the handsomest and most appropriate bow for a ship which they had ever seen. With regard to the origin of these vessels, I do not wish to be understood to have touched upon the respective merits of Mr. Elder, Sir Samuel Baker, or others in this matter; in fact, I think myself it argues rather a low standard of feeling, when we find continually in discussions of this kind, when we are dealing with actual results that have been obtained, people who proposed them in an abstract and theoretical form spring up and almost stop the discussions upon the essential merits of the thing, to discuss who had the first finger in it. I do not wish to say anything too immodest, but I must say I attend a good many discussions in which, if I thought it prudent and proper, I might say I had thought beforehand of the novelties then being propounded, but I do not think that is a subject to engage our attention in matters of this kind.

Sir John Aclay made some remarks, which are very true, with regard to the mounting of guns on the *en barbette* system; but I need not point out, because Admiral Selwyn has stated it, that Admiral Popoff in his second vessel abandoned the *en barbette* system, which was quite an incident of the first design, and has adopted the disappearing principle in the second, and no doubt he is perfectly free in so far as any limitations of the circular form are involved, to adopt turrets or any other means of carrying guns that may be desirable. There is nothing in the circular system at all to interfere with that. Admiral Stewart appealed to me as to the objects with which these vessels were introduced. A memorandum has been put into my hand to-day by a friend of Admiral Popoff, as a point for me to fall back upon, if necessary. "The idea of circular ironclads was originated in a desire to strengthen the defences of Kertch Strait and of the Dnieper Liman; and, therefore, these vessels were built for the special service, viz., the action behind certain obstructions, such as, for instance, a row of fixed torpedoes, &c., laid down in the narrowest place of these Straits, so that these vessels may choose the distance, behind that line, and on approach of the enemy towards that line, they can retreat, and place themselves at such a position that the men at the guns would be safe from the rifle fire of the enemy. Thus, the open turret and speed of eight knots of the 'Norgorod' do not form any deficiency whatever, considering the real purpose for which that first ship was designed." I feel sure that, in the minds of the bulk of this meeting, the subject has been lifted by my paper off the narrow basis in which it would naturally be placed by many persons. I view it only from this point of view. The "Inflexible" is our latest design. I hope, in referring to her, I shall not be supposed to view the ship depreciatingly. I think the vessel is a vessel of remarkably high character, which will be found to express the power of this country in a most admirable manner; but, still speaking quite abstractedly, and with a view to the future progress of design, I simply say we must recognize in such a construction the existence of those lengthened ends. I believe the circular form, or the circular form with a bow, for sea-going purposes, will be found to give advantages even over this type, and you have heard from the

responsible head of the construction branch of the Navy that the subject is receiving his consideration: therefore I do feel I have not brought an unworthy subject before you. I will take the liberty of thanking Admiral Inglefield, as well as Admiral Stewart, for their kind feeling in choosing this occasion to say a good word, and a practical word coming from trustworthy sources, respecting the qualities of certain of Her Majesty's ships. You know here well enough how anxious a task the construction of those ships is, and you have also heard to-day how ready some persons are to cast discredit, contumely, and ridicule upon them. It is a very satisfactory thing to know, when ships get to sea on service, that those vessels give satisfaction to their Officers. Here we find a flag-ship in a distant part of the world, and another after performing a lengthened voyage in the Mediterranean, giving a good account of themselves, and it is very gratifying that, in meetings like this, Officers should have the generosity and spirit to rise and say that Her Majesty's ships are not what many persons suppose them to be, but are efficient and perform their duty well. I thank you, Sir, and the meeting very much indeed, for the extreme kindness with which you have listened both to my paper and to my remarks in reply.

The CHAIRMAN: I am sure every one present will join with me in offering a hearty and cordial vote of thanks to Mr. Reed for his very excellent lecture.