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## Royal United Services Institution. Journal

Publication details, including instructions for  
authors and subscription information:

<http://www.tandfonline.com/loi/rusi19>

### The Corrugated Ship

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Published online: 11 Sep 2009.

To cite this article: Captain G. S. Macilwaine R.N. (1912) The Corrugated  
Ship, Royal United Services Institution. Journal, 56:417, 1515-1534, DOI:  
[10.1080/03071841209435578](https://doi.org/10.1080/03071841209435578)

To link to this article: <http://dx.doi.org/10.1080/03071841209435578>

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# THE JOURNAL

OF THE

## ROYAL UNITED SERVICE INSTITUTION.

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VOL. LVI.

NOVEMBER, 1912,

No. 417.

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### THE CORRUGATED SHIP.

By CAPTAIN G. S. MACILWAINE, R.N.

On Wednesday, 16th October, 1912.

Rear-Admiral the Hon. T. S. BRAND in the Chair.

[See photographs facing page 1526.]

#### ORIGIN OF IDEA, AND STEPS WHICH LED TO ITS EMBODIMENT IN A SHIP.

THE corrugated ship is the subject of my paper.

Before commencing it I should like it to be clearly understood that I hold no brief for this ship, and am in no way commercially concerned, either with her or her management.

The idea of the corrugated ship was worked out by Mr. Arthur H. Haver, Naval Architect to the Monitor Corporation.

Photographs have been prepared which will assist in the following of the paper, both as regards the exterior and interior description of the ship.

Mr. Haver's experiments with corrugated models showed a reduction in effective horse-power of from 14 per cent. to 23 per cent.

The confidence of the Corporation in Mr. Haver was sufficient to lead them to give an order for a ship on his discoveries, and the "Monitoria" was the result.

The "Monitoria" was so successful that she was followed by the "Hyltonia," a ship on similar lines, and built to the order of the same Corporation.

The "Hyltonia" proved to be even more successful than "Monitoria."

A third and similar ship was launched in May last, a fourth in July, a fifth of somewhat smaller dimensions is now being built, a sixth has been contracted for, and a seventh is being built in Norway.

The builders in this country are Messrs. Osbourne, Graham & Co., Hylton, Sunderland.

These builders had built several other ships of the ordinary or plain type, of exactly the same dimensions, with identical machinery and propellers.

The "Monitoria" has been running for three years, and the "Hyltonia" for one. So that a direct comparison can be made between the two types.

The dimensions of "Hyltonia" are:—

Net register tonnage, 1,149.

Displacement, 4,614.

Dead weight carrying capacity, 3,340.

Length between perpendiculars, 279 feet.

Beam, 39 feet 10 inches.

Draught, 18 feet.

Freeboard, 3 feet.

The evolution of the corrugated ship was due to the inductive process, of which the great Darwin said, "My mind is so fixed with the inductive method that I cannot appreciate deductive reasoning."

To those who go down to the sea in ships or do business in great waters the idea of the corrugated ship will probably be new; it is, however, one which has given rise to considerable discussion, and, it is feared, some searching of hearts among naval architects.

Mr. Haver's experiments were carried out in the Caw's pendulum tank, which, as its name implies, is a tank of water in which the models are actuated, and resistances determined, by a pendulum.

There is only one of these tanks in England, and that is in Sunderland.

The pendulum is perhaps the most beautiful, the most delicate, and the most accurate of Nature's instruments.

There are many uses to which the pendulum is applied, its application to the comparative determination of ships' resistances was, to my mind, a most brilliant idea, one of which more will probably be heard.

It is claimed for the corrugated ship that she fully realized the expectations formed on the experimental results on which she was built.

#### A VERY CURSORY GLANCE AT SHIPBUILDING AND SHIPS.

The first ship I went to sea in was a three-decker of 131 guns and 800 horse-power.

There were some remarkable ships in those days, both sail and steam, but on what principle they could have been built I do not know, for at that time Fronde had not given to the world the work which later made him so famous.

Some years after that I served in one of the earliest of the Reed ships, and I remember the impression created by the inclination tests for stability.

After that we began to hear of Fronde, his experiments and eventually his tank.

The corrugated ship follows a number of digressions from the normal, some of them more or less ephemeral, and is, I believe, destined to a more prolonged life than some of her predecessors.

Treading on her heels comes a further development on apparently analogous lines, which I believe to have potentiality; I mean an altered form of bow suggested by Lord Rayleigh.

#### THE CORRUGATED SHIP DESCRIBED.

Let us now consider what a corrugated ship is.

She differs from the plain ship in that she has two corrugations, or projections, running in a fore and aft direction below the load line.

From the top of the upper corrugation to the bottom of the lower is thirteen feet three, the groove between may be said to be of similar dimensions to the corrugations.

From the inner edges of the frames the corrugations project twenty-two inches; they taper forward and aft until they merge into the normal form of the ship's ends.

It is not to be understood that any sort of corrugations will suit any ship, or that no more than two will be carried; experiments are necessary until the most suitable form is discovered.

And now, having got our corrugated ship, let us see what she has to say for herself, let us put her in the dock—not the dry dock this time, the felon's dock—and try her for her life, for she is suspect among the experts, and is charged with fraudulent misrepresentation. She will make no attempt to cloud or obscure the issue, she asks neither partiality, favour nor affection. She demands a fair field and no favour.

#### THE CLAIMS OF THE CORRUGATED SHIP.

Her claims are :—

1. That she is stronger than the plain ship.
2. That she is steadier at sea and that her stability is greater.
3. That vibration is much reduced.

4. That though her tonnage remains the same her capacity for cargo, both bulk and weight, has increased; that her construction facilitates the handling of cargo in her holds; that her cost of construction is no greater, and in time will probably be less, than that of the plain ship.

5. That she is handier, answers her helm more quickly.

6. That she is faster for the same horse-power, or more economical in fuel for the same speed.

Before commencing a consideration of the various claims, two points may be mentioned.

At sea the screw can be seen working, and this, I understand, is not possible in an ordinary ship.

The wake of the ship is peculiar, it is not so broad as in an ordinary ship, and the water is less disturbed.

Both these peculiarities are apparently due to the construction of the ship.

With a view to gaining some personal experience I made a passage to Kronstadt in a corrugated ship, and spent a month on board.

From Liverpool to Barry and from Kronstadt to Umea in Sweden, we were in ballast.

From Barry to Kronstadt there was a full cargo of coal.

From the Swedish coast to Liverpool a heavy cargo of pit props was carried.

#### AN EXAMINATION OF THESE CLAIMS.

I will now take the various claims in order.

The idea of greatly increased strength from a corrugated side was what first attracted me to this novel idea. A simple and convincing experiment strengthened the idea, and my experience at sea confirmed it.

You see that a plate, which plain, has very little strength, is when corrugated enormously strengthened.

It does not follow that the corrugated ship is strong in proportion, but the experiment which you have just seen must carry a certain amount of conviction with it.

At sea a certain sense of rigidity is got, which tends to confirm the belief in greatly increased strength.

In the "Hyltonia" every alternate frame has been left out under the highest classification of the British Corporation, a fact which seems to prove that they consider the corrugated ship a strong one.

The "Hyltonia's" frames are 48 inches apart, as against 28 inches in "Monitoria." This 28 inches was a concession to the corrugated idea, the usual frame spacing is  $23\frac{1}{2}$  inches.

The difficulty of fairing indents has been urged as an objection to corrugated sides, and as it is ultimately a question of strength of construction, perhaps I may refer to it here.

The "Monitoria" has been running for three years, and has never received more than can fairly be said to have been trivial damage to her hull.

The "Hyltonia," during her year's work, has not been damaged.

I saw, and felt, "Hyltonia" take rather heavily against a lock wall, and was surprised at the way she stood it; there was not a mark on the corrugation where she struck.

I have no hesitation in saying that of the two the corrugated ship is much less vulnerable than her plain sister, that she would stand collisions of all sorts better, and in case of injury would be more easily repaired, and that she is in every way much stronger than the plain ship.

Increased steadiness at sea must be experienced to be appreciated. So far as my personal experience went it went to prove the corrugated ship a steadier ship than the plain ship as regards both pitching and rolling, and in all weathers. The confidence in the steadiness on board is such that the water cans in cabins and bath-room and coal scuttle in saloon stand unsecured on the deck.

That the corrugations increase the steadiness is beyond the possibility of a doubt.

The question of increased stability is more difficult.

Without attempting to go into the matter scientifically, it would appear to me possible that the altered form may necessitate a re-consideration of the method usual in inclination tests.

From a stability point of view the ship inspires confidence at sea.

In one of her runs "Monitoria" carried 1,246 standards of wood, about 90 per cent. of which was mining timber, the odd 10 per cent. pit props.

The deck cargo was 43 per cent. of the whole.

The average height of the deck cargo was 18 feet.

On another occasion about 1,300 standards of pit props were carried.

In the passage I made in "Hyltonia," she had a very heavy cargo of pit props.

Had I not actually seen and experienced it I should have said it was quite impossible for a ship to carry such a load.

For a variety of reasons it is difficult to give actual figures, but the average height of the wood from the deck was not less than 19 feet, and what was carried on deck could not, I think, have been less than 45 per cent. of the whole cargo.

With these deck cargoes about 428 tons of water is carried in the tanks.

Such things can only be done by ships of abnormal stability.

Though many similar cargoes have been carried, no loss of cargo has ever occurred.

This appears to throw a strange light on the usual tests and calculations for stability.

At Garston and other docks the corrugated ships are looked upon as phenomenal carriers of deck cargoes.

In water ballast the vibration is very slight, it decreases with the immersion of the ship, and when she is fully loaded it may be said to disappear.

My experience was gained in the ship with the fewer number of frames, and it seems fair to argue that the greater the number of frames the greater the rigidity, the less the vibration.

It is evident that the construction of the ship increases her carrying capacity.

As an illustration, "Hyltonia" early this year brought from Cyprus a cargo of locust beans on charter.

She actually carried 85 tons more than was estimated for, a circumstance which the shippers no doubt viewed with a certain amount of satisfaction.

The absence of stringer plates greatly facilitates the handling of cargo in the holds; it also improves the stowage and increases the capacity.

Another and very great advantage is that internal inspection is much easier, corrosion more readily detected and more easily dealt with when discovered.

Leaving out alternate frames in "Hyltonia" meant a saving in dead weight of 50 tons.

Besides watching the way in which the ship steered, I took an occasional trick at the helm, and there is no doubt that "Hyltonia" is an extremely handy ship and answers her helm quickly.

There remains the claim to increased speed or its complement, reduced expenditure of fuel to get the same speed.

This claim has, to me, been satisfactorily and conclusively established, and I hope the figures I am able to give will convince others that I have a solid basis for my belief.

All figures given are genuine. I may say I am in a position to guarantee them.

When travelling in ballast and at the same number of revolutions the "Hyltonia" made on one trip an average of 7.88 knots an hour, in the other 8.7, but the conditions of wind



and sea were different in the two passages, and a ship when light is such a plaything of the elements, that it is perhaps unnecessary to pursue this point further.

From Liverpool to Kronstadt a cargo of coal was carried—3,025 tons.

Bunker coal, water and stores brought the total dead weight to 3,340 tons.

The draught of water was 17 feet 9 inches forward, 18 feet 3 inches aft.

The engine distance was 1,832.7, actual, 1,758.

Average revolutions, 57.6.

Expenditure of coal, actual progress, 9 cwt. per hour, or 10.85 tons per day.

Average speed, 8.5 knots.

Average slip, 4.07%.

Average distance per ton of coal, 18.7 miles. The coal was Lancashire, not the best steaming coal.

These are interesting and instructive figures.

#### A CONSIDERATION OF THE EFFECT OF CORRUGATIONS.

It is now that the effect of the corrugations begins to discover itself.

I may perhaps here mention that at 16 feet the screw is fully immersed, and that the full effect of the corrugations is not realized short of this draught.

The space between the corrugations seems to act as a conduit pipe supplying the screw, which, in its turn, seems almost to play the part of a pump, drawing a solid body of water along the ship's side in which to work.

A curious effect, apparently due to the corrugations, was noticed in a Swedish port.

The ship was moored head and stern, and there was a light breeze direct on one beam with a light current in the same direction setting up small waves on the ship's side.

A boat was made fast to the Jacob's ladder on the weather side with a short drift of painter, and, as might be expected, kept bumping against the ship's side, driven on to it by wind and tide.

Astern of this boat and secured to the ring in her stern was a second boat which actually floated clear of the ship, being apparently thrown off, against wind and tide, by a back wash from the corrugations, which were immersed.

When the painter of the first boat was given more drift she, too, floated clear of the ship.

A passing ship, which increased the wash on the ship's side, had the effect of making the boats float further off, and an increase of the breeze had a similar effect.

A bottle filled with water so that it sank was put over the side, and when lowered below the upper corrugation was drawn into the groove between the corrugations, and when there felt as if its weight in the water was distinctly reduced.

This effect was noticeable both sides of the ship, weather and lee.

At sea and in a beam sea the back wash from the corrugations reduces the force with which water is taken on board.

In these directions, as in others, a field is open for investigations which might prove interesting.

Having watched the corrugated ship at sea, and having given the problem the best consideration of which I am capable, it would appear to me that the advantages claimed under the head now being dealt with can be considered, principally, as a question of reduction of slip.

On the passage out the average slip was 4.07 per cent.

One day it was 10 per cent., another 6 per cent., another 5.8 per cent., while on five days it did not exceed 2.5 per cent., and one day it was .6 per cent.

The days of the higher percentages had something special in the way of wind and tide to increase the slip.

Possibly similar remarks might be made in favour of the days of low slip, but I have some interesting figures going to show that the lower percentages were nearer the normal than the higher.

In March of this year "Hyltonia" left Glasgow for Venice with coal drawing 16 feet 9 inches forward, and 17 feet 2 inches aft, the corrugations were therefore immersed.

After experiencing very heavy weather in the Bay, fine weather was experienced from Gibraltar to Venice.

The average slip for these nine days was 1.2 per cent., on two days it was nothing, the highest day was 3 per cent.

Leaving Alexandria for Dunkirk the draught was 15 feet forward and 15 feet 2 inches aft.

At this draught the upper corrugation is not immersed.

Of the 18 days on this passage nine showed a slip of less than 10 per cent., the average for the nine days being 8.57 per cent.

This second run appears to prove the advantage gained by the immersion of the corrugations, the increase of slip being evidently due to their not being properly immersed.

The weather was the same during these two runs.

On the second run the slip was perhaps a little below what an economical ship of the ordinary type would have shown.

There are, of course, no currents to speak of in the Mediterranean.

On the homeward passage, which I made in "Hyltonia," her average slip was 11.1 per cent., but as she was piled with a deck load of timber 19 feet high, and as there is nothing at all approaching this with which a comparison can be made, there is no more to be said, except that in view of the bad weather experienced in the North Sea, and the resistance offered by the deck cargo to the wind, an average of 11 per cent. of slip is a remarkable performance.

The "Monitoria's" figures for slip are practically the same as those of "Hyltonia."

On one run of nine days, Glasgow to Kronstadt, the average slip was 2.5 per cent.

On a homeward run, St. Petersburg to Liverpool, the average for the nine days was 3.2 per cent.

When the engineer officers of these ships claim in fairly fine weather an average slip of 2 per cent., their claim would appear to me to be not only fully justified, but over the mark.

So far as I have seen an average of 1 per cent. in fine weather might be claimed, for on many days there is no slip, and generally the steering was bad enough to account for 1 per cent.

Slip is an evasive element and difficult to trace home.

I will pursue my line of argument on an average slip of 2 per cent. for the corrugated ship.

I hope I am not putting it too high when in plain ships of the class and build of the corrugated ship I assume a fair average slip to be 13 per cent. for an ordinary passage.

From 13 per cent. to 2 per cent. gives a very large reduction in favour of the corrugated ship.

The engine speed of the corrugated ship at 58 revolutions, her normal sea speed is nine knots, and she travels 18 to 19 miles per ton of coal in moderate weather.

A reduction from 13 per cent. to 2 per cent. in slip means a saving of over a ton of coals a day, the expenditure being about 10.8 tons a day with 630 h.p. in the corrugated ship, against about 12 tons a day with from 700 to 750 h.p. to drive the plain ship the same speed; figures which will, I believe, be found to be below the average.

With better steaming coal a further saving of half a ton a day has been effected, reducing the daily expenditure from 10.8 to about 10.35 tons.

This saving must have been what the prophetic Shakespeare had in his mind when he wrote of the snapping up of unconsidered trifles.

That slip is reduced in the corrugated ship, I consider to be an incontrovertible fact.

There would appear to be only one way of accounting for the reduction : it apparently must be due to the corrugations.

The revolutions for a given speed are fewer, this proving the propeller to be more efficient.

That increased speed is obtained for the same horse-power, or, that less fuel is consumed for the same speed, has been, I consider, established.

When the reason for this is sought the problem becomes difficult.

I have already expressed an opinion as to the direction in which a partial solution of the difficulty can best be sought, but more is required for a complete solution.

To the lay mind the unavoidable conclusion would appear to be that the resistance offered by the ship has been reduced, but we know that this is impossible ! for wetted area has been increased, and by long established theory resistance increases as wetted area !

Perhaps the engineer will be able to solve a problem on which naval architects, so far as I have been able to follow the discussions, have been unable to agree.

Indicator diagrams from the engines of the corrugated ship are at the disposal of anyone wishing to have them for purposes of analysis and comparison.

#### **A MORE CONCRETE ANALYSIS OF ADVANTAGES CLAIMED.**

All the claims made on behalf of the corrugated ship have been for me satisfactorily and conclusively established.

Some of them can be represented in figures, others only in terms.

Lightly built and heavily engined torpedo craft could be strengthened almost to infinity, regulated to will.

I am almost inclined to believe that the terrible results of under-water collisions with submarines would have been mitigated had these vessels been corrugated.

All sorts of vessels under all sorts of conditions at sea would be steadier if corrugated.

Considerable increase of stability would be secured.

Vibration would be sensibly reduced.

The cargo carrying capacity of the ships already built has been increased 3 per cent. to 4 per cent. There is a prospect of a higher percentage in future ships.

Reduced cost of construction, through reduction of labour owing to simplification of construction and reduced amount of material used in construction, the material saved in weight going to increase the carrying capacity.

A large reduction of slip compared with plain ships.

A reduction of h.p. for the same speed of anything up to 16 per cent.; possibly more, or an increase of speed for the same expenditure of fuel in proportion.

A corrugated ship is carried about 20 per cent. further for a ton of coal than a plain ship of similar dimensions.

For a number of passages "Monitoria" made about 3.5 miles more per ton of coal than her plain sisters.

This, in a war ship, means either increase in effective range, or increase of armour, armament, etc., advantages which cannot be ignored.

The corrugated principle is applicable to vessels of all sorts, from the yacht to the most heavily armoured battle ship.

We have in it a means of at least improving the prospects of recovering a certain cup from across the water.

The mercantile advantages are manifest.

As regards Imperial ships, it would appear to me that, in addition to other advantages, the system might tend to reduce the chances of penetration of armoured ships when, as in a celebrated naval action, they roll and are liable to be taken between wind and water.

Being of an extremely critical, even sceptical disposition myself, I cannot, and do not, expect all my views and experiences to be immediately and universally accepted, the more so as they appear to conflict with long established theories.

There may be those to whom the experiences of a practical professional man, one without any axe of his own to grind, may appeal, and who may be inclined to look into the matter for themselves.

I have endeavoured to tell a plain and unvarnished tale of a discovery in which I believe.

I commenced by saying I was in no way commercially concerned, now perhaps I may say that I am actuated by patriotic motives only.

#### **SOME PRACTICAL SUGGESTIONS AS TO THE BUILDING OF CORRUGATED SHIPS FOR NAVY AND MERCHANT SERVICE.**

My faith in the corrugated ship is such that in my humble judgment the country cannot afford to stand aside and see her pass into other hands.

An experiment in the building of a torpedo boat or destroyer, even if it failed to realize the highest expectations, would cost nothing; if successful it would inaugurate a new era.

Such a vessel would be certainly stronger, certainly steadier, and either of these results would justify the experiment.

She would be no more expensive to build than existing types.

A reduction in speed or an increase in expenditure of fuel is scarcely to be anticipated, judging by results obtained in corrugated ships, increased speed and reduced expenditure of fuel could be confidently looked for.

At the worst, the corrugations could be removed and plain plates substituted, an operation the cost of which would be nominal.

The figures which I have given will enable the shipping community to come to a decision as to whether they can afford to forego the advantages offered.

We have here the possibilities of a fresh departure of absorbing interest and great potentiality.

As with the corrugated ship, so with the Caw's tank; I am at a loss to imagine why both have hitherto failed to attract more attention, and I have a similar difficulty in connection with the modified bow suggested by Lord Rayleigh, which, so far as I know, is still in a chrysalis stage.

### CONCLUSION.

The alluring, but elusive, characteristics of the sea are perhaps scarcely appreciated except by the few.

The principle, or mystery, in the corrugated ship seems to me to contain, or to be contained in, a hitherto undiscovered something appurtenant to the sea from which the veil has been raised, though to what extent is not yet accurately determinable.

The partial unveiling of the mystery is directly attributable to the Caw's pendulum tank, which still has the means of compelling further disclosures if intelligently consulted.

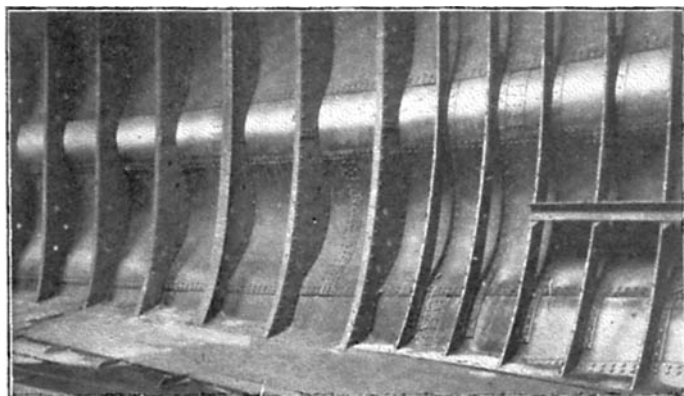
Professor Schäfer, in his wonderful address to the British Association this year, spoke of the means by which medicine has been transformed from a mere art practised empirically to a real science based upon experiment, this being the true inductive method.

In its conception and development this is what the corrugated ship has in her power to do for shipbuilding, with the assistance of the Caw's tank, and, possibly, Lord Rayleigh's bows.

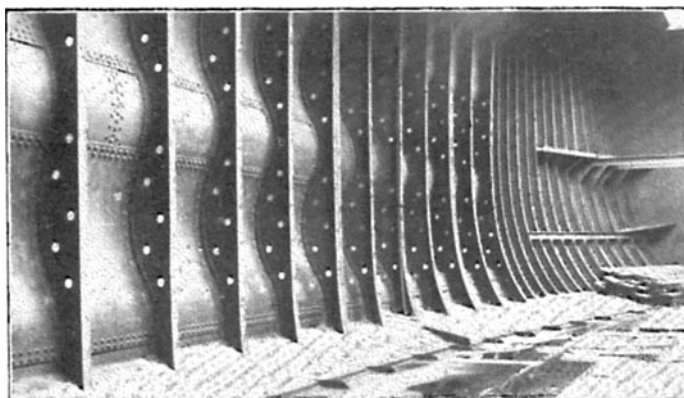
PHOTOGRAPHS TO ILLUSTRATE THE  
LECTURE ON  
"THE CORRUGATED SHIP,"

By CAPTAIN G. S. MACILWAINE R.N.

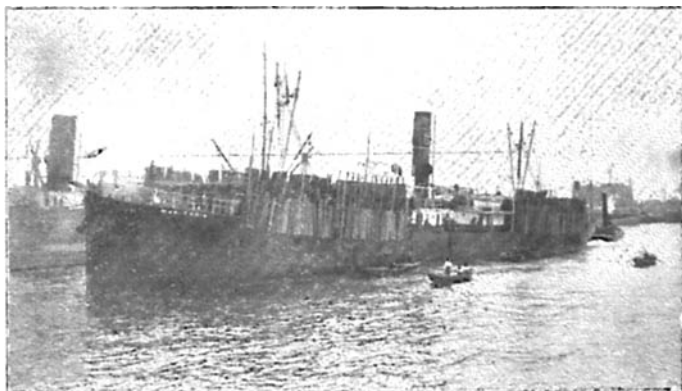
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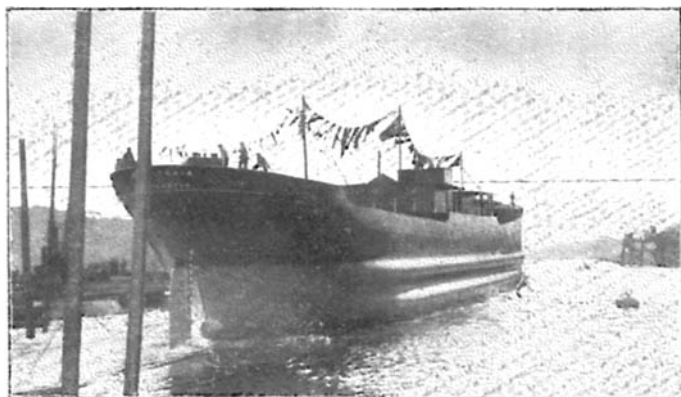
1.—Hull of Corrugated Ship looking aft. Frame spacing 48 inches.



2.—Hull of Corrugated Ship looking forward. Frame spacing 48 inches.

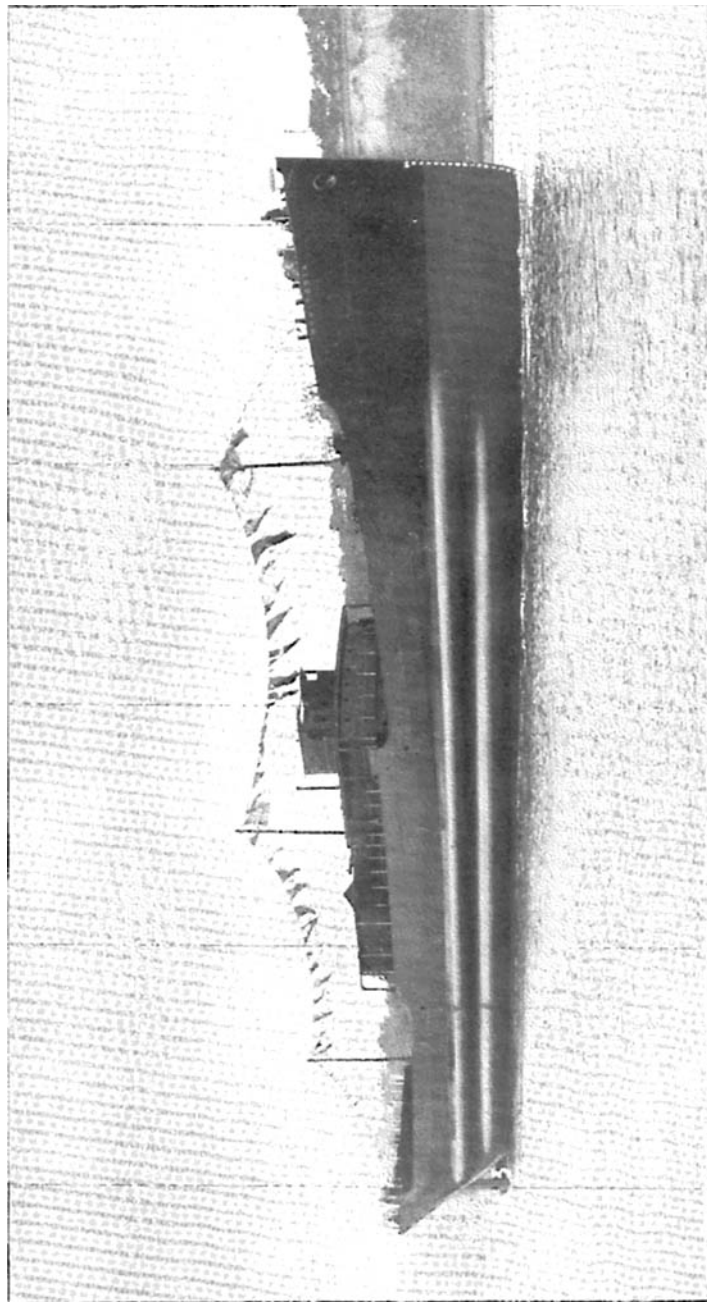


3.—Corrugated Ship with a load of timber, 43% of which was carried on deck.



4.—Corrugated Ship leaving the ways.

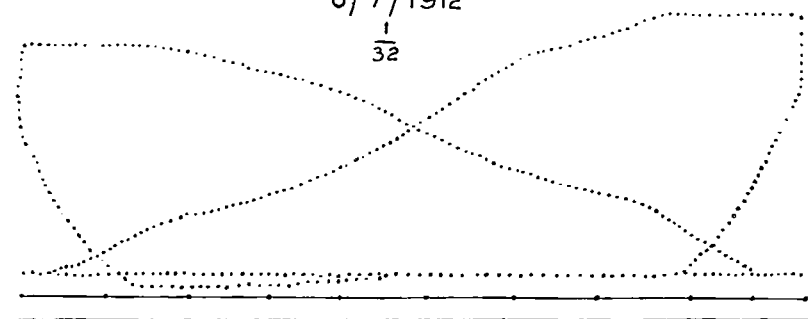




5.—The Corrugated Ship.

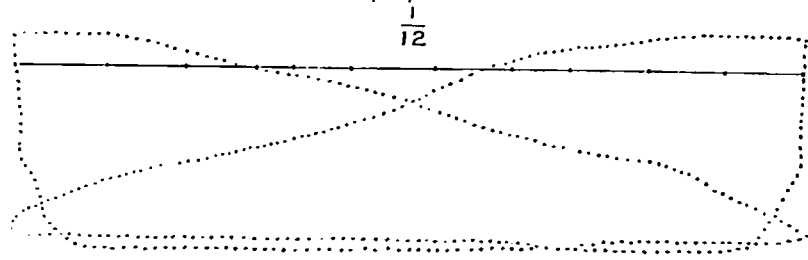
6/7/1912

$\frac{1}{32}$



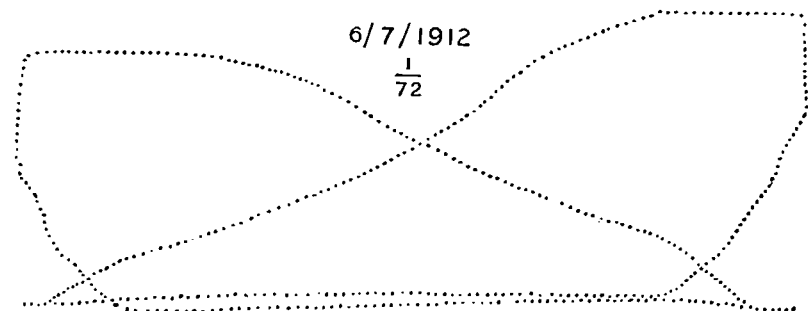
6/7/1912

$\frac{1}{12}$



6/7/1912

$\frac{1}{72}$



Steam, 180 lb. Vacuum,  $25\frac{1}{2}$  inches. Revolutions, 58 $\frac{1}{2}$ .  
 I.H.P.—H.P., 204 I.P., 207 L.P., 222 Total, 633 I.H.P.  
 Mean effective pressures—H.P., 55.4 lbs. I.P., 22.5 lbs. L.P., 8.5 lbs.  
 Coals per day, 11 tons, 10 cwt. Actual propelling force, 10 tons, 17 cwt.  
 Auxiliary Machinery, 13 cwt. Coal per I.H.P. per hour, 1.6 lbs. Lancashire Coal.  
 Observation, 197 Screw, 209.8 8.28 Knots. Slip, 6.1%  
 Steaming time, 23 hours, 48 minutes. Total revolutions, 81,700  
 Fresh head wind with swell. Calm when cards were taken.  
 Constants H.P. .0629 I.P. .1555 L.P. .4476  
 36 in. Stroke 21 ins. x 33 ins. x 56 ins.

"Hyllonia."

Indicator Diagrams taken on passage to Kronstadt.

If I am right the birth of the corrugated idea means nothing short of a revolution in the building of the ship, whether pleasure, life saving, mercantile, or—Imperial.

### DISCUSSION.

**Commander W. F. Caborne, C.B., R.N.R.:** I think we have had a very interesting and instructive paper. The corrugated ship and the claims advanced on its behalf are not altogether new to me, because I have followed the reports of the "Monitoria" and the "Hyltonia" from time to time since the launching of the former vessel. Here, in this Institution, the members are naturally more concerned with war vessels than with merchant ships, but it must be remembered that the warship and the commercial ship, up to a certain point, are identical as regards their requirements and characteristics. I am of opinion that an extremely good case has been made out in favour of the corrugated ship. With regard to the relative strength of corrugated and plain plates, the Lecturer has given us a very practical experimental illustration, although it is common knowledge that a corrugated piece of metal is stronger than a plain one. With regard to steadiness at sea, which must be materially assisted by the corrugations being placed below the load-line, that is a very important point indeed, especially in connection with the Royal Navy, because a steady gun platform is all important. Then, if these corrugations reduce the vibration, that again is a very excellent thing. My own experience of a destroyer—I do not know what may be the case at the present moment—was that the vibration running at full speed was practically enough to separate body from soul so far as the people on board were concerned; and if that vibration can be obviated or reduced it will be a great boon to everyone serving in such craft. With regard to the increased dead-weight carrying capacity of the system, that is a matter which applies not only to the Mercantile Marine but also to the Royal Navy, because I believe that one of the great troubles of naval architects is to get the weight of armour, guns, ammunition and other things into a vessel of certain dimensions without too greatly increasing her draught.

### TONNAGE AND HORSE-POWER.

With respect to a corrugated vessel of the same tonnage as a plain vessel being driven by less horse-power, it seems to me a very extraordinary fact indeed, and it appears to be clear proof that in this case, for some reason, theory and practice do not go hand in hand. I did not quite understand what the Lecturer meant when he said that the propeller could always be seen at work, but he will no doubt mention in his reply what he does mean. Captain MacIlwaine has referred to the old ships of the past, and has stated that he does not quite know upon what principle they were built. Personally, I first went to sea, some 47 years ago, in one of the old frigate-built East Indiamen, a celebrated ship in her day, named the "Hotspur," and while I cannot enlighten the Lecturer upon the subject of the principle upon which she, and other similar wooden vessels of the period, were constructed, I do know this, that they were extremely fine ships, and I think that he, like myself, must have a little feeling of regret in his heart that they should have passed away for ever. However, it is clear that it is no good regretting the past. It is now our duty to throw ourselves into the van of progress,

and it is much to be hoped that the Admiralty will carry out some experiments with this corrugated principle, in connection, at any rate, with small and speedy craft.

**Sir Theodore V. S. Angler:** It seems rather strange to me that in this large gathering I do not see a single face of a ship-owner except that of a friend who is sitting by me. Ship-owners, of course, cannot exactly discuss this lecture, in fact, I do not know who, except the scientific naval architect and engineer, can do so. The paper is not capable of discussion from our point of view. But speaking as a ship-owner, I can tell the Lecturer this, that from what he has said, he has convinced a practical owner that there is a very great deal in this new idea. I may tell you that among ship-owners I was a bit of an experimentalist myself. I was one of the first who bought turret ships and sailed in them, and I am very glad to hear that we have a Lecturer to-day who has actually tested the corrugated ship by making voyages in one. That is the only test I would take. Before I bought turret ships I took great care to voyage in them, to watch them very carefully, and to gain practical and personal knowledge of their capacities. We have had to-day the result of the personal experience of a very good type of man to carry out these practical tests, and he has carried to my mind a certain amount of conviction. From the model itself, and the construction, I can very well take the Lecturer's word, more especially on that very difficult question of "slip."

Every practical man knows that every ship has a different way of conducting herself. Even if two ships are laid down on exactly the same lines, and are sister ships, as they are called, they have totally different behaviour and capacities when you sail them at sea. That is a very strange thing indeed. This ship certainly does to my mind carry convincing proof that she would in her sailing save an enormous amount of "slip." The groove formed by the corrugation is a conductor of the sea towards the propeller; it is evident that it is a feeder, and the experience of the Lecturer goes to prove it; and at any rate we will take his word for it.

#### DECK LOAD AND STABILITY.

Then the Lecturer tried to praise up the ship because she would carry an enormous amount of deck load. I advise him to be quiet about that, because all present-day legislation is taking the deck load away from us; very few feet of deck load is now allowed. We used to be able to pile up the deck load to the top of the funnel, and a little bit over sometimes if we liked to do it, but new regulations have stopped all that now, and it is very likely that these wonderful ships will be prevented from showing their capacities in that respect. With regard to the stability of these ships, that is, I think, very patent to anyone, especially those acquainted with the various craft that are built to-day. We have always found, for instance, that the bilge clogs do have a distinct effect in steadying ships at sea. Here, in this instance, you have the double bilge clog, and I think of a very much better shape than the ordinary bar bilge keel. A plain bar is rivetted on to the bilge plate fore and aft, and that is supposed to catch the sea and stop the rolling. I presume that I am talking to some who do not understand what a bilge keel is, although, of course, the vast majority of those present know far better than I do what it is. But here, in this instance, you

can see pretty plainly that you have a double rounded bilge keel, and of a better type than a rigid flat bar.

Then another claim that is made for this class of ship is its superiority in speed and economy in coal. Of course, the speed follows from the saving of "slip." If you save "slip" you gain speed; there is no mistake about that. If you get increased speed out of a ship you are saving in your coal; your coal costs less because you get through the voyage quicker. I do not quite follow how you are going to see better on the corrugated ship, say when you are inspecting or surveying for deterioration and making an observation of the plates. I do not see much in that contention of the Lecturer's, because you are looking at the skin of the ship, and a plain plate is just as easy to see as a circular plate as far as that goes. With regard to the tonnage—I assume that I am not speaking only to experts, but to those who do not understand how to measure a ship—I may say that you measure the ship from the inside of the frames. In the corrugated ship the side is bulged cut in two places, and all that is not counted in. Therefore the owner of a corrugated ship gets a lot of carrying room which is not reckoned in the register tonnage, and you save money on dues. The owner is able to carry cargo in those bulges for which he gets freight. That is a strong recommendation in favour of the corrugated ship.

#### OWNERS AND NOVELTIES.

The Lecturer told us just now that he was very much surprised that ship-owners did not take more interest in corrugated ships. I can give him an answer to that. The fact of the matter is that ship-builders and ship-owners are so rolling in money that they have not time to look at a fresh article. I remember that I used at one time to lecture Sir Thomas Sutherland on the necessity of improving his ships by giving passengers larger and independent cabins, etc. He always used to say to me, "My dear Angier, as long as they pay me 30 per cent. on my capital I need not bother." There is a great deal of that sort of thing going on to-day. Owners and builders are making such piles of money from various causes with existing types that they will not look at a fresh article. But you must remember that the present conditions are largely the result of the natural reaction from a ten years' depression—do not forget that. They were losing money for ten years, but the revulsion has now taken place that always happens right through nature. At present they are piling the money up, and that is one great reason why they do not look into novelties. Wait until they cannot make money, and then they will tell the engineers that they must design a ship which will be more economical. These are the observations that have occurred to me as a man who has to buy ships, and who has to live by them when he has got them. They are not very nice children to manage.

**Mr. Walter G. Wilson:** The Lecturer showed us how in making the corrugations in the plate he strengthened the plate considerably from the bending point of view. I should like to know if he can give us the results of any experiments or any reasons why the corrugations should not be put in the bottom of the ship. I notice from the model that is exhibited that the ship is flat-bottomed. A ship, as far as strength is concerned, must be looked at in two ways, horizontal stiffness and vertical

stiffness. She is a girder of which the booms are the ship's sides. That is for the bending in a horizontal direction. She is also a girder of which the bottom of the ship is the bottom boom, and the deck is the top boom. That is for the bending in a vertical plane. I think you will find that at sea the majority of the vibration is in the vertical plane, and the trouble of designing is generally to get a ship stiff enough in the vertical plane. I can quite see that these corrugations stiffen her in the horizontal plane, but I would like to have some information, if the Lecturer can give it, as to whether she is stiffened in the vertical plane.

**Colonel F. N. Maude, C.B. (late R.E.):** I was going to make the same remark as the previous speaker—why not extend the corrugations round to the bottom, on the ground that it would stiffen the tension and compression flanges of the girder and give greater strength?

Then there is another point I would like to mention. I daresay many of you here will remember that a few years ago Capt. Hodgetts, of the old Indian Navy, introduced the idea, not exactly of corrugating the side of a vessel, but of constructing the bottom of it in two semi-circular arcs, with the object of obtaining stability. Incidentally he found that he got the same feed to the screw which the Lecturer has just told us you get with the horizontal corrugation. Therefore if you have the corrugation all round you would probably get a better feed to the screw than we do now. Capt. Hodgetts constructed two model boats of about five to fifteen tons, Thames measurement, which were exhibited at Cowes. One of them was a sailing boat which I remember very well, because it would carry canvas when no other boat was able to do so. The other was a model of a long cargo boat. With this model Capt. Hodgetts used to get ten men to sit on the edge, where you would have thought only two would have upset her, but she was so stiff that she would not turn over, hence, I imagine that the inventor of this idea would obtain even further advantages by extending the corrugation underneath.

#### THE QUESTION OF TWIN SCREWS.

There is one other question I should like to ask. I understand that the vessels that the Lecturer has been testing are all single-screw vessels. The point I wish to raise is, how would it affect the twin-screw principle? It seems to me it might create difficulties in steering. I have no practical experience on the matter, but that occurs to me as a point worth investigating. Then we have been told about the economy of coal and the increase of speed on ordinary economic cruising. Since most cruising is at economical speeds, the more you can save on that the more coal you have when it comes to forcing the ship. But I am very much puzzled to understand how these corrugations are going to affect the ship when you are really driving her at high speeds. It seems to me—it is a heresy I know—that once you get a vessel going with those corrugations the unexpected will happen, and that the ship will go certainly as well and possibly a little better. What particular angle of inclination should be used is more than mathematics or physics or anything else can tell you, because nobody has investigated it, but it is an exceedingly interesting thing. As soon as the bow of the corrugated vessel begins to go up and the stern settles down, the water will flow diagonally across the corrugations, thus, apparently, increasing the resistance, but I am by no means sure that you will find that it will. Things that have been happening lately rather lead one to think that it will not be the case. If you have a vessel

which is both faster at economical speeds and faster when she is being driven, that will be a tremendous advantage to everyone. Lastly, I think it would be exceedingly interesting if we could hear a little more about the Caw's pendulum and the experiments that were made with it. The name is quite unfamiliar to most of us, and also the particular set of experiments. I do not know if I am asking for too much, but if the Lecturer can supply us with the information I am sure we shall only be too glad to hear it.

The Lecturer, Captain G. S. MacIlwaine, R.N., in reply, said: The Lecturer's task in replying is a very much easier one than he thought it was going to be. Nothing has been said in the course of the discussion but what is kind. I thought all sorts of disagreeable things were going to be said, and therefore I am agreeably surprised.

Taking the points in order, Commander Caborne wants to know what I mean by saying that you can see the screw working. What I mean by that is, that if you look over the quarter and you have good eyes you will see the screw working, and that is a thing that is never seen in an ordinary ship as far as my experience of the sea goes. It is absolutely like a crystal; you see every blade going round; and the effect of the screw working in that water is, as I described, a most extraordinary modification of the wake. Then Sir Theodore Angier said that I have convinced ship-owners. If the convinced owners will take my advice they will lose no time in ordering corrugated ships. Let them prove their convictions by proceeding to order, and they may take it from me that they will not regret it.

#### THE HOLD OF A CORRUGATED SHIP.

With regard to the question of deterioration in-board, I do not think Sir Theodore Angier quite understood what I said. All you have to do is to go down in the hold of one of these ships, and then you will see exactly what I mean. If you go down into the hold of an ordinary ship you will find it is cut up into rectangles; the frames are 23 inches apart up and down, and you have stringer plates fore and aft, which cut up everything into little boxes, and you cannot get cargo into them.

**Sir Theodore Angier:** Do you not have stringers here at all?

**The Lecturer:** No, there are no stringers. If you will look at the picture you will see that there are no stringer plates; the sight in the hold is a most extraordinary one to a seaman. The hold is perfectly plain, and you can get at every part of it. You can see in a minute whether any deterioration has taken place, which you cannot do with the ordinary frames and stringers.

Then Mr. Wilson and Colonel Maude wanted to know whether corrugating the bottom of the ship would not be a very good thing. I do not say it would not, but they have both—if they will excuse me for saying so—rather failed to grasp what appears to be the essential element of the corrugations, which is the supply of water to the screw.

If you look at the model you will see that in the groove between the corrugations the water runs direct into the screw, and that appears to be the mystery and the secret of the corrugations.

## TRANSVERSE AND VERTICAL STRAINING.

Then Mr. Wilson raised the point as to vertical and transverse strains and stiffening. I have read a great deal about vertical strains and transverse strains, and as the Chairman has warned us off science, I do not want to say anything about it, because as a matter of fact I know very little on the subject; but I do know this, that the minute you get to sea in a ship everything vertical and everything transverse disappears. There is no such thing as transverse, and there is no such thing as vertical; it is mixed. The least little bit of a cant one way or the other and the vertical disappears; a pitch is exactly the same thing. If she is on an even keel there is no necessity to trouble about strains at all, because there are none. Then Colonel Maude asked a question about the effect of corrugations on twin screws. At present there is no answer to that question. The whole thing is a conception of a very active brain. The original idea was to work with a single screw, and with the single screw it has proved phenomenally successful; I have no reason myself to doubt that it will be equally successful with twin screws.

With regard to the effect of corrugations on high speed mentioned by Colonel Maude, that is exactly the direction I suggest the Admiralty should move in. The *Times* in last Wednesday's Engineering Supplement says that what really is required is a determination of the relative resistance of smooth and corrugated ships at high speed. In my lecture I point out how the Admiralty can do that without any expense whatever, and I have a firm belief that if they will do it they will be satisfied with the results. Then there is the question raised by Colonel Maude as to trim with corrugations, the idea underlying his observations evidently being that unless a ship is on an even keel you do not get the full benefit of the corrugation. Whether the ship is a foot down by the head or the stern does not matter with the corrugations. That is a curious thing. It was one of the first questions I asked myself.

**Col. Maude:** There is no difference one way or the other?

**The Lecturer:** Apparently not. A very successful run was made by a ship the other day. She started a foot by the head, and curiously enough she has achieved the very best results that I have yet discovered. I have given you some figures in my paper, they are all good; but since then the very ship in which I was in the Baltic has made a more successful run still, so that my figures look rather foolish. She came back from St. Petersburg to the East Coast, and her average revolutions were 57.98; the expenditure of coal was the same as that given in the paper; the I.H.P. was the same; she got up to a speed of 8.8 knots; for six and a half days her average slip was 1.2 per cent.; and the average distance per ton of coal instead of being 18.7 had risen to 19.5.

## CAW'S PENDULUM TANK.

She had a very heavy load of timber on board. There is only one other point left to which I have to refer, and that is Caw's pendulum tank. I am very glad to have an opportunity of explaining that. If you will take it from me in the most popular and least scientific way in the world, I will show you the Caw's tank in one minute. This is not science; I am not going into it from a scientific point of view. When I read of Caw's pendulum tank I could not understand what it meant. I



said, "What in the world has that to do with the resistance of ships?" I thought it was timed by the pendulum. Under Mr. Haver's directions I was allowed to visit the Caw's pendulum tank. It is a very old thing; it is so old that the patents have run out, and nobody that I ever yet met had the least idea of what the tank was. I have here a model, and I ask you to imagine for one moment that the desk on which the model sits is the water. This is a model nearly of the size of the models with which the experiments were made by Mr. Haver in the Caw's tank. What Mr. Haver does is this. He takes the model back, and he measures the angle at which the pendulum starts. It is held back by a string. Having measured that angle, he burns the string so as not to give a jar in cutting it. You can calculate the force of the pendulum to the last point of a decimal, and it is clear that the amplitude of the swing is inversely proportional to the resistance. I am not showing you this as a scientific experiment; it is only to illustrate the principle on which the Caw's tank is worked. To me it is absolutely beautiful. The model with corrugations swings every time further than the plain model. What can that mean but that the resistance offered by the corrugations is less than the resistance offered by the plain model? Except for the personal and practical observations which I was able to make at sea my paper is not of much use. For anything that is of value in it I have to thank Mr. Haver and Mr. George Cockburn, who is the chief engineer of the "Hyltonia," the ship in which I went to sea, and I am very glad to have this opportunity of thus referring to both of them.

Of the first Ericsson it was said that "his inventions have revolutionized both the navigation and the navies of the world." My belief is that we shall not be much older before something of the same sort is said of Ericsson, the originator of "The Corrugated Ship."

**The Chairman, Rear-Admiral The Honble. T. S. Brand:** Ladies and gentlemen, I think we may congratulate ourselves upon having had a very interesting and important discussion. May I just say for one moment that I think if the Mercantile Marine and the Royal Navy were more often brought together in this theatre to discuss matters which affect them both it would be a very good thing. My attention was called to this particular form of ship and to the lecture that was going to be given, and I must own that from my own point of view the great points that occurred to a plain man who is not a scientist were the fact that one was able to see the screw; the fact that there was little or no wake behind the screw; and that the water was introduced to the screw in some manner better than it is in the plain ship. I believe the scientific explanation is that it makes it a better streamline.

Ladies and gentlemen, I need not detain you longer to-day; I simply have to propose a vote of thanks to the Lecturer, which I am sure will be most heartily given, and I will ask Mr. Ericsson to second that proposition.

**Mr. Axel F. Ericsson, J.P.:** You can imagine that I esteem it a great privilege, as a non-member of this Institution, to be allowed by the Chairman to second a vote of thanks to one of his professional brethren. I do so with the greatest pleasure and the greatest cordiality, because my experience of our patent for seven years has proved to me conclusively how exceedingly difficult it is to introduce anything which leads to opposition. In seconding this vote of thanks I should like to congratulate the Services upon

having men who are able and willing without pay and without prejudice, to approach a problem of this sort. I should be failing in my duty if I did not tell you what occurred when this patent was brought to Captain MacIlwaine's notice. I met him in London by appointment; I had not the pleasure of knowing him, but by accident he had been introduced to me. The first thing he said to me was, "Mr. Ericsson, you must understand that even for my best friend I could not do anything of this sort, nor for money. I can only do it for the benefit of my country and of the Service that I have served all my life." Gentlemen, I will not refer to the very kind remarks that Captain MacIlwaine has made about me; they are entirely beside the question to-day. I thank him very much indeed, however, for what he has said; it was very kind of him to do so. But I am here on national grounds to say that the country is exceedingly fortunate when it has in the Services gentlemen like Captain MacIlwaine, who are willing to take up a new thing for the benefit of the Navy, which is the greatest interest that Great Britain has. It has been a very great pleasure indeed to me to hear the discussion. It has been proved by the ships already built that the principle is a commercial success. The whole thing turns on economics, and as an economical ship I do not think it can be beaten to-day. The Norwegians, who next to our own country, are the keenest seamen afloat, have built and are building five of these ships, so that I think it is quite time British owners should see what they can do.

