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CORROSION AND FOULING OF THE BOTTOMS OF IRON AND STEEL SHIPS, AND MEANS OF PREVENTING THE SAME.

By CHARLES F. HENWOOD, N.A.

THIS matter is of great national importance, both in relation to our ships-of-war and our vast mercantile marine, involving as it does at the present time the annual loss of hundreds of thousands of pounds sterling.

Ever since the introduction of iron, and more recently of steel, in the construction of ships, corrosion has been and is an element of weakness and danger, more particularly so in regard to steel-built vessels, in which the margin of thickness of the skin-plates is not so large as in iron.

It would appear from the early rules of Lloyd's Committee, the thickness of the plates for twelve years' iron ships was an eighth of an inch greater than for those of the six years' grade. The experience of the Committee, therefore, pointed to one-eighth of an inch as the waste due to six years' corrosion. And the following experiments made by Dr. Calvert and Mr. Johnson are interesting, although the conditions under which they were made differ materially from the conditions pertaining to the actual life of iron and steel ships, and are the results from oxidation of both sides of the plates.

Loss of Weight per Month per Square Foot of Surface.

	In a vessel of sea-water.	In the sea.
	lb.	lb.
Copper	0.0027	0.0061
Zinc	0.0012	0.0070
Iron	0.0056	0.0204
Steel	0.0060	0.0216

The effect of zinc in protecting iron or steel from oxidation has been known for many years past. When the two metals are in contact, an electric or galvanic relation is established between them, by which the iron or steel ceases to be susceptible of corrosion by dilute acids, saline solutions, or atmospheric humidity.

Here is a piece of bright iron, protected by zinc on either side, which has been immersed first in a strong solution of sulphuric acid, and for the last eight months in strong salt water; and you may observe the iron remains bright, without any appearance of rust; even the nut and screw-bolt making the connection between the two metals is also completely protected from corrosion.

Marine boilers are now protected on this principle, and with the most satisfactory results, as regards efficiency and economy.

In former times wooden ships have been sheathed with zinc, but more for the purpose of preserving them from seaworms than from fouling; for in spite of the experiments of Dr. Calvert and Mr. Johnson, it was found that in case of wooden ships, treenail-fastened, a hard oxide was soon formed on the zinc, to which barnacles and weeds adhered very firmly.

On the other hand, on wooden ships, copper-fastened, the zinc wasted away in patches, the copper being electro-negative to zinc. No existing compositions really meet the difficulty of fouling; nor is there much prospect of success in that direction, as neither smooth surface nor poisonous composition will keep off barnacles and other marine growths; and the only means of accomplishing this is by the oxidation and wasting away of the surface, which, in parting with a portion of itself, carries away with it such parasites.

Within the last few days, I have had placed in my hand a circular of a Mr. E. Wood, "Manufacturing Chemist and Contractor to H.M. Board of Admiralty," advertising his "Protective and Anti-fouling Compositions, &c., for the bottoms of iron, steel and wooden ships," and which, he states, is "An excellent preservative to *metal sheathing*, lessening wear and tear."

Mr. Wood remarks as follows in his circular:—"Constantly is a rumour heard of the coming perfect anti-fouling, until at last there is utter scepticism as to its possibility, and shipowners swear by the latest specimen that, by some accident, they have been persuaded to accept, and generally without inquiry into the matter at all commensurate with its importance. A bill for a few hundred pounds spent on the boilers or engines, in order to obtain a knot or two more of speed, is expected as a matter of course, and then the vessel is supplied with some composition on the bottom, which neutralizes the extra power in the engine-room.

"But the anti-fouling ought only to be considered as coincident with the protection of the plates, for if the iron is not thoroughly protected from the sea-water, or perchance of any composition that may be applied over the protective coatings, the very iron of the ship may suffer. The requirements of the protective coatings are then a 'thorough bite of the iron' and 'insolubility in water.'

"Compositions may, broadly speaking, be classified into two divisions—the *grease* and the *paint*.

"Greases, such as tallow, and others sold under different denominations, have been in general use, but with very moderate results. Their efficacy depends on the gradual falling away of the grease, and with it the various attachments. The greases labour under the great disadvantage of having to be applied in a warm state, and, in the opinion of many, of retarding the vessel.

"The Patent Office records show numerous attempts on these clinging followers of the deep, in the shape of doses of arsenic, mercury, &c.; but it is now generally thought that these substances, poisonous to human and other life when taken into the system, are not poisonous to the low order of sea-life, nor indeed do we know that they take the poison into their systems.

"It is better to pass over the wonderful nostrums recorded in some of these patents, in which nearly every article that can be made up into the shape of a composition is included, in the apparent hope that, amongst the variety of ingredients, something may act. In some instances, they have come like a comet on the scene, and, having served their purpose, have disappeared. And, indeed, it is easy to get a reputation for a good anti-fouling; given a steamer which sails for a month or two straight ahead, goes even into tropical waters, reposes in a clean or different water (such as a fresh water river, &c.), and with a quick return to the dry dock, we have the data for showing good results. Given also a voyage at certain seasons of the year, even in waters usually with a great tendency to fouling, and a clean bottom is the result. Given a voyage to certain ports that are blessed with cool and clean water, and we have the elements of success for any composition."

I may here quote the following, extracted from "A Manual of Naval Architecture," by the present Director of Naval Construction at the Admiralty, published in 1877. Mr. White writes:—"Various plans have been tried for attaching zinc sheathing to iron hulls; that more commonly used in the Royal Navy is as follows:—A single thickness of planks (3 to 4 inches) is bolted outside the skin plating; to this the zinc sheets are nailed; the strakes of planking are not caulked, but the water which finds its way under the sheathing can pass freely through the seams to the iron skin. Iron stems and stern-posts are employed; and by various means a certain amount of metallic connection is made between the zinc and the iron hull, such connection, as explained previously, being desirable in order to keep the surface of the zinc free from incrustation."

Now, it will readily be seen that by this plan there exists no *metallic* contact whatever; consequently no electric or galvanic action, or, if any, of the feeblest possible character. In addition to which there exists an insulating material between the iron hull and zinc sheathing, in the shape of the wooden planks.

Other plans have been proposed and patented, among which I may briefly describe those of Mr. Daft, Sir Nathaniel Barnaby, and Mr. McIntyre.

Mr. Daft's plan required that the ship should be specially built, or at least that the skin-plating of the vessel should be specially arranged; that is to say, the outside plating was to be worked flush with internal butt-straps at the seams as well as the ends of the plates. A space of about an inch in width was left around each plate, forming when rivetted up a groove into which compressed teak was to be placed. The zinc sheets were to be of about the same size as the iron plates, and nailed with zinc nails to the compressed teak in the grooves surrounding each plate; and where the plates were large, holes were to be drilled in the centre part, where required, and plugged with compressed teak or ebonite to receive zinc nails. Here the zinc sheets were to be laid directly on to the iron plating, without any insulating material between them; and so far a better plan than the above, yet the necessity for special construction, and its great expense, were reasonable objections to its adoption.

The plan of Sir Nathaniel Barnaby was more simple than that of Mr. Daft. He required no special construction or arrangement of the skin-plating, like Mr. Daft. He proposed to drill or form holes in the rivets, after the vessels were rivetted up, and fill such holes with a soft metal or other substance, and nail the zinc sheets with zinc nails into the soft metal or other substance. The simplicity of this plan of sheathing iron ships with zinc is apparent; but the risk attending the adoption of such a plan is also apparent.

Mr. McIntyre's plan consisted of rivetting galvanized iron strips, with grooves to receive the edges of the zinc sheathing, to the ships' plating, the middle portions of the zinc plates being secured by similar strips, or screws, into the iron plates.

I understand a vessel was actually sheathed on this plan of Mr. McIntyre, and proceeded to Australia, but when she arrived at Australia the whole of the zinc sheets had disappeared, not from

oxidation or wasting away, however, but from the insecurity of the method of fastening the zinc sheets to the iron hull.

In each of these plans for sheathing iron ships with zinc sheathing, the main element of success is wanting; that is, contact between the two metals, the iron and the zinc, in order to establish complete galvanic action. The two metals, be it noted, must be in contact, not their respective oxides, which alone obtains in the plans I have referred to.

"Hitherto," Mr. White writes in 1877, "the practical difficulty has been to adjust the relative amounts of the surfaces of iron and zinc, contributing to galvanic action on the latter, in such a manner as to prevent too rapid or too local wearing of the zinc, without interfering with its anti-fouling properties."

I presume Mr. White had in his mind, when he wrote this, the plan "commonly used in the Royal Navy," in which, as I have pointed out, no metallic contact exists, and as a natural consequence galvanic action fails.

However, Mr. White further wrote (just ten years since):—"Before many years the question will probably be in a much more settled condition; and although there is little hope that zinc can ever be made to equal copper in its anti-fouling qualities and smoothness of surface, yet, if it be made fairly successful in this respect, it will greatly reduce the cost of construction, and the risks of accident or collision. Already it seems certain that a very great improvement upon the condition of unsheathed iron ships can be secured by the use of zinc sheathing. At present, therefore, the question of preventing foulness of bottom of iron ships stands as follows (1877):—By far the greater number of ships have their bottoms coated with some anti-fouling composition, and are docked for cleaning and re-coating once or twice a year, when it is practicable, and no serious loss of speed ensues. A few iron ships, designed for distant voyages, and in which the power of keeping the sea, without serious loss of speed during long periods, is of great importance, have copper or zinc sheathing. Copper can be made to answer well as regards anti-fouling, but it involves a large additional outlay, and is open to the charge of possible damage to the iron hull in case of accident."

The plan commonly used in the Royal Navy was adopted on an ironclad belonging to the Brazilian Government, and I am favoured by Sir Edward Reed, K.C.B., M.P., with the following account:—

"The sheathing of the ironclad you refer to was composed of East India teak, of good quality, $2\frac{1}{2}$ to 3 inches thick, excepting the keel, which was of English elm. The outer surface of the bottom plating was scraped and cleaned, and three coats of the best red lead were applied, and the inside surface and edges of the planks were covered with a thick coat of red lead. The planking was not caulked, and was secured to the iron plating of the vessel with $\frac{3}{4}$ -inch iron screw bolts, spaced about 2 feet apart, the holes in the bottom plating to receive these bolts were very carefully tapped, and the joints of the bolts were further secured by nuts, with a hemp grummet and washer on the inside. The bolts were made with a suitable slot in the head, and were hove up by a ratchet brace, observing that the heads were in all cases flush with the outer surface of the wood planks. The outer surface of the whole of the wood sheathing was covered with a thick coating of marine glue, and was further sheathed with Veille Montagne zinc, about $\frac{1}{16}$ th of an inch thick, secured with $\frac{1}{4}$ -inch zinc nails.

"The wood and zinc sheathing extended from about $2\frac{1}{2}$ feet below the load water-line on the one side of the ship, to a similar height on the other, and at the upper edge the wood was snapped away, and the zinc sheathing brought over it and fastened to the armour plating by galvanized tap screws.

"The whole of this work was performed in June, 1875, and the vessel was in continuous service in South American waters, without being docked from that date to September, 1885, when she was placed in a dry dock in England. During this time I believe certain parts of the zinc sheathing were renewed by divers, but an examination of the state of the iron bottom in 1885 showed it to be in a remarkably good state of preservation, and requiring no attention whatever. The wood sheathing was also in a good state, and did not require renewal.

"The zinc sheathing had wasted away considerably, more especially in the region of the fastenings of the wood planking, showing conclusively that the galvanic action set up had acted as was originally intended, and that the plating of the ship was fully preserved."

Now we have seen that, to obtain proper galvanic action, the two metals must be in contact.

It will be apparent also, and experiments prove it, that zinc sheets of the same surface as the iron or steel will oxidize or waste away uniformly and evenly, and not locally or in patches.

It is found also, from experiments, that the waste or oxidation of the zinc sheathing, when in galvanic contact with iron or steel, is from the outer surface chiefly, and the oxidation or waste is from 2 to 2½ ounces per square foot per annum; that of copper on wooden ships being about 3 ounces per square foot per annum.

In the plan I have now the pleasure of submitting to you for preventing corrosion and fouling of iron and steel vessels, the two metals, the electro-negative iron or steel and the electro-positive zinc sheathing, are placed and permanently fixed in contact, by which means an electric or galvanic relation is established between them.

There is no insulating material placed between the hull and the zinc sheathing, which is fitted as closely as possible to the iron or steel hull.

No holes are drilled into the iron or steel hull, nor is any alteration of structure required.

The zinc sheathing is secured to the iron or steel hull by means of a zinc solder, which is less electro-positive to iron or steel than zinc itself, consequently will be more enduring.

The attachments are made at about 12 inches from centre to centre; and of such strength, that the sheathing may be torn off, leaving portions still attached to the solder, which also adheres firmly to the iron or steel.

The zinc sheets are 8 feet long and 3 feet wide. A template is made of the size of the sheet zinc, with holes about five-eighths of an inch in diameter, 12 inches from centre to centre, and 6 inches from the edges (Diagram A). The zinc sheet has similar holes punched in it, and around each hole a layer of zinc solder is fixed, about 1 inch in width; also along the upper edge and after end. The sheet is now ready to be attached to the side or bottom of the iron or steel ship. The template is then applied to the side of the ship where the sheathing is to be applied, and its position marked on the ship, and the position

of the holes (Diagram B). At the position of these holes the oxide of iron or steel is removed (with chisel and hammer or emery wheel) for an area of about $2\frac{1}{2}$ square inches, over which a layer of zinc solder is fixed. This part of the ship is thus prepared to receive the sheet zinc similarly prepared, and when put in place, the respective layers of zinc solder are united with a hot soldering-bit, at the same time the hole in the sheet zinc is filled up flush, and the attachment is complete. A practised hand can make about sixty attachments in an hour, and the largest vessel may thus be sheathed with zinc in about a week or ten days.

To test galvanically the endurance of such attachments an experiment was made by Professor Mosely, of the London University, who wrote as follows:—

"At your request I put on paper the result of an experiment made by us with a view of testing the power of resisting corrosion of a combination of zinc solder and iron prepared by you. You handed me a small square of iron plate about 3 inches in the side and one fifth of an inch in thickness, to either face of which were attached by means of their centres with solder similar but thinner plates of zinc. These plates of zinc were closely applied to the two surfaces of the iron.

"This combination of metals was placed by us in a large volume of a mixture of equal parts of commercial hydrochloric acid and water, which was allowed to act upon it for about a quarter of an hour.

"When the sample specimen was withdrawn, it was found that the iron had not been corroded at all, and that the solder on both sides of the plate had, as far as could be detected, not been acted upon at all by the acid.

"The zinc, on the other hand, was nearly removed, a thin, imperfect lamina only remaining on either face of the iron plate, still firmly held in position by the solder.

"I should infer that during prolonged exposure of a similar combination of metals in sea-water, all the zinc would be removed by corrosion before either the solder or iron would be attacked. It is important to note that the zinc has not, in the specimen referred to, been corroded most around the soldering point, but on the contrary, at its extremities."

This latter result is chiefly accounted for by the fact of the extremities not having had zinc protection.

With regard to the cost, I may mention that iron or steel ships may be sheathed with zinc sheathing on this plan at about one-tenth of the cost of the plan commonly used in the Royal Navy.

At the I.N.A., in 1864, Mr. Lamport observed, and the like observation may be made at the present time:—"Some gentlemen made light of the question of fouling. I took up the 'Shipping Gazette' the other day, and looked at all the ships overdue from China, the longest average voyage we have. They were all of them over six months on a voyage, which is from two to three months more than they ought to be."

A commander of the P. and O. Company observed:—"I have been in the habit of taking out several iron steamers before to distant

parts of the world, coated with different compositions, but invariably found that their bottoms were fouled with weeds and barnacles before we had been six weeks at sea, much retarding the latter part of the voyage, notwithstanding we had taken opportunities of scrubbing them off as far down as we could reach."

The late Admiral Fishbourne stated that when he was on the coast of Africa, an iron whaler came out from England; and though she had only left six months, and been cleaned as well as they could at sea with long brooms and ropes under her bottom every month, she had long grass and barnacles of immense size attached to her, in consequence of which she was not safe, as she would neither sail nor steer, and was not manageable.

The "Times" of 25th January, 1865, reported that:—"The 'Royal Oak's' bottom was found to be foul beyond all conception. Immense quantities of zoophytes, weeds, and coralline flourished in the wildest profusion, and so hard had the little insects formed their habitation, that nothing short of a general scraping with short scrapers would remove the incrustation, the result of barely six months' accumulation. Whether this rapid growth is due to the Muntz metal with which the ship's bottom is sheathed, or the result of some general galvanic action, is hard to conjecture." On the other hand, the armour-plating above the sheathing was found to be eaten away into holes and grooves half an inch to five-eighths in depth. Some of the plates contained no less than 188 of these, whilst none had less than forty. This corrosion appeared to have occurred wherever the paint had been worn off.

The "Times" of 3rd November, 1865, reported that:—"The condition of the 'Agincourt' at Devonport has created considerable surprise in the minds of the officers of the dockyard and others. About six weeks since she was removed from the Prince's Dock, after having been coated a second time with Hay's anti-fouling composition, and was placed alongside the sheer-hulk in Hamoaze, where she received her five iron masts, and was otherwise prepared for preliminary trial of her engines, which took place on the 12th ultimo. On Monday last the 'Agincourt' was replaced in Prince's Dock, and as the water was pumped out her bottom below the line of flotation looked, as one of the artizans described it, 'like a field of grass,' so regular was the growth of the weeds. Some were nearly 2 inches long, and it extended from stern to stem and down to the keel."

The French ironclad "Invincible" had not been docked for ten months, and when docked, the copper sheathing was found covered with a thick mass of marine vegetation, a sort of white coral, and many kinds of shell fish formed a stratum which completely hid the sheathing, and was 5 centimetres or nearly 2 inches thick over certain parts. There were also in certain places patches of oysters, which firmly adhered to the sheathing. There were not less than 10 tons of vegetable matter or fouling removed from the bottom.

Just before being docked and cleaned, she was tried under full steam, the weather being calm and water smooth, when her greatest speed was 9·8 knots with 51·5 revolutions. After being docked and

cleaned she was again tried, when her speed was 13·2 knots with 53 revolutions.

The "Shipping and Mercantile Gazette" of September 1st, 1865, records that the "Ceylon" and "Poonah" of the P. and O. Company were each coated with a new composition, and the result was "most extraordinary." Both ships have returned after their first voyage of a few weeks in sorry plight. The "Ceylon," notwithstanding she had been twice scrubbed abroad, in less than two months was found covered with grass from 12 to 18 inches long, and barnacles, zoophytes, &c., had begun to form all over the bottom, so that she was delayed on her homeward voyage several days. The "Poonah" was nearly as bad after only six weeks' absence.

And the following case is of recent, and I might almost say, of daily occurrence:—

A screw steam vessel, with a carrying capacity of 3,500 tons dead weight, started on a voyage from England to Cape Town, loaded; from thence she proceeded in ballast to Cocanada, and loaded for Liverpool *via* the Suez Canal. On the voyage out she indicated 947·06 horse-power, boiler pressure 76 lbs., speed 10 knots, and draught 23 feet on an even keel. On the voyage home she indicated 970·96 horse-power, boiler pressure 80 lbs., speed 7 knots, and draught mean 24 feet 2 inches (22 feet 9 inches forward and 25 feet 7 inches aft). As the small difference in her draught, taking also into consideration her trim, cannot be held accountable for a loss of three knots, there is nothing else but the state of her bottom to explain it. When placed in dry dock on arrival in England she looked exactly like a half-tide rock, and four railway-truck loads of barnacles and other zoophytes were removed from the dock. When cleaned she again made 10 knots speed, with 76 lbs. pressure, and 947·06 indicated horse-power.

The extra resistance of the fouling matter is plainly shown by the greater pressure on the boilers and greater horse-power.

The value of such a steamer may be reasonably taken at about 54*l.* per day. The loss of time due to fouling is eighteen days, thus making the total loss on a voyage of four months 972*l.*, without making allowance for the extra coals burnt.

To obtain 7 knots with a clean bottom would not require more than about half the amount of coal to obtain 10 knots; and taking the full consumption at 24 tons a-day there was a further loss of, say, 12 tons for 18 days, 216 tons at, say 30 shillings a ton, amounting to 324*l.*, making a total loss of about 1,296*l.*

If such be the loss on one steamer during a four months' voyage, the loss on the numerous long voyage steamers and sailing ships must amount to an enormous sum every year.

"When one thinks" (remarks Admiral Paris) "of the number of steamers on the seas, of the thousands of tons of coal they burn, one cannot help seeing that the wealth of the whole country is being spent in this obstacle; the overcoming of which would produce enormous profits."

In conclusion, the position of the matter at present is as follows:—

Zinc as a sheathing, even as hitherto imperfectly applied, preserves iron or steel from corrosion in sea-water; and in certain cases from fouling.

It may, then, be fairly and reasonably assumed that zinc sheathing if applied so that the electro-positive zinc is in contact with the electro-negative iron or steel, an electric or galvanic relation being thus established between them, the zinc would be perpetually dissolving away in an oxide, and carry with it the barnacles and other zoophytes, leaving a clean surface; and thus iron or steel ships, so sheathed with zinc, may navigate the seas practically as free from fouling as our old copper-sheathed wooden ships.

The CHAIRMAN: This is a much more important subject than it generally looks, and I am sure we shall be very glad to hear anybody who can speak with some knowledge or authority upon it.

Mr. MARTELL (Lloyd's): I did not purpose making any remarks on this paper. I came here to hear what Mr. Henwood had to say, because I think there is a good deal of credit due to him for giving his attention to this question, which is one of very great importance to the mercantile marine. The principal reason why I now wish to speak is in reference to a statement made by Mr. Henwood, which I think, without some explanation, would be rather misleading. Mr. Henwood states that, judging from the rules of Lloyd's Committee, they consider that there would be something like a deterioration of one-eighth of an inch in iron plates, or waste by corrosion, in six years; that would be very misleading to go out to the public. The reason why Lloyd's rules made differences in their scantlings for different classes of ships was in order to enable shipowners to build ships of certain scantlings that would suit the particular requirements of their trade. A ship that was intended for over-sea voyage, or for North Atlantic voyages with the roughest kinds of cargoes, evidently would require greater scantlings than a ship engaged in coasting voyages, or shorter voyages, or carrying lighter goods, and consequently it was necessary to lay down different scales of scantlings, to meet certain particular trades that owners wished to build ships for, and still enable them to obtain a class in Lloyd's Register Book. The number of years assigned to those was more for the purpose of requiring that at the end of that time those ships should have a thorough examination; that all parts should be exposed in the inside, so as to be perfectly certain as to the amount of deterioration that had gone on; but to imply from that that Lloyd's Register Committee supposed that a vessel built of iron would deteriorate one-eighth of an inch in six years would be perfectly misleading. The rules were not framed at all on such an assumption as that. With reference to this general question of coating iron ships with zinc, of course, as Mr. Henwood has pointed out, various modes have been adopted in order to accomplish this, and if something of the kind could be done by which the bottoms of iron ships might be protected from deterioration and fouling to a greater extent than they are at the present time, a most important desideratum would be accomplished. Practical men and chemists of the greatest experience have devoted their attention to this, and I regret very much to say that up to the present time we have not accomplished so much as is necessary, and as we hope we shall be able to look forward to. But with reference to Mr. Henwood's particular plan, I think it is to be regretted that in this paper he has not called our attention to a vessel where his plan has been specifically applied, and where I believe, if I am not incorrect, it was done under the special supervision of Mr. Henwood himself. I allude to the yacht "Bessie," which I remember distinctly was so dealt with something like five or six years ago in the Clyde. Now in these remarks I am making, I trust Mr. Henwood will not think I am unduly criticizing his plans, but I merely wish to bring before the audience and the public, if it will come before the public, in any way, that there has been the actual practical application of this plan that has been brought forward here, to a sea-going vessel, and that consequently we have some very great and specific experience with reference to this, and I think this experience ought to be placed before us, in order to

enable us to judge as to the practicability of applying this plan, and likewise as to the efficiency of it after its application. It would be very interesting if Mr. Henwood would tell us what experience has likewise been gained since that time in other vessels; whether it has been applied to any other vessel, and if so, whether any better means have been adopted for securing this zinc on to the bottom; whether he has more specific data to bring before us as to the efficacy of this plan. In the yacht "Bessie," where this plan was applied with the full cognizance and under the supervision of Mr. Henwood himself, quite in accordance with the plan pointed out here, not a mere experimental plan in any way, but done in accordance with what Mr. Henwood professes to be his particular plan—after she had been running something like twelve months she was docked, and a large portion of this sheathing was found to be lost. A portion of it at the fore-part had been torn away, and the water had got between the surface of the zinc and the iron, and had burst through at the upper part in many places, forcing off the zinc at these parts. That only applies to the practical manner of attaching the zinc. I think it is very likely that that might be overcome, and therefore I would not condemn such a plan as this merely because some difficulty was found in keeping it perfectly secured to the bottom of a vessel. But there was something of far greater importance, and that was the actual principle of this application as to the effect which was claimed, and the initial purpose for which it was introduced, that is, the non-fouling of the bottom. Now the owner of this vessel found that, notwithstanding that this zinc was attached in this manner to the bottom of this vessel continuously, not as Mr. Henwood says as the Admiralty may do it, here and there, or in contact with the bottom at certain parts, but in actual contact throughout with the iron plate of the vessel. Notwithstanding that, this zinc was continually fouling, not occasionally, but continually; and they were brushing it over continually, in order to get a clean bottom. When that vessel was put in dry dock, it was found that the grass had grown on the bottom of that zinc to the extent of 3 feet in length. Now that is a very important thing for Mr. Henwood to explain to us. He says, that in two metals coming in contact in this way, the galvanic action is found to take place externally upon the surface of the iron, and that consequently you would expect, and would have in fact, exfoliation taking place on the external surface of the zinc, and that therefore any adhesive substance which might be on that would naturally drop away. But that was not found to be the case when it was actually tried on the vessel referred to. It has occurred to me that it is possible that when two metals are brought together, zinc and iron, in this way, that where galvanic action takes place, it would be more likely to take place on the inner surface of the zinc, instead of on the outer surface, because a large surface like a vessel's bottom, where the vessel was passing through the seas, would be very differently affected from two metals put in contact with each other in a battery where you had a small quantity of water, and the water might be thoroughly saturated, so that the whole surface of the zinc might be affected on both sides. I am somewhat borne out in this by the actual result of the survey made by one of our surveyors, and which may be taken to be perfectly reliable, in which he found that on the internal surface there was a very thick oxide of zinc and salt, showing that there had been considerable galvanic action going on between these two internal surfaces, but it was very evident from the fact of those grasses 3 feet in length adhering to the external surface, that there could not have been any exfoliation, or else they could not have adhered as they did. I think it right to point this out, because it is a very important matter, and we have so many anti-fouling compositions at the present time that, as has been very properly said by Mr. Henwood, we scarcely know where we are with reference to a great number of them, and if anything could be applied that would have a thoroughly anti-fouling effect, and I appreciate it from your point of view as a naval Officer with regard to men-of-war, that it would be a matter of very great consideration, and I am sure, speaking for the mercantile marine, it is a matter that all shipowners are looking forward to, and that we professional men are looking to constantly. We hope the time will arrive when we shall obtain something which will be an effective protection against corrosion, and likewise against the foulings of the bottoms of iron and steel ships, but I fear that until we get either more experience or at least further explanation from Mr. Henwood, we cannot

accept, at least I feel that I cannot, his mere assertion that his plan would be effective for this purpose.

The CHAIRMAN: I ought to point out that in the discussion we may go by the title of the paper rather than the substance of it, because we have really come here to discuss the whole question of corrosion. If the paper had had another title we might have been tied to the particular plan before us, but if gentlemen who speak will refer to the general question, I think it will be better carrying out the object which the Council had in view.

Mr. MARTELL: If that is a sort of censure on the remarks that I have made or the view that I have taken, I feel, Sir, I must join issue with you on that point. This paper is as to the means of preventing the corrosion of the bottoms of iron and steel ships, and here it is specifically pointed out that there is one particular plan by which this might be effected, and I have dealt with that particular plan.

The CHAIRMAN: I think you were perfectly right. What crossed my mind was that you were restraining yourself to the particular points of the paper, which I do not think, owing to the title, it would be necessary for other speakers to do, but you were perfectly in order as far as you went.

Admiral BOYS: I wish to say just a few words, as a practical naval Officer, bearing on the general question of the fouling of iron ships' bottoms, my object being to give my experience as to the necessity and immense importance of keeping vessels under water as clean as possible. On taking command of the "Warrior," for her second commission, in 1867, I had a correspondence with her previous Captain, Captain Cochrane, a man well known in the scientific and naval world, respecting her qualities, and he told me that he considered the loss of speed of the "Warrior," when going at what in those days was thought to be high speed, viz., from 10 to 12 knots, was approximately 1½ knots after she had been six months out of dock. My experience of her was the same. Nearly every question connected with a ship is involved, fighting efficiency, economy, consumption of coal, speed, and deterioration of bottom. I mention this fact to point out the absolute necessity of more being done with this object, and possibly something in the direction which the lecturer has indicated would have the desired result.

Mr. LEE: I am here to represent Mr. Scrutton, but I did not intend to say anything upon the subject. I will not speak on the scientific question specially, but I have been connected with dry docks for many years, and have had opportunities of seeing the condition of the bottoms of ships, and judging of the extent of the deterioration that has taken place. I have known many vessels which have been going to India and back for many years, coated with the present existing compositions, and really as far as the deterioration and the wasting of plates is concerned it has seemed to be almost imperceptible. Take for instance Mr. John Corry's ships, they are a very good class of ships, well built, and have been coated with a variety of compositions. One of these ships, "Star of Greece," made a voyage to India and back within six months, being as short a time as that in which very many copper-bottomed ships would do that work. That may apply to ships going to Calcutta, but of course in some waters where ships are very liable to foul, the bottom would suffer very much more quickly. I do not know that I can say further than that, but my experience is that the deterioration in the iron is a very slow process if the plates are well protected inside, and I have known some ships that in twenty years have only wasted to an almost imperceptible extent.

Mr. LEWIS: We have all heard anti-fouling compositions called very hard names, and I am conscious that I myself have called them perhaps harder names than almost anyone; yet I confess it is rather startling when we are told of ships being covered with coralline and masses of weed after a voyage of six weeks' duration, and those statements being brought forward from isolated newspaper cuttings. I think if Mr. Henwood had taken the trouble to inspect ships of the Peninsular and Oriental, or any well-known line, when they come into dry dock after fairly long voyages, he would not have made the case quite so strong against present anti-fouling compositions. If he took any ships coated with one of the dozen best of these, I think he would find that the deterioration of the plates and also the fouling is not nearly as bad as he makes out, and that really these compositions have a very much longer life than he supposes. What I would specially point out to you now is that

we want to prolong the life of our compositions, and not to bring out any more compositions or any more schemes which will only serve to protect and keep clean for a short time. We have plenty of anti-fouling compositions in the market which will do their work in the most admirable manner, for spaces of time extending with some, we may safely say, up to nearly nine months, and the great point which must be aimed at in anti-fouling compositions and protectives now is to find schemes which will carry on that period to a later date, to protect a ship for fifteen months or two years, instead of as at present, nine months. The question has entirely left the short period phase, because you can absolutely and perfectly protect your ships, and also keep them clean for periods under nine months. Now if you look at the subject of sheathing ships with zinc there are several very important points which must be considered. In the first place, if Mr. Henwood will carefully examine the zincs in any form of battery he pleases, I think he will not be quite as sure about the wasting of the zinc taking place on the outside, and not on the side of the plate nearest the other metal, and as in the case which Mr. Martell has pointed out, there undoubtedly would be a large amount of wasting of zinc between the two metals. And secondly, if the zinc plating is to keep off all fouling from the bottom, the exterior surface of that zinc must exfoliate so rapidly, that is to say you must have so strong a galvanic current, that instead of its being a prolonged method of protecting a ship, the plates would be destroyed in four or five months. Mr. Henwood gives some figures as to the rate of wasting of zinc when in galvanic contact with other metals, and I hope that in his reply he will tell us how those figures were obtained. He says, "it is found also from experiments that the waste or oxidation of the zinc sheathing, when in contact with iron or steel, is from the outer surface chiefly, and the oxidation or waste is from 2 to 2½ ounces per square foot per annum; that of copper on wooden ships being about 3 ounces per square foot per annum." I should like to know the experiment by which those figures were determined, and under what conditions the zinc wasted 2½ ounces per square foot per annum, because you must remember that when you have a large surface of zinc in contact with a large surface of iron, as in the bottom of a ship, you would, in the presence of sea-water, have really a very strong galvanic current, and if that is strong enough to throw off the fouling from its outer surface by a process of solution of the zinc, then I imagine that that zinc would have a very short life indeed. There is another matter to be considered, and that is the expense. If you look at the relative amounts of waste in iron and zinc, you will find that for every fifty-six parts by weight of iron saved from oxidation, you have sixty-five parts of zinc oxidized, and I dare say there are practical gentlemen present who can tell us something about the relative costs of iron and zinc. And not only do we have this wasting of zinc at the same rate, say, that iron would waste, but we have it wasted at an enormously quicker pace, on account of the galvanic action we have set up by making perfect contact with the iron, and I think it is from these points that we must look at Mr. Henwood's proposition.

M. CARL AUGUST HARTMANN: I wish to ask if Mr. Henwood can give us any idea of the cost of placing his sheathing on iron ships. I will not discuss as to whether the method is practicable or not, but even if it is so, it seems to me that it would be a great additional expense in the building of ships; or in the case of old ships it would necessitate the same being placed in dry dock for a very long time, and, of course, would greatly add to the expense. If a ship is to be protected with zinc sheathing, I believe it can only at the best be a surface protection. I have seen many ships coated with zinc sheathing that have become very foul after a comparatively short period, and I can also corroborate what Mr. Lewis has said as to the surface of the zinc being very much impaired. It seems to me, therefore, that the zinc itself will have to be coated with some composition, and it strikes me that if we are to have both the zinc and the coating it will mean a very serious question of expense. I therefore think it would be well if he could give us some idea as to what approximately would be the cost of putting zinc sheathing on iron ships.

Mr. C. F. T. Young, C.E.: It seems to be imagined that it is necessary for a tremendous oxidizing power to be applied to the zinc in order to keep it clean. That is not so; for so long as the surface is soluble the motion of the ship through

the water will keep the surface clean. The action is thus mechanical—it is a sort of chemo-mechanical action exercised on the outside of the plate. One of the speakers has alluded to zinc sheathing being more foul, but he does not tell us whether the ship was a wooden one or an iron one, because I have seen a wooden ship sheathed with zinc as foul as any iron ship has ever been. It is a great mistake to think that copper keeps clean by being poisonous, it is simply because the surface oxidizes and keeps greasy, and the passage of the ship through the water clears the dirt off. In one case where the zinc sheathing on iron plate had been under water for twelve months, I found that it had oxidized very equally and fairly. There is no doubt that the rate of oxidation will be increased by galvanic contact with unprotected iron. I do not see myself any particular difficulty in the matter. The only thing is it wants to be practically tested. We all remember that when Sir Henry Bessemer first proposed to blow cold air into hot iron to make it hotter he was laughed at and called a fool, but I believe the error was in not understanding the principle of the thing. I consider Mr. Henwood's plan has solved the question of practical application.

MR. HENWOOD: I will first reply to Mr. Martell's observations, and I may say I agree entirely with what he said, and perhaps I might, at the expense of lengthening my paper, have explained more fully about the thickness of plating and corrosion of iron ships. I quite agree with what he said, because I know from my own experience that iron ships may be practically called imperishable. There is a river steam-boat built forty-six years ago which was running the other day carrying passengers, and is still serviceable. It was not with that object I introduced the subject, it was merely as an indication of former ideas. Of course there was nothing stated in the early Register of Lloyd's as the ground of this difference, and it was really left to the imagination to surmise the reason. I know further experience shows that iron ships will last an indefinite period. Now I did not refer to the matter of the "Bessie," and I did not refer to it on this account, because it is not identical with that which I have now introduced to you. The "Bessie" was the first experiment I made to sheathe a small vessel with zinc sheathing directly on the iron.

THE CHAIRMAN: How long was that ago?

MR. HENWOOD: The spring of 1881. I could not possibly get the men to work this zinc solder. I tried them in the laboratory, but could not get them to do it with their usual appliances for soldering, and a friend of mine who was interested with me in the matter suggested that we should fasten it on with common solder. Rather than not have the trial, and not having made the experiments which I have since done, I assented to its being so done. Now common solder is not of the same character as zinc solder. It acts in the first place as an insulating material, so that there was no galvanic contact between the zinc sheathing and the iron plating. On the other hand, I discovered after some time, especially in this ship, that we could not make sound connections with common solder, and this will be easily understood, especially by Mr. Martell, who knows, as I doubt not, that common solder directly it gets to the melting point runs, so that when the heat was applied to the solder it mostly ran down, and we only got a very slight attachment round the holes of the zinc sheets, not more than in some cases one-sixteenth of an inch. All along the edge of the water-line, although it looked pretty fair, when it was taken off it was found that there was practically very little attachment, in fact, if the next day or the day after I had applied the wedge test as I have done to this specimen, I should have pulled the whole sheathing off, so feebly was it attached, and it was probably kept so long as it was in its position from not being exposed to rough seas. The "Bessie" was only employed about the mouth of the Clyde. The Captain wrote to me that during the first portion of the time, about six months, the zinc on the outside was always of a greasy nature, and that putting his hand on it under water it had more the feeling of a live fish than anything else. But there being no galvanic contact between the iron and the zinc, it can easily be understood how it was that after some nine or ten months she began to foul, and she did foul in the same way as ships that I have seen in the Government dock-yards. Ships with the zinc sheathing fastened on to the wood lining on coming back to England have been very foul indeed. I think this explanation will answer Mr. Martell by showing him that the attachments on the "Bessie" were very

different to these attachments. This zinc solder will not "run" like common solder, and you can make the attachments perfectly sound and strong everywhere like this specimen. There was another vessel similarly sheathed, but not with my sanction. The late Mr. William Denny saw the "Bessie" in course of being sheathed, and he liked the idea so much, he said he would have his vessel sheathed, but I found out by that time that it was useless trying to make sound and strong attachments with common solder. It was, however, done by my then partner without my knowledge or consent. The "Bessie" met with an accident about three months after she was sheathed with zinc. She was going at full speed, and ran at about 10 knots on to a rock; she knocked her stem away and bulged her iron plates. She came back, and after her iron bow was repaired, I re-sheathed the new plating as before. The iron hull was perfectly covered with an inside of zinc, and there was no trace of corrosion, but the zinc sheathing itself did not appear to have wasted away at all, and apparently not at all on the inside. It is the same in these laboratory experiments, and if you look at them you will see the inside of the zinc practically is not touched.

Mr. MARTELL: Is that done in salt water?

Mr. HENWOOD: No, in a strong solution of sulphuric acid, but the same occurred in the "Bessie." The effect on the zinc inside did not appear so great as on the outside. Of course during those few months the depreciation of the zinc was very small indeed, in fact it was inappreciable. The question of fouling is answered by the fact that there was no proper galvanic action between the two metals in the case of the "Bessie;" that shows, if there is no galvanic contact between the two metals, and consequently no galvanic action, the fouling will take place just the same as it does in the cases of vessels of the Royal Navy sheathed with zinc over the wood lining where the zinc fouls almost if not quite as readily as on a wooden ship.

The CHAIRMAN: What experiments are there to show that if the galvanic action were perfect, there would not be fouling?

Mr. HENWOOD: Only laboratory experiments. There were, however, some experiments, I think in reference to Mr. Daft's plan, made under the sanction of the Admiralty in Portsmouth Dockyard. I hoped Mr. Young would have told us about that. Also a sheet of zinc and iron were secured on Mr. Daft's plan, and put down at Shoeburyness, and were there I believe some twelve months, but being in a quiescent state, the zinc was covered with a slimy substance which, however, could easily be rubbed off by the hand, leaving a perfectly clean zinc beneath. If that sheet of zinc which was exposed at Shoeburyness had been on the bottom of a ship passing through the water, there would have been the friction of the water to have removed this accumulation, so that the zinc would, by that mechanical operation, have exhibited a clean surface, and it was from such experiments and others I obtained the data that the oxidation was at the rate of from 2 to 2½ ounces per square foot per annum.

Mr. LEWIS: Is not the water at Shoeburyness brackish water?

Mr. HENWOOD: I should think very salt water.

Mr. LEWIS: I think a ship coated with zinc, the "Audacious," which was guard-ship at Hull for some little time under very much the same circumstances, almost as near the sea, and in this brackish water no fouling or oxidation took place whatever, and it was thought the whole question had been settled. She was again coated with zinc and sent to sea; and the zinc plates I believe were very much acted upon, and the portions left were very foul, showing that experiments in brackish water at the mouths of rivers are not to be relied on as giving anything like normal results.

Mr. HENWOOD: This specimen at Shoeburyness was not perfectly clean; it was covered with some slight accumulation, and it was only when that was removed, which could easily be done by hand, that the clean zinc was exhibited beneath, so that it could not have been under similar conditions to those mentioned in the north. The only other question I think was, as to the cost and time it would take. The cost at present, without special appliances, is about 10s. per square yard, and the largest ship might be sheathed on this plan in from seven to ten days.¹

¹ About four months after the "Bessie" was sheathed, the Captain wrote me as

THE CHAIRMAN: Gentlemen, I am sure we shall all accord a hearty vote of thanks to the lecturer for his interesting paper, but before asking you to do so it is usual for the Chairman to make one or two remarks, and I suppose that, as I was last year Chairman of an Admiralty Committee on this subject, I might be expected to say something. I wish the paper had been read last year, because I was then hot on the subject, very hot, and I could have said, I think, something that would have been useful. Now, with the number of other matters that have come before me since, I am not so clear as I was twelve months ago, but still there are one or two points which are very prominently before me. I ventured to interrupt Mr. Henwood in his reply to put that question to him, where were the data to show that if the galvanic action was strong, good, and complete, there would not be fouling? As far as we have got you have observed the data are not very strong. I am not aware myself of any accurate comparative experiments ever having been tried, where in the one case there was complete galvanic action, and in the other case, under precisely similar circumstances, there was not. It seems to me, before other experiments are tried, that point ought to be established. My experience of fouling from the very first days when I came to consider it was that where the galvanic action was ostensibly strongest, the fouling was greatest. In paddle-wheel steamers, with copper sheathing, which were the first ships I served in, the fouling was always greatest in the wake of the paddle-wheels, and I rather assumed from that that there may be some special attraction to marine growths in galvanic action, and that then when they once get a grip, that they stop the exfoliation altogether. In the "Audacious," where I served for more than three years, I thought some of the strongest language I have ever thought in my life. I hope I did not express it, but I thought it on this very question of the enormous quantity of fouling that went on with zinc sheathing. I never saw anything like it. I never knew any kind of bottom foul so rapidly or to such an extent as on that zinc sheathing of Her Majesty's ship "Audacious." Of course the answer is made by the lecturer, that if the galvanic action had been complete, fouling would not have taken place. But the only proof that you can adduce on that head would be, was the iron of the ship attacked? Because it is natural to suppose if the galvanic action was not complete it would have shown itself on the iron. Now the iron was like virgin iron when the zinc sheathing was taken off in places, not a sign of corrosion. The zinc plates were continually wearing away, and, therefore, exfoliation of some kind was going on. These are facts which have been before me, and seem to me to bear very much upon the question. But, I think, as far as anti-corrosion goes, the zinc sheathing, however applied, is a complete remedy. But then I do not think that at the present moment (I follow Mr. Lewis) the corrosion is so important a matter as the fouling. The fouling is before us constantly. It was the great trouble of our forefathers in the last century. I think almost the greatest trouble they had. The cry for clean ships, the difficulty of keeping up blockade owing to rapid fouling of ships before the invention of copper sheathing, fills the official letters up to the close of last century. Now the result of that was the blockading squadrons were continually weakened by ships being sent home to be "cleaned and tallowed," as the phrase went. And as we stand at present, so far as I know, we should have to conduct our blockading in precisely the same way. While the enemy inside his ports would always have clean ships, being close to their docks, we on the outside would have ships that were fouling very rapidly after a time, and would have to be sent home continually to be cleaned

follows:—"The zinc on 'Bessie' does not yet show any signs of corrosion or fouling, while the buoy to which she is moored, and which has only been thirty-four days in the water, has a growth of baby barnacles on it already, besides a glutty sort of weed at least a couple of inches long; but then the buoy is of wood, coated with red-lead. As far as appearances go at present, the zinc sheathing looks like a success; in fact, if it continues to act as it seems to do at present, the success is a certainty. It looks extremely well without the patchy blotched appearance of paint, besides giving a perfectly smooth surface, much smoother than any sort of paint or enamel that I have seen tried."

just as they were in the middle and end of the last century. That of course would seriously weaken every blockading squadron, and would necessitate our providing at this present moment a greater number of ships for blockading purposes than would be necessary were we certain that their bottoms would not foul. That shows what a very important subject this is from the Royal Naval point of view. I had a letter only the day before yesterday from the owner of the "Galatea," the yacht which raced last year for the American Cup, and he pointed out that this question of the method of coating the bottom had a great deal to do with the racing trouble; and if something could be found which was absolutely smooth and would not foul, they would be very much better off than they are at present. These are the two plans only for anti-fouling before us, the plan of exfoliation, which has been adverted to to-day, and the plan of poisoning. So little is known about the subject that it is, I believe, almost impossible to say as yet how much the poison has to do with it, or how much exfoliation exercises its function in cases where manufacturers believe in the one or the other. Mr. Lewis put the case precisely. We want to extend the time. As he said, any of the good compositions will last for several months, as much as nine months in cases. That means that the ship will be in a fair condition for nine months, but then it very much depends upon the water she is in, her motion through it, the season, and a number of things that we know very little about. These seem to affect the fouling, and sometimes under apparently precisely the same conditions, you get totally opposite results in the fouling. The sum of it to my mind is, that we should look to compositions more than to any system of sheathing, that at present we are more likely to get on a sound basis in that way; but the inquiry must be made scientifically. The facts are not known; nobody really knows very much about it either way. I was only sorry that the money ran so short that our Committee could not go on sitting, because we were attacking the subject in a way that had already given us results, and we were bound to have got more results, because with the aid of Mr. Lewis for chemical matters, and with the aid of the naturalists of the British Museum for the animal and vegetable growths, we were gradually coming to see certain laws that were evolving themselves out of our method of proceeding, and if we had been able to go on, I think we should have got still more laws and have been able to have laid down for the guidance of manufacturers some definite data on which they might have worked, with the hope of getting ultimately to the bottom of the whole question. As it stands, the experiments are isolated, not classified. Nobody really knows what the true results are or the causes of those results, and it is only by meetings like these, where real attention is drawn to the subject, that we may hope that it may be taken up in a scientific way and ultimately solved. I have much pleasure in asking you to accord a cordial vote of thanks to Mr. Henwood for his lecture.