INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1897-8.

President—J. Fortescue Flannery, Esq., M.P.

Volume IX.

SEVENTY-SECOND PAPER

(OF TRANSACTIONS)

ON CERTAIN DEFECTS FOUND IN PROPELLER SHAFTS.

BY

Mr. M. W. AISBITT

(MEMBER).

READ AT

THE UNIVERSITY COLLEGE, CARDIFF,

On WEDNESDAY, DECEMBER 22nd, 1897.

THE INSTITUTE PREMISES, 58 ROMFORD ROAD, STRATFORD,

On MONDAY, JANUARY 10th, 1898.

THE ARTS SOCIETY HALL, SOUTHAMPTON,

On TUESDAY, JANUARY 11th, 1898.

PREFACE.

58 ROMFORD ROAD,

STRATFORD, LONDON, E.,

January 10th, 1898.

A meeting of the Institute of Marine Engineers was held here this evening, when a Paper " On Certain Defects found in Propeller Shafts," by Mr. M. W. AISBITT (Member) was read, in the absence of the author, by the Hon. Secretary. The chair was occupied by Mr. JOHN H. THOMSON (Vice-President).

The Paper was read previously before the Bristol Channel Centre in the University College, Cardiff, and was then illustrated by means of lantern views.

The discussion this evening was adjourned to January 24th, on which occasion it is intended that the views to illustrate the Paper, and also a case referred to in the discussion, will be exhibited.

JAS. ADAMSON,

Hon. Secretary.

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In proposing to read a paper on this subject, I would wish you to kindly understand that it is more from a desire to open a thorough discussion, collectively and individually, upon this very important matter, than to lay before you my individual opinions.

On the importance of the subject I am sure we are all agreed, especially when we remember that the failure of propeller shafts is often the cause of many precious lives, together with much valuable property, being lost, and, in addition, the anxiety that is entailed upon us to decide as to whether or not a given shaft is safe, is of considerable moment to us all.

Possibly many shafts, which have afterwards been proved to be perfectly safe, have been condemned, but I think the gain has undoubtedly been greater than the loss, as regards risk, for, at any rate, if sometimes we have erred, it has been on the right side.

The subject, as no doubt you are aware, has already been ably treated by the Institution of Engineers and Shipbuilders (Scotland), as also by Mr. Milton, at the Naval Architects Meeting in 1881, and by Mr. Manuel before our Institute in May, 1890, and recently by Mr. Gravell, in a special report to the Bureau Veritas in October, 1897, all of whom have very carefully and ably investigated the various causes and effects of the breakages of propeller shafts; but, as the matter has not yet arrived at a definite conclusion, I think there is still room for ample discussion by an Institute such as our own, with a view, if possible, to arriving at some definite data and facts concerning the various causes and effects.

Before fully entering into the matter, I will lay before you the following list of defective shafts which have come under my immediate notice for the years 1895-96-97. The average life of these appears to be about four to five years, but it must be remembered that in so averaging them I have taken the life of the vessel, and that therefore the actual average will be considerably lower. In the year 1895 there were forty shafts condemned under my notice; in the year 1896 sixty; in the year 1897 seventy.

Before proceeding further, I will enumerate the various defects usually found in propeller shafts, viz.: Those which are actually fractured in a diagonal line, say, between the inner and outer liner, caused by the propeller striking some semi-submerged substance, etc.; those which are also caused by the propeller striking some submerged substance and creating a fracture longitudinally along the keyway in the propeller or around the same; those that are caused through watermarks or corrosion immediately in front of or behind the after liners.

The two former I think we need not at present discuss, seeing that they are undoubted fractures, and are generally the result of some undue strain.

As to the latter, namely, those caused through corrosion and so-called watermarks at either end of the after sleeve, I would desire the benefit of your experience and assistance in order to elucidate their primary cause and ultimate effect.

Before investigating this, it may be well for us to arrive at the usual basis for determining the length of propeller shafts even at the risk of being considered by you, who are so well versed in the subject, somewhat prolix.

What we have to consider, therefore, is the necessary actual length of a propeller shaft, the diameter of course having already been fixed by Lloyd's and other Registry Societies. Many years ago certain investigations were made by our Government as to the best wearing substance for these shafts, and it was found after many experiments that a shaft fitted with a brass sleeve and the outer end running upon lignum vitæ gave the lowest frictional resistance, but it was also found necessary to have an inner brass liner or sleeve, fitted on the shaft in way of the stern gland to carry it. The engineers of that date, therefore, submitted to the shipbuilders drawings showing the diameter of the coupling and stern gland, and requested the latter to inform them of the length of the stern tube necessary. This, of course, was a question of the fineness of the vessel aft, and averages generally from

17 to 18 ft. Then and since it has been the custom to fix the stern gland at a distance from the boss post of about the same extent, but latterly, owing to modern vessels having assumed a much fuller form aft, this necessity has been dispensed with, and it is now quite possible to fix the stern gland at a distance of from 6 to 8 ft. from the boss post. The average propeller shaft, however, in the meantime has not decreased in length, the average being about 24 ft. in length, and having two brass sleeves, the outer one running on lignum vitæ.

In vessels built fifteen to twenty years ago, owing to the fineness of form, the propeller was more immersed when in water ballast than at present. In modern boats of the present type, owing to their being fuller aft and forward, the propellers are now in many instances only semi-submerged when in ballast, and sustain much greater strains than originally. Furthermore, owing to the dead weight capacity of the steamers having largely increased—say to the extent of 20 per cent.—the strains thrown on the propeller and also on the shaft are largely increased. Hence, perhaps, one of the reasons why we at the present day find so many shafts proving defective at sea.

I will now give you several instances of defects which have occurred before actual breakage has taken place.

DESCRIPTION OF PHOTOS.

1.—The tail shaft of the ss. *Henrietta* shows a defect in the form of what might be described as the end of an old slab weld, and is not now commonly found.

2.—Is the tail shaft of ss. *Londonderry*, on which you will be able to clearly trace the line of the so-called watermark, which runs practically parallel to

No. 1.—HENRIETTE H.

No. 2.—LORD LONDONDERRY.

No. 3.—TUSKAR.

No. 4.—TUSKAR.

No. 5.—THYRA.

No. 6.—THYRA.

No. 7.—HENRIETTE H.

No. 8.—RIVER ETTRICK.

No. 9.—BEETHOVEN.

No. 10.—BEETHOVEN.

the outside surface of the shaft. You will also notice on the left hand of the photo that a certain amount of scale is clearly shown on the brass sleeve.

3.—The shaft of the ss. *Tuskar* which you will notice is apparently composed of very good metal, although somewhat open at the heart. The causes of its condemnation were the two marks as shown in chalk, together with a slight trace of corrosive action extending circumferentially.

4.—The shaft of the same vessel before breakage, which clearly shows the marks mentioned, and where the brass sleeve had been at some previous time cut back.

5.—The tail shaft of the ss. *Thyra*, upon the brass sleeve of which strong evidence of scale is shown.

6.—The shaft after breakage shows a very clean fracture, and, with the exception of being rather open at the heart, no signs of defect.

7.—Is a photo of the shaft of the ss. *Henrietta*, which I think shows strong evidence of crystallization.

8.—The shaft of the ss. *River Ettrick*, which also shows evidence of the same nature as the *Henrietta*, but the defects after breakage were much more apparent, extending inward in some places to the extent of three inches.

9 and 10.—The shaft of the ss. *Beethoven*, which is also crystalline, and shows a considerable defect circumferentially. On examining the fore and aft view it will be noted that the surface of the shaft appears deeply pitted in several places, which I imagine must be attributable to the presence of steel in the forging.

11 and 12.—The shaft of the ss. *Handel* before being broken, and the section of which you will observe has a large number of cross marks at some distance from the brass sleeve, and appears generally in a badly corroded condition. The sections number 12 also show that considerable action has taken place circumferentially.

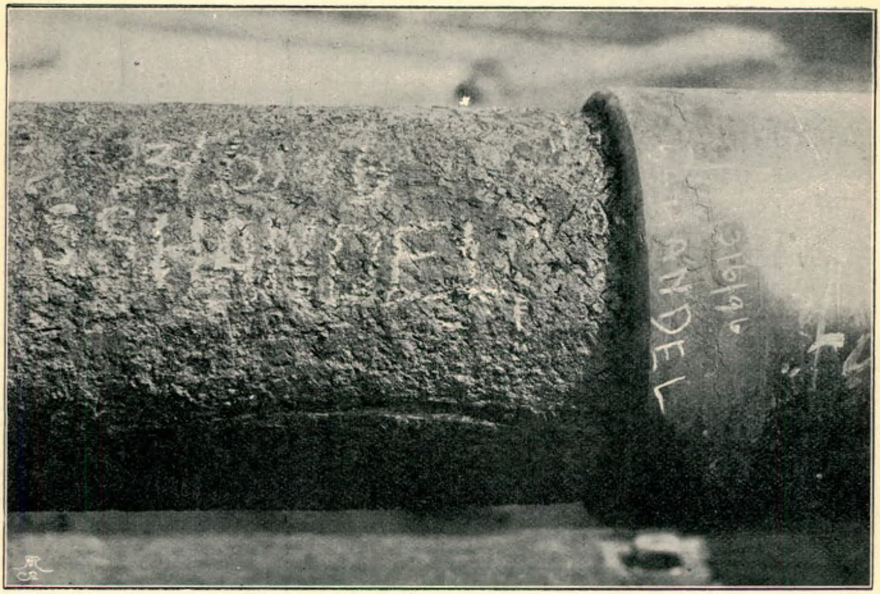
13 and 14.—Are the shafts of the *Topaze* and ss. *Hart*, both of which show a considerable defect circumferentially.

15.—Is the shaft of the ss. *Gardepee* after being stranded at Peniche Point, near Lisbon, in which vessel I came home, and in which you will note the fracture extends well in towards the centre.

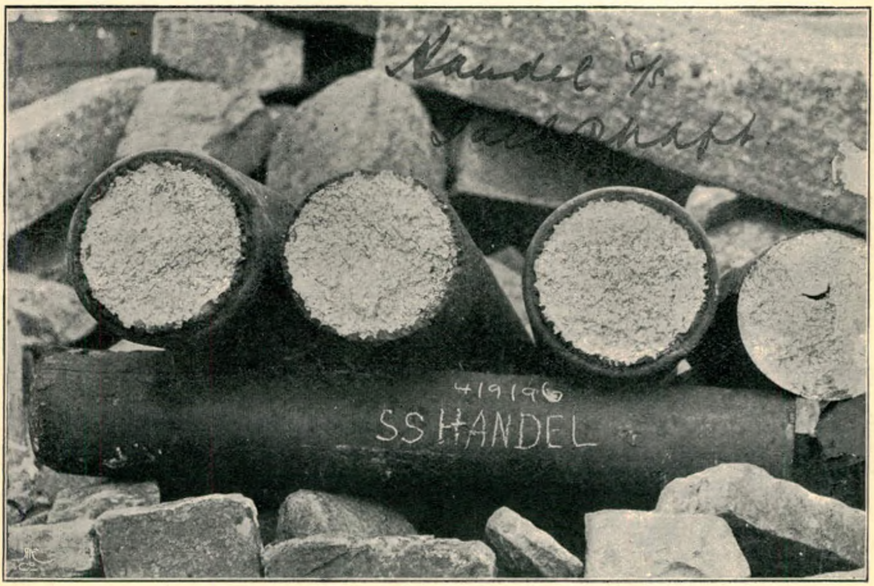
16.—Is the ss. *Headlands*, and is peculiar in that the defects are not continuous, as usual, circumferentially around the shaft, but at varied distances from the after end of the liner. You will also note that a considerable depression has taken place in the diameter of the shaft through corrosion, extending for about 7 to 8 in. forward of the sleeve.

17 and 18.—Is the shaft of the ss. *Prodano*, from which, after being broken, a considerable quantity of water escaped from the piping at the heart. As there was apparently no means of access into the centre of the shaft for the water, we were somewhat puzzled at first how it got there. However, on removing the key and the two studs attaching same to the shaft, we found that the studs had entered the piping at the smaller diameter of the tail end, and the water had obtained access by this means, and hence along to the point shown.

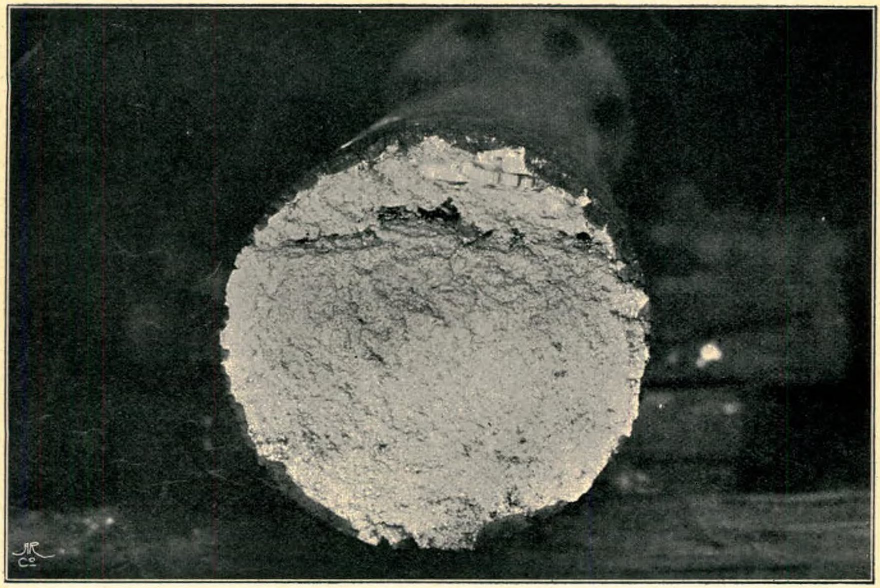
19.—The ss. *Uplands* is an instance of corrosion taking place, at the after end of the after liner between it and the propeller, where the surface has been exposed.



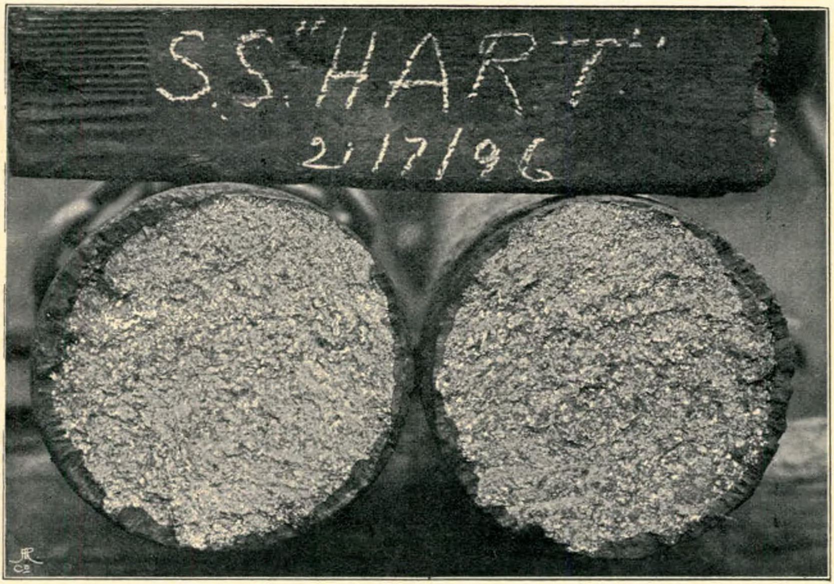
No. 11.—HANDEL.



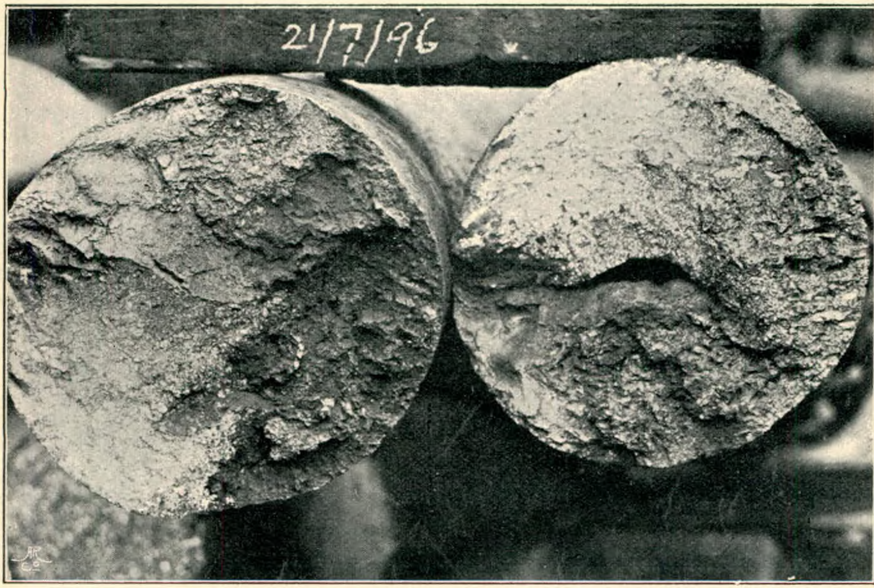
No. 12.—HANDEL.



No. 13.—TOPAZ.

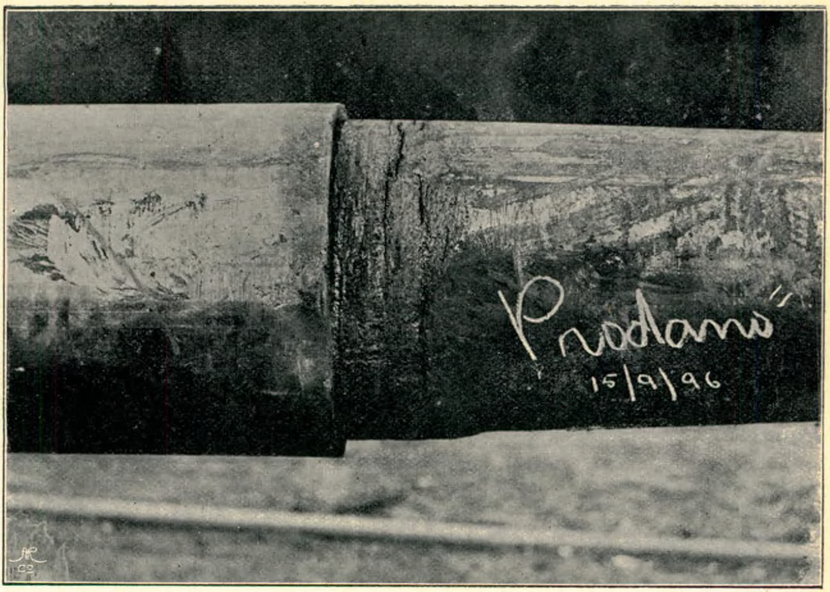


No. 14.—HART.



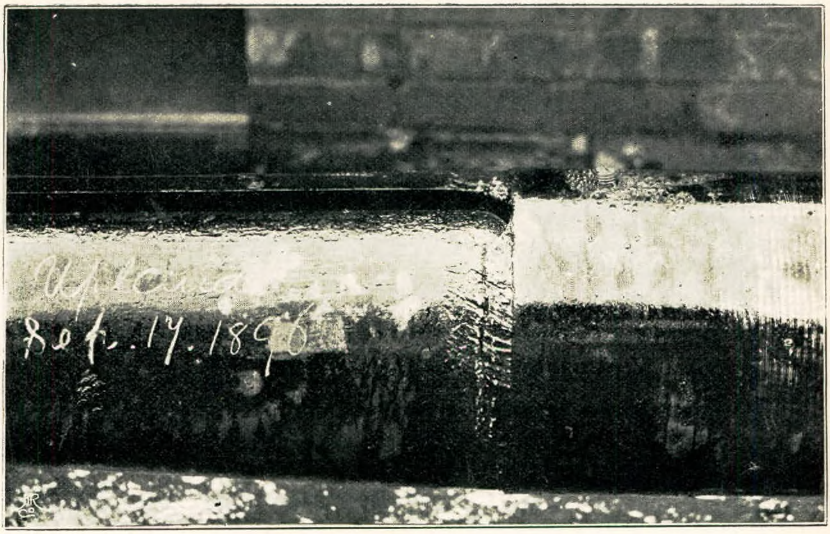
No. 15.—GARDEPEE.

No. 16.—HEADLANDS.

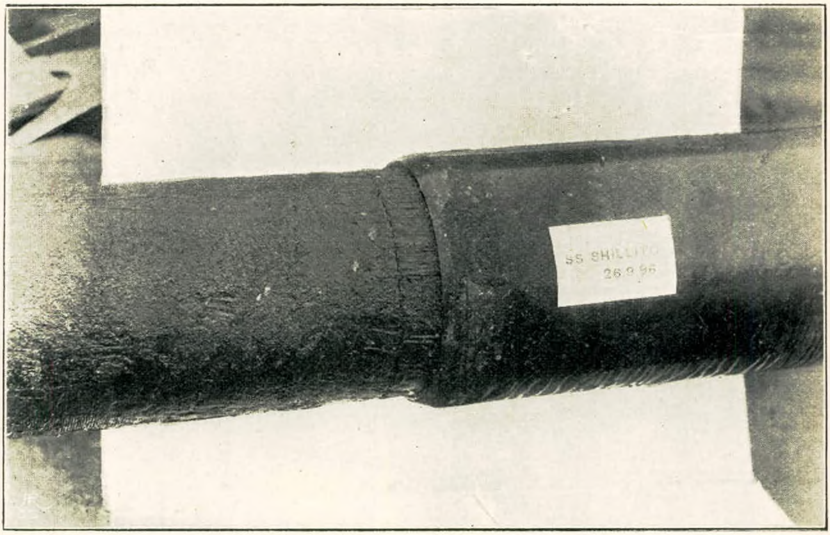


No. 17.—PRODANO.

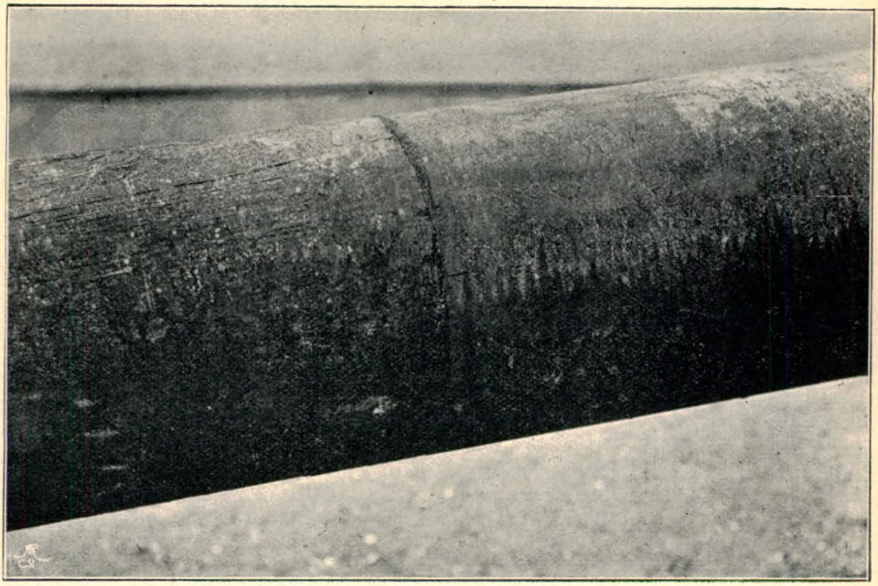
No. 18.—PRODANO.



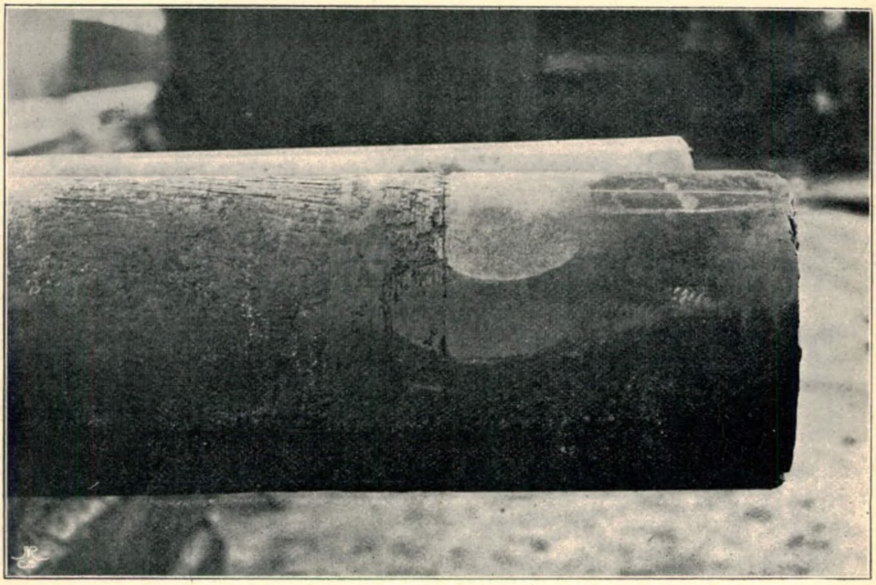
No. 19.—UPLANDS.



No. 20.—SHILLITO.

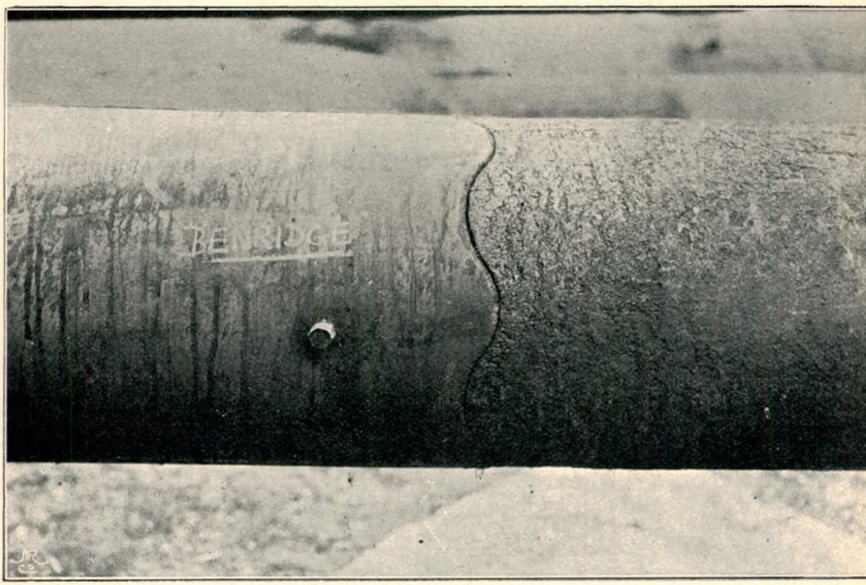


No. 21.—CALLIOPE.



No. 22.—CALLIOPE.

No. 23.—CALLIOPE.



No. 24.—BENRIDGE.

20.—The ss. *Shillito* is a very good example of an instance where the brass liner has been cut back, and the scale is distinctly seen on it.

21, 22 and 23.—The shaft of the ss. *Calliope*, which was condemned owing to the mark or defect as shown, and which after considerable discussion it was decided to break, with the result as seen.

Before proceeding further it may be of advantage to consider the construction of the propeller shaft itself, which is generally composed of one or other of three materials—viz., either forged scrap iron, forged scrap iron mixed with steel, or steel entirely.

Forged scrap iron is assumed to be wrought iron pure and simple, and generally made up of faggots composed of cuttings from wrought iron plates with a number of punchings intermingled. In many instances these punchings are carefully scaled and cleaned, but I am afraid that in many others a considerable amount of dirt and foreign matter is present; hence some of the defects that we find in propeller shafts. In other instances some steel has perhaps unavoidably been mixed with the wrought iron, and, through non-amalgamation of the two properties, may cause local defects.

Propeller shafts made of ingot steel pure and simple are undoubtedly homogeneous, but from the very fact of their being pure metal are more liable to corrosion from the presence of the copper contained in the brass sleeve. Both Mr. Manuel and Mr. Gravell, I think, advocate in their papers the substitution of steel shafts made from ingots, with which I am inclined to agree under certain conditions.

Mr. Manuel refers in his paper to the fact of some of the propeller shafts being finished off to a smooth surface through water being thrown on them, and attributes some of the defects in them to this cause.

This argument, I think, on due consideration is untenable, for this reason, that shafts which have least possible skin surface turned off them have proved more effective than those which have been forged larger and have afterwards been turned down, say, an inch and a half less in diameter. That this must be so, I think, is obvious, seeing that the original skin of the shaft must always be better than the material at the heart of it, of which we have ample evidence in the photos already shown. In wood shipbuilding it was always best to take the smallest possible scantling of timber for a given purpose so as to secure the outside skin, and the same, I think, holds good as to the forgings. After the propeller shaft has been forged and turned in the lathe, as we all know, two brass liners or sleeves are prepared and shrunk on to same and secured by several pins.

Several years ago the great trouble that existed with propeller shafts was principally through corrosion at the after end of the after liner; between it and the propeller, where exposed to the salt water, deep corrosion occurred, and what are termed watermarks. However, owing to the introduction of a method of continuing the after end of the after liner into the propeller and carefully covering same with red lead, this trouble, I am glad to say, has become practically nil.

The present difficulty, in many instances, is with the corrosion and watermark so-called, which occurs at the fore end of the after liner in the stern tube. Sometimes a certain amount of corrosion is found at the after end of the forward liner, but this is not of frequent occurence or of great extent, the principal difficulty being with the corrosion or watermark at the fore end of the after liner. Many means have been suggested and adopted for overcoming this defect, one of which is that introduced by our fellow-townsman,* Mr. Jordan, of the Junction Dry Dock, of introducing a composition of red lead immediately under the fore

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* Cardiff.

end of the liner and in front of it, but this, although an improvement only, I think causes the galvanic action to be carried some distance further forward. Another improvement has been patented by Mr. Mudd, of the Central Engineering Works, Hartlepool, of covering the propeller shaft between the brass liners with an india-rubber sleeve supposed to be hermetically sealed on the shaft. A third idea is to wrap the shaft with fine marline between the two sleeves, coating same with pitch or tar. But all of those methods have the objection, especially the latter, that when drawing the propeller shaft the coating may be destroyed locally, and that at some future period it may unwrap and cause trouble in the stern tube. A further improvement has been suggested by several engineers of shortening the stern tube so that the after liner will extend to the stern gland—say 6 ft.—leaving the propeller shaft of the same length as usual—say 24 ft. Of this mode of improvement I will speak hereafter, our present subject or investigation being, "What is the cause of the watermark and corrosion which we find so frequently at the fore end of the after liner?"

In many instances we find that the so-called watermark precedes the corrosion, and further that the watermark invariably runs immediately parallel with, and close to, the fore end of the after liner around the shaft, the corrosion apparently taking place subsequently.

Several years ago I investigated this matter as far as I was able, and, together with several others, was of the opinion that two forces were at work producing the so-called watermarks and corrosions found—namely, firstly, mechanical; secondly, chemical or galvanic action.

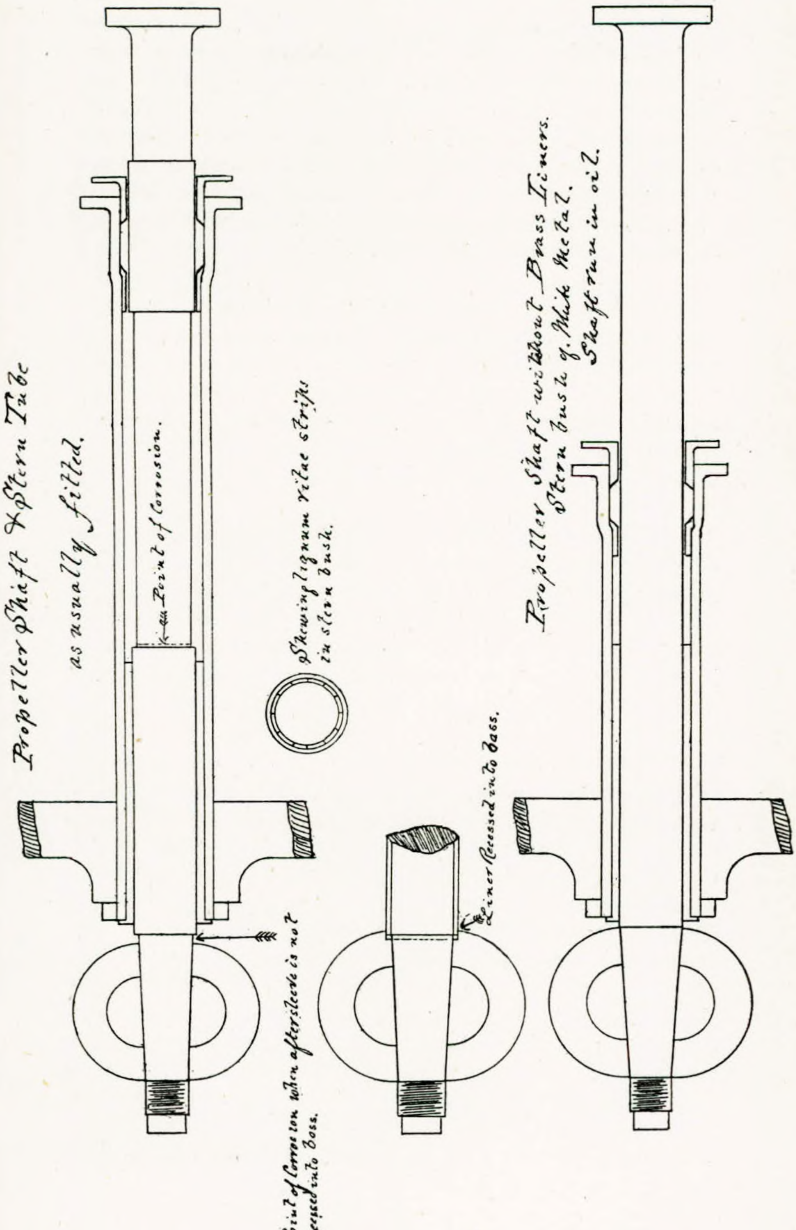
The mechanical action was assumed to be caused by the beating or hammering of the propeller shaft in the stern bush through slackness, say, when the clearance was worn to $\frac{3}{8}$ or $\frac{1}{2}$ in. causing a *skin* fracture on the shaft immediately in front of the after liner, and that the chemical or galvanic action of the brass would afterwards act upon this fracture and cause the marks as shown. However, from further investigation, I am convinced that the so-called watermark is really attributable to chemical and galvanic or electrical action. My reasons for stating so are these:

I have noticed that in almost all cases where the watermark action and corrosion exist, there has always been a slight scale on the forward end of the after liner which extends beyond the lignum vitæ. This scale I have had removed and analysed, of which the results are as follows:

TAIL SHAFTS.

ANALYSIS OF SCALE.

	June 3, 1893	Feb. 2, 1895	Mar. 9, 1895	Oct. 20, 1897	Dec. 14, 1897
Organic Matter, etc. (By ignition).	4·86	15·94	6·49	6·67	4·90
Silica	—	2·68	1·38	·26	0·70
Carbonate of Lime	42·60	13·87	46·81	63·90	—
Carbonate of Magnesium ...	—	13·25	12·26	—	—
Traces of Chlorine, Magnesium and Alkalies	0·30	—	—	—	0·61
Carbonate of Iron	—	17·82	6·60	—	—
Peroxide of Iron	2·93	26·45	1·06	—	7·59
Oxide of Iron	—	—	—	1·50	—
Oxide of Zinc	0·13	2·04	0·13	0·14	trace
Sulphuric Oxide	0·09	—	—	—	—
Oxide of Copper	14·92	6·74	24·36	25·60	15·31
Chloride of Sodium	—	1·13	0·91	—	—
Carbonic Acid	33·75	—	—	—	—
Sulphate	—	—	—	1·40	30·90
Magnesium	—	—	—	0·53	—
Residue Insoluble in Acids ...	0·42	—	—	—	—
Alumina	—	—	—	—	trace
Water	—	—	—	—	1·50
Lime	—	—	—	—	38·39
	100·00	99·92	100·00	100·00	99·90


Propeller Shaft & Stern Tube
as usually fitted.
Point of Corrosion.
Showing lignum vitae strips
in stern bush.
Point of Corrosion when aftersleeve is not
recessed into boss.
Liner Recessed into Boss.
Propeller Shaft without Brass Liners.
Stern bush of White Metal.
Shaft run in oil.

My opinion is that, through the revolutions of the shaft on the lignum vitæ, a certain portion of the after brass sleeve or liner is ground away, and, in doing so, the copper, tin, and zinc forming the brass liner are dissolved, the light properties floating away, and the heavier copper being deposited on the inner end of the brass liner is found immediately adjacent to the exposed softer wrought iron. The salt water flowing over this almost pure copper naturally attacks the iron shaft and causes the defects which we find. Also, on examining a large number of shafts which we have had broken in way of these defects, I have invariably found that the so-called watermark finishes distinctly at a given point, and is not in the nature of a fracture which would be shaded off towards the centre, of which I produce a very fair sample.

Originally the idea was that these watermarks were caused through the water in the stern tube producing a sawing action on the propeller shaft, but, after taking into consideration the speed of the shaft in the stern tube, I am compelled to admit that the watermark idea so far as regards the sawing action is fallacious, and that we must look to other causes than that.

If the mechanical action, as aforesaid, was the cause of those defects which we find in the propeller shaft, we should naturally expect to find whatever mark is on the shaft tapering invariably towards the centre. On the contrary, we find those marks finishing with a distinct edge, the rest of the metal being practically intact. Doubtless a shaft after many years use becomes crystalline, but at whatever time a defect may happen to show, whether the material of the shaft were crystalline or not, it would only be natural to expect to find the fracture extend gradually towards the centre.

I am, therefore, compelled to dispense with the mechanical plus chemical theory, and to accept the chemical alone as regards the cause of the defects at the fore end of the after liner; and, in corroboration of this, I noticed some weeks ago a propeller shaft which had been covered with a brass liner, the inner end of which was corrugated around the shaft. The defect followed the line of the corrugation exactly, and did not run at right angles to the line of shaft as usual, proving, I think, beyond doubt that the action of the copper in the brass was the cause of the defect, and not any mechanical action.

Photo 24.—The shaft of the ss. *Benbridge*, in which you will note that the fore end of the after liner has been corrugated with a view to dispensing with the chemical action, in spite of which it has taken place and closely followed the edge of the liner, proving, I think, conclusively that these marks are attributable to chemical action, and not to any mechanical action.

Lastly, as to what I would propose in order to obviate those defects which we have so frequently had experience of, I would suggest:

Firstly, that the stern gland be fitted at the fore end of the after liner, say, 4 to 6 ft. from the boss post, and that the peak bulkhead be cut and the engineer in charge have access right up to this gland; or perhaps a better arrangement would be to forge the shaft larger, in way of the stern bush, equal to the diameter of the brass sleeve, and that the stern bush be lined with white metal instead of lignum vitæ. If the latter mode be adopted, it is, I think, absolutely necessary that the stern tube should be filled with oil or other lubricating matter, as wrought iron on white metal with water as lubricant has not proved, so far, successful.

Furthermore, I should not advocate a long propeller shaft being carried with a second bearing inside of the proposed stern gland, as, should this be done and the propeller shaft wear down on the outer end of the stern bush, which it is only natural to expect, the shaft will be bound at two points with the weight of the propeller on the outer end suspended at a considerable distance from the stern gland. My idea is that a short propeller shaft is more convenient to carry in the recess, and, if suitable means are adopted to allow of its giving at the after coupling in case of the outer edge wearing down, as is frequently done in the case of paddle ships, greater security will be obtained, even at the risk of breaking the after coupling-bolts, so long as the centres of the two couplings are kept in line. I think that even if the propeller shaft was kept at its present length a great improvement would be effected by increasing it in diameter to that of the present brass sleeves, leaving the intermediate portion unturned and running same in oil on white metal.

So far as running on white metal is concerned, I am convinced from the experience we have already obtained of using this material for main bearings of crank-shafts, etc., we have ample grounds for adopting it, while at the same time dispensing with the chemical action previously mentioned.

In any case, whatever method is adopted, it lies with us all to devise some means by which the present serious defects in propeller shafts may be avoided.

PREFACE.

BRISTOL CHANNEL CENTRE.

35 STACEY ROAD, CARDIFF,
December 22*nd*, 1897.

A Meeting of the Bristol Channel Centre of the Institute of Marine Engineers was held this evening in the University College, Cardiff, presided over by Professor A. C. ELLIOTT (President of the Centre), when Mr. M. W. AISBITT (Member) read a paper, "On Certain Defects Found in Propeller Shafts."

The subject was illustrated by photograph slides, and a well-sustained discussion followed.

GEO. SLOGGETT,
Hon. Local Secretary.

BRISTOL CHANNEL CENTRE.

DISCUSSION

ON

CERTAIN DEFECTS IN PROPELLER SHAFTS.

DECEMBER 22nd, 1897.

CHAIRMAN:

MR. T. W. WAILES (MEMBER).

The CHAIRMAN: It has afforded me very great pleasure to have heard such an interesting paper, and it is now open for discussion, which, I believe, will probably be a very long one, and will not be completed to-night, but to make a start I have very great pleasure in calling upon Mr. Chellew to say a few words on the subject.

Mr. CHELLEW (Member) said they were all deeply indebted to Mr. Aisbitt for his interesting paper and the information it contained. The speaker had had one or two breakages of tail shafts on long voyages, and therefore the subject was to him a most interesting one. He had tried several expedients with his boats, and had had much experience with the india-rubber sleeve, but when this sleeve got torn, below it was found an accumulation of brass and other stuff. He was in the North the other day and saw some naval work being done, in which a long liner, the whole length of the tail shaft, was fitted on, and he believed this had proved fairly successful. Another suggestion, which he had seen tried by the Germans, was that of filling the after tube with grease. This he had heard gave excellent results, but he could not vouch for it himself.

Mr. FLEMMING (Member) contended that the main fault was due to the ship. He could not say much on the subject at present, as he had only had the paper put in his hand on entering the room, but he was sorry to say he had had considerable experience of broken shafts, and his experience had taught him many things, the chief of which was that the commencement of the fracture was due to the ship. Of course, they all knew that once a soft place was opened out the chemical action with the copper, etc., would take place, and the shaft become fractured.

The CHAIRMAN: You think the ship finds the weakest place out, and the chemical action does the remainder?

Mr. FLEMMING: That is my experience. I have constantly noticed that in the old conditions we were never troubled with breakages of shafts, whereas now they are breaking all the time; so I have come to the conclusion that it is the ship more than the shaft.

Mr. J. R. FOTHERGILL said that as a visitor he had not anticipated being called upon to address the meeting, but as the subject was one not only of great interest, but one which the majority of marine engineers at the present time were peculiarly interested in, he did not hesitate to join in the discussion. No doubt experience had helped most of them to form some opinion as to what caused the great destruction of propeller shafts. He was unable to accept the opinion expressed by Mr. Flemming, for whatever deflection you may have in a steamer, that deflection in the region of the whole shaft distributed through the length of shafting would certainly not produce any strain of sufficient moment to account for the wholesale destruction going on. If the steamer was to blame it was because she was not sufficiently ballasted as a light ship. Modern steamers left the Continent for the Bristol Channel in water ballast and some five to six or eight days' coal on board, drawing about 11 to 12 ft. aft, and only half the propeller submerged. Imagine a steamer under such conditions caught in a gale off the Land's End. The wonder was, not that she broke her shaft, but that any shaft could stand such straining, Take a steamer about 5,000 tons, say 12 in. shaft and 17 ft. propeller, weighing 6 tons, making, say, 65 to 70 revolutions on a light ship. As soon as the propeller left the water the revolutions would run up to 100, giving a periphery speed of 5,300 ft. per minute. At this enormous speed the propeller was plunged into the water and the revolutions in a few seconds reduced so low that the engines were almost brought up. The strains produced in overcoming the inertia of the propeller at such a high speed must seriously disturb the molecular structure of the material and affect the life of the shaft. The torsional and bending strains produced mechanical action at the surface of the shaft, and small fine cracks running in no particular direction were produced. The lips of these cracks were quickly acted upon, and rapid corrosion developed by electrical action set up by the brass liner, and of course the effect of this action would be more severely felt at the immediate termination of the brass liner. The constant recurrence of these strains extended and renewed the surfaces of the cracks, materially assisting corrosive action, which developed in an extraordinary degree. He wished to emphasise the opinion that the damage originated in small cracks mechanically produced by excessive strains, and rapidly developed to a serious degree by corrosion largely produced electrically. He had seen a new shaft that had been for a considerable time immersed in salt water; the iron was much corroded, but there was no sign of distinctive cracking, so strongly in evidence when a shaft is subject to corrosion under mechanical stress. Again, he had seen several marked cases where the distinctive form of cracking had taken place some 8 or 10 in. from the end of the brass liner, due to this particular part of the shaft having been carefully wrapped with greasy canvas and lapped with marline. On removal of the wrapping the shaft was quite bright and in good order. This would appear to prove it had at that particular part been insulated to electrical corrosion. This went far to dispose of the theory that the cracking at the end of the liner was due to rigidity produced by the liner, and this was further supported by the fact that a few years ago the greatest difficulty was experienced at the top of the cone. This was attributed to the same cause, abrupt change of form; but since means had been taken to keep the water out, this difficulty had disappeared. He was strongly of the opinion that if the shaft was properly protected from the water the life of the shaft would be enormously increased. Mr. Aisbitt had given many excellent protographic examples of shafts purposely broken; these were interesting, but he doubted if they proved much as to the condition of the material. The appearance of the material at the point of fracture depended greatly upon the way in which the shaft was broken, the number of blows, where and how delivered, etc. The analysis given in the paper was very interesting, but what he thought would be of greater interest was an analysis of the corrosion at the fracture; this would enable them to determine whether any fine ground brass off the liner actually deposited in the crack and assisted corrosion. In conclusion, he desired to thank Mr. Aisbitt for a most interesting and able paper.

Mr. DARLING (Lloyd's Surveyor), said that he quite agreed with Mr. Fothergill as to the mechanical action that took place, and did not think he could say much more than he had. Perhaps he could give them a few instances bearing out that it was the mechanical action which caused the corrosion. He had a case at Darlington. The shaft was fitted with the ordinary brass liners, but at the fore end of the after liner there was a long tapering piece of white metal fastened round the shaft to which it adhered as well as to the after liner. When they came to examine the shaft they found that the white metal was fractured circumferentially at the after end of the after liner. The inner end of the after liner was quite intact. The white metal still adhered to the inner end, but the fracture showed distinctly, and when the shaft was broken it was found to be watermarked to the extent of 2 inches. At the after end of the after liner the same treatment had been done, and there they found the shaft fractured, partially through the white metal and partially out of it, running in a line. There was no corrosion whatever. The white metal was adhering perfectly to the shaft at the point of fracture on either side of it. Then they tried putting on a fixed liner, or rather burning the liner, but he was sorry to say that that had not been satisfactory. He thought that those cases pretty clearly proved Mr. Fothergill's contention that it was a mechanical action in the first instance. Of course, what Mr. Fothergill had said about the mechanical fracture opening up the surface of the material, and therefore leaving a clean surface for the galvanic action to take place, was quite correct. He could not see how Mr. Fothergill could have any other theory than that of mechanical action, in addition to and prior to the chemical action, as if it were solely due to chemical action that these shafts got fractured the same thing should occur on all shafts, which was certainly not the case.

At this point Mr. J. F. WALLIKER rose and said that he had been asked to move the adjournment of the discussion to their next meeting. The paper had only been placed in their hands that evening, and they had not had that time to examine it which the importance of the subject demanded. He should like to add his appreciation of Mr. Aisbitt's paper to that of his friends who had spoken before him, but he could not help thinking that Mr. Aisbitt had almost fallen amongst thieves. He had not heard anyone there that night supporting what he considered Mr. Aisbitt's rather new theory as to what they had always considered fractures in screw steamers. If he could prove to them that they had been wrong in the theory they had previously held his paper would not have been read in vain. Before sitting down he should like to point out one thing, and that was that they should all remember that a screw shaft as they put it in the ship was about the most unmechanical structure made—(cries of "Lloyd's requirements!"). They had this awkward piece of material, they put it at a part of the ship where it had to do all the work of the ship, and they shrank upon it two rings, which he thought enormously increased its stiength. Then they had what was called a break in the finite structure, and wherever there was a break that was the weakest part of the shaft.

Mr. T. A. REED seconded the adjournment, which was duly put to the meeting and carried. Mr. Reed suggested that they should have the photographs reproduced in such a manner that each member could have a copy, and the secretary (Mr. Sloggett) was requested to make inquiries as to the cost of this, and get it done if necessary.

BRISTOL CHANNEL CENTRE.

DICUSSION CONTINUED.

JANUARY 12th, 1898.

CHAIRMAN:

(PROF. A. C. ELLIOTT, D.SC.)

The discussion was resumed on Mr. M. W. Aisbitt's paper, read at the previous meeting, dealing with defects in propeller shafts, their cause and prevention.

Mr. J. F. WALLIKER (Chief Engineer Surveyor, Lloyd's, South Wales District) said there were several points in the paper upon which he was in agreement with Mr. Aisbitt. In the first place, he agreed that the corrosion found between the liners was due to acidulated water. In the second, that harm was done to wrought shafts by turning off too much material. He further concurred that corrosion at the end of the cone had been stopped by fitting the after bush into the propeller, and by protecting with an india-rubber ring, or by being properly lapped. There was nothing like plenty of observation, and it was better to condemn a shaft in good time than to risk a breakdown at sea. He was of opinion that a screw shaft in the form in which they found it was weak as a mechanical structure. In order to strengthen the Armstrong gun a ring was shrunk round it, and this was what was practically done with a screw shaft. A ring of brass was shrunk upon it, and the shaft was much stronger for what had been done at that part. But at the ends of the liners there was an abrupt change of form, and they all knew that where an abrupt change of form occurred in any structure that was its weakest part.

This he believed to be the weakest part of the screw shaft, and this was where they usually had the failures—the corner where the liner ended and the plain shaft began. The coincidence of the end of the liner and of the stern bush much accentuated the stress, and in consequence, the lengthening of the after liner, by distributing the strain, acted most beneficially on the life of the shaft. The taper of the wood in the stern bush through wear was seldom noted, but he had there some strips of lignum vitæ taken out of the bottoms of stern bushes, which showed that the inner end was at least one-eighth of an inch higher than the outer end, where the propeller came, showing in the most striking manner the enormous stress that the shaft had to sustain. The after end of the liner was also liable to fracture, but this did not occur so frequently, one reason being that the propeller was often fitted on to the liner, making the shaft and propeller practically one structure, the weak part being distributed and assisted by the boss. Where the propeller was away from the liner they were still liable to fracture, and frequently condemned the shaft for that reason. Mr. Aisbitt seemed to contend that watermarks or corrosion was due to the alteration in the type and size of vessels of late years, but this idea seemed to him entirely untenable. Corrosion was not a thing of to-day or yesterday. Shafts used to be found frequently deeply corded and reduced in area, and were condemned for that alone. Now, why was the corrosion so local? He submitted that it attacked the small fractures which commenced through stress at the end of the liner, and that it gradually deepened as the fractures developed, the shaft being ultimately removed before the corrosion had time to spread to the plain part. Nowadays they had much bigger ships on a light draught; they ran frequently in ballast trim; the engines were heavier, and had a fairly constant speed due to the three cranks. The I.H.P., therefore, of the engines must be given out at the propeller end, and was practically constant at all degrees of immersion, and the use of the governor being practically abandoned, it followed that the shocks to the shaft were much increased in intensity, and this he considered a most important point. As to covering shafts, covers would certainly stop corrosion, but would never stop fracture—(hear, hear). He had known white metal, placed at the ends of liners, fracture through, and the shaft also fracture underneath. In another instance, the fracture came right at the end of the white metal. As to the end of the liner being corrugated, he had found, when they got the liner off, the shaft fractured and corroded round the wavy line, which proved his contention that the shaft had failed at the weakest point — where there was an abrupt change of form in the structure, and that the fracture followed the line of least resistance round the shaft. As to star marks, these he believed showed the presence of steel. It usually happened that while the outside skin was cooling it was in a high state of tension, owing to the heat at the heart of the metal, and that cracks were then set up which, if observed, were taken up by a wash-heat which practically annulled them. But in the stress to which the shaft was afterwards subjected these cracks reappeared. They, however, were not in his experience usually very serious. They did not run into one another, and they were more or less like blotches of corrosion. As to Mr. Aisbitt's analysis of scale, he was struck with their extraordinary discrepancies, and hoped that these differences would be further explained. Scale was found at the end of all liners when not in contact with the bush, so that he should not be inclined, at all events, to give it that prominence which Mr. Aisbitt had done. Now it might be asked, what did he consider a good shaft? He thought they were all agreed that the best shaft was a parallel shaft of good material. They could cover it with brass if they chose. If they did that, and made the liner continuous, the shaft was practically one solid structure right away through. They could put on these liners of any length; there was no mechanical difficulty about putting them on, and, if they wished, could force into the recess a composition which would make the shaft solid from end to end, and there was no possibility of anything getting in to deteriorate it. They would have thus a practically homogeneous structure, with which they would experience much less trouble than they had known in the past—(applause).

Mr. T. A. REED (Member), said he would not go over the ground traversed by Mr. Walliker, as he generally agreed with that gentleman's remarks. His (Mr. Reed's) experience had been that, despite lapping the shaft, he still found the so-called water-marks at the end of the liners. As to the star marks, which he understood Mr. Walliker attributed to corrosion, if they were simply corrosion, why did they not star mark all over the surface, instead of taking a circumferential direction over the weakest part, viz., at the end of the liner?

Mr. WALLIKER, interposing, said that what he said was that the star marks, in his opinion, were due to surface tension.

Mr. REED apologised for misapprehending Mr. Walliker. He submitted a specimen sawn from a shaft which had been fractured between the propeller and the after end of the liner. This shaft on removal from the vessel was then broken, the broken ends sawn off, put together, and brought to the meeting for the inspection of anyone present. The fracture extended in for a distance of about two-and-a-half inches. This shaft was also badly starred at the forward end of the after liner. He submitted that the same cause (viz., mechanical action) which fractured the shaft as shown also created the star marks or surface fractures. Undoubtedly these star fractures were the result of "fatigue" in the shaft in the locality where they occur. He was also of opinion that it was mechanical action first, and corrosion afterwards, that caused the cutting in at the end of the liners. The plan he had adopted to prevent the corrosion between the liners was to fit a small cylinder on the peak bulkhead, with a pipe leading to the stern tube, and force solidified oil into the space, which excluded all the water. This grease, being gradually worked out at the after end of the tube, carried away with it any particles of copper or corrosive matter. It practically took no more oil for this purpose than was used for an ordinary bearing. Further benefit also appeared to be derived in being able to run the stern gland slack, thereby reducing friction.

*Mr. J. M. NISBET (Member): Every engineer whose attention has been drawn to this particular subject must perforce form theories from personal observation, and need not be in any way ashamed if his theories should turn out not altogether correct—nay, should the theories turn out altogether wrong, it is better to have a wrong theory than none at all; in this respect, that the possession of a theory indicates that the theorist has given the matter his attention and intelligent consideration.

Several years ago the writer was engineer of a corvette engined by Messrs. Penn. Shortly after entering on commission a noise was heard within the stern tube; the vessel was put into the first available port for examination, when the outer sleeve of the propeller shaft was found to have worked loose. On drawing in the propeller shaft and cutting off the sleeve a circumferential defect was found at the fore end of this sleeve, as far as it was possible to judge $\frac{1}{8}$ in. deep. Being in a port where a reliable casting was not procurable nor a guarantee of alloy in proportions such as our regulations required, the writer had a sleeve cast from Babbit's metal blocks, a goodly stock of which was carried on board. The Babbit's metal sleeve was cast about 5 in. longer than the

* Contributed by Letter.

original sleeve to cover the defect in the shaft already referred to. The Babbit's metal sleeve worked very well indeed, and was examined several times in various dry docks; and on the writer handing over charge of the machinery two years later the sleeve was still found in fair condition, but grooving in the shaft at the fore end of the Babbit's metal sleeve was just as marked and decisive as that formerly observed at the fore end of the brass liner. This shook the writer's absolute belief in "galvanic action" being the principal cause, as was at that time the generally accepted theory.

Later deductions from calculations to which the writer would ask your consideration are as follows:

First.—If a given torsional strain be transmitted through a shaft of uniform section, and the end at the propeller be held rigid, harmonic lines of torsion and harmonic lines of resistance to torsion will meet at a point somewhere in the middle of the length of shafting. Couplings, if equally distributed fore and aft of this neutral point, will not affect the neutral point itself, but couplings, if at varied distributed distances fore and aft of this neutral point, will alter the neutral point of action and reaction.

Second.—The nearer the torsional strain is approached or equalised by the work effected in the propulsion of the vessel, the nearer does the neutral point of action and reaction approach the propeller itself, and is invariably found to lie in the propeller length of shafting.

Third.—Any departure from uniformity of shaft section, such as swellings of the metal in parts of the shaft, or merely stiffening up of the shaft by liners or sleeves, disturbs harmonic torsion and harmonic resistance to torsion, and sets up local strains.

Example First.—Cut a strip of tin 10 in. long by $\frac{1}{4}$ in. wide, and in twisting this between the forefingers and thumbs of both hands you will find the curves or lines of torsion and resistance to torsion uniform and symmetrical.

Example Second.—Cut a strip of tin 10 in. long, $\frac{1}{4}$ in. wide for the first inch, $\frac{1}{2}$ in. wide for the next 2 in., $\frac{1}{4}$ in. wide for the next $4\frac{3}{4}$ in., $\frac{1}{2}$ in. wide for the next $1\frac{1}{4}$ in., and $\frac{1}{4}$ in. wide for the last inch.

Note the $\frac{1}{4}$ in. wide pieces represent the shaft's diameter, and the two $\frac{1}{2}$ in. wide portions represent the sleeves or swelled pieces respectively. Now, with the same twisting effort between forefingers and thumbs as used in the former example it will be seen that the intense points of torsional strain focus themselves at the fore and after ends of these swelled pieces representing sleeves, and if the twisting be persisted in the tin will sheer through at one or other of these points.

From the above reasoning the writer is of the opinion that the defects in propeller shafts are largely due to the non-uniformity of the section, and that to the disturbance of the molecules of the metal at these points rendering the metal more easily assailable to the wasting and cutting action of the water, assisted to some extent by the corrosive action of the alloys in the sleeves, is altogether due the many uniform defects in propeller shafts now under consideration.

The same defect occurs where a long sleeve in two pieces is shrunk over the whole length of a shaft. Even when these pieces are tenered or stepped over each other, the line of junction is the departing line of harmonic torsion, and as moisture gets through the grooving action begins just as it does at the exposed ends of the sleeves.

A more perfect propeller shaft could, in the writer's opinion, be assured if the shaft itself were of perfectly uniform section and the stern tube had a long bush at the fore and after ends of the tube, these bushes being lined with antifrictional metal, and easy to withdraw and refill as required.

This subject is all-important, and has many equally interesting points for consideration, such as slab corrosion and fore and aft grooving in the body pieces between the sleeves, all of which must have get-at-able reasons for their presence. Some engineers, too, think the centre of a shaft is of less reliable material than the outer skin, though the writer has not been able to establish this belief in the testing-house; but may not the central quality of material in a shaft be over-valued when we consider that the fourth power of any diameter of shaft, if multiplied by 1·0666 and the fourth root of the quotient be again extracted, gives a new diameter of shaft, half of which may be bored out of the centre of the shaft without lessening its power to resist torsion.

Example.—A 10 in. shaft raised to its fourth power and multiplied by $1{\cdot}0666 = 10666$, and

$$\sqrt[4]{10666} = 10{\cdot}162 \text{ in.}$$

Thus we see that a 10 in. solid shaft is no stronger to resist torsion than is a shaft slightly over $10\frac{1}{64}$ in. diameter with a hole $5\frac{1}{128}$ in. diameter drilled throughout its length.

Mr. DAVID GIBSON said, in regard to Mr. Aisbitt's findings, that gentleman had committed himself to a specific cause of fracture, which he was afraid he would have some considerable difficulty in proving. The author attributed the corrosive or water-mark fracture to chemical and galvanic or electrical action. If he had stood by the finding of his first investigation he would have found himself in more general agreement with most authorities. He (Mr. Gibson) did not say for a moment that there was no galvanic action, but he did contend that its effects on the shaft were only in proportion to the mechanical, and that if there was no mechanical action he was of opinion that there would be very little, if any, galvanic action. What helped him in this opinion was that there were shafts which lasted to a very great age. He had one which was over eleven years old, and he knew of others thirteen and fourteen years old. His shaft was corroded generally, but it had none of those marks of corrosion of water-marks now under discussion; and if galvanic and corrosive action were the principal agents to destroy a tail shaft, this particular shaft had had ample time to develop the defect. The long life of this shaft was not due to any unusual strength of the ship, as she had only a ninety class, but it was due more to the comparative absence of the mechanical action, the ship being well immersed when in ballast, and the material being of iron and made when there was no steel scrap about as at present. The mixture of steel forgings with that of iron for the manufacture of shafts was to be deplored very much, and he was afraid that so long as propeller shafts were made of this unwholesome mixture they would have trouble. Evidently it had not occurred to Mr. Aisbitt to ask himself the question whether tail shafts were strong enough when made to Lloyd's rules for the work they had to do. He (the speaker) contended they were not. Doubtless they were quite strong enough in the old iron deep three-deck rate ships, when iron was iron, but the conditions had quite altered. These were the days of the large, shallow, flexible steel ships, and notwithstanding that the conditions of the working of the shafting was being changed, Lloyd's allowed a reduction in the size of shafting in tri-compound engines, and he was pleased to learn that many owners were having their new shafts made above Lloyd's requirements. He would like to add to the author's recommendation that propeller shafts be made stronger than provided for by Lloyd's rules, that Lloyd's rules be revised, and that in the revision of the rules the depth of the ship be taken into consideration, and that the shafts be made of pure iron and be guaranteed free from steel scrap.

Mr. T. W. WAILES described the magnetic action set up in connection with working operations upon a shaft while the steel was hot, and thought the subject worth investigating in this direction.

Mr. NEVILLE APPELBEE (Cardiff Borough Electrical Engineer) agreed with Mr. Gibson to a certain extent. He considered that the mechanical forces at work on the shaft assisted somewhat the electrical action, by virtue of the opening or cracks in the shaft being electrically cleaner. His theory as to the corrosion was, that electrical action was set up by the two dissimilar metals of the shaft and the liner in contact with salt water. The brass ground off from the liner aided local electrical action, which action took place in that part of the shaft that was mechanically the weakest.

Mr. R. N. STRONG thought there could be no question that mechanical action was first set up in the shaft, and that this was aggravated by chemical action. The stern tube at the bottom formed a recess, and the water never got away, and was dead. By doing as the old Scotch engineers used to do, namely, insert a pipe at the end, the water would be brought away from there, a free circulation would follow in the tube, and acids would be washed away. In boilers where there was no free circulation in the water spaces the same thing took place as in a tail end shaft. He could not agree with Mr. Gibson with regard to white metal. He had used it for the end of paddle shafts instead of brass. In muddy waters the brass would not last more than eighteen months or two years, whereas white metal had a life of from four to five years, and the shaft was not in the slightest degree damaged. In his opinion, if a shaft was covered with a liner from end to end it would be a much better plan than that of using liners as at present. He did not agree that star marks were always corrosion. Where there was corrosion the metal was soft, but in many cases where the shaft was fractured the grains of the metal were quite plain.

Mr. W. EVANS was of opinion that chemical action was the first to set up. He had known new shafts upon which, on being drawn after a few months of having been fitted, were already indications of water-mark. If this were due to mechanical action he did not believe the water-mark would be so regular, and it would not be in so close contact with the end of the liner as it was generally found. He knew several Norwegian ships that had no liners at all, and in none of these cases did he remember a single water-mark in a straight line, as shown in shafts fitted with liners. In cases where liners were used on Norwegian boats the stern tube was filled up with tallow, oil being supplied at intervals, and on the outside of the shaft was a spring gland fitted between the boss of the propeller and the end of the stern tube. This was to prevent water coming into the stern tube. Where he had examined shafts in these cases he had failed to find the slightest appearance of water-mark at the end of the liners. In some instances india-rubber sleeves were fitted in between the liners, but in pulling out the shaft there was danger of the india-rubber liner being disturbed and perhaps damaged. Where these liners were good and hermetically sealed, and the water prevented from coming in contact with the shaft, there was no appearance as a rule of water-marks. The plan of shortening the propeller shaft had been found to be beneficial where it had been tried. A good plan for preventing the sand in muddy waters getting into the stern bush was to fill it with white metal, and lubricate it properly.

The HON. SECRETARY (Mr. Geo. Sloggett), read the following contribution from Mr. Charles E. Smith (West Hartlepool):

Mr. CHARLES E. SMITH: In the first place Mr. Aisbitt attributes the rapid deterioration of propeller shafts principally to chemical action.

There is no doubt whatever that this takes place in the ordinary shaft with the two liners to a large extent.

If you will kindly look at the accompanying drawing of a tail shaft, as fitted in the ss. *Aros* and other vessels, you will see that it has one brass liner, which is between 8 ft. and 9 ft. in length, shrunk on in one piece; this, if carefully done—the heat obtained from a properly constructed gas furnace, with a number of burners, which are manipulated as required—can be shrunk on even to a much greater length.

The shaft is considerably shorter than the ordinary one, fitted with the two liners.

The vessels are of the modern semi-spar-decked type, carrying 5,000 tons deadweight on 20 ft. 3 in. draught, thereby as much resembling a plank floating on the flat as the old type of vessel did one floating on the edge.

What I wish to impress is that (as you are doubtless all aware) the new type of ship is bound to labour and strain more heavily in a sea-way than the older deep iron vessel.

Hence Mr. Flemming's contention that the shafting works under worse conditions than formerly, holds good.

The writer's experience is this: the *Argo* has steamed in ballast, drawing a little over 10 ft., once from the Cape to Pensacola, and once from the River Plate to the same port; on both occasions experiencing heavy weather and racing heavily. The shaft has been examined several times and found in excellent condition, but each time after experiencing heavy weather the after coupling has been found slightly started, which, in my opinion, proves that a mechanical action must take place; and, as the short shaft fitted with a long liner is very rigid, hence the slight starting of the aftermost coupling, which in some instances would not be observed but for the enamel paint, with which it is coated, being cracked.

I may be going over old ground again, but think I am justified in advancing the opinion that was so ably put before you the other night by Mr. Walliker: that by abruptly cutting away the liners the shaft is thereby weakened, and by the mechanical action in the long shaft the fibre of the iron is torn asunder, rendering it a fit subject for the chemical action which afterwards takes place and thus causing the very rapid deterioration.

If by supporting Mr. Aisbitt in his contention that short tail end shafts are more suitable for the modern cargo steamer I have been of any service I shall be glad.

Mr. J. W. DONOVAN (contributed by letter): With Mr. Aisbitt's opinion as to the causes of shaft failures to a certain extent I agree, but take exception to the methods he proposes for their prevention. I have invariably found the fractures close in, at the junction of the brass liner and the iron or steel shaft, and principally at the forward and after end of after liner, and in some cases at the after end of forward liner. I have not in my experience found any fracture occurring at the forward end of forward liner, and this, in my

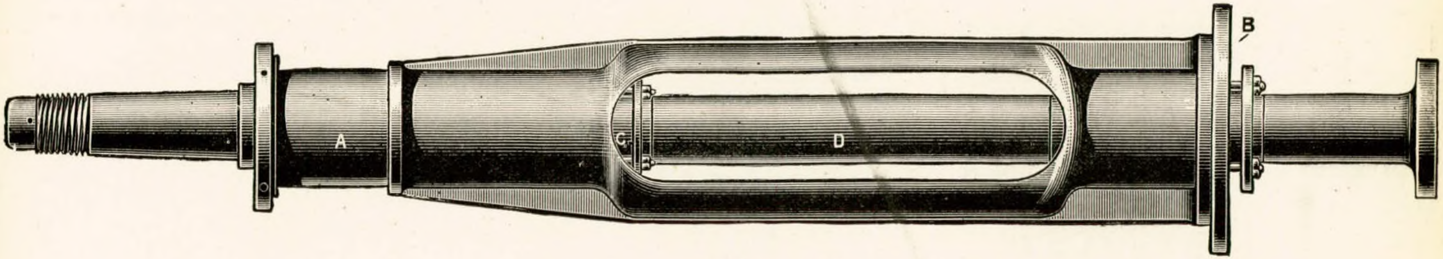


Fig. 1

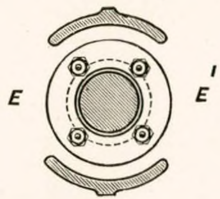


Fig. 2

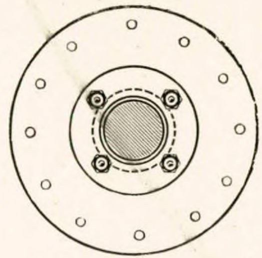


Fig. 3

opinion, points to the fact that this end being run practically dry prevents any chemical action taking place between the brass liner and the iron or steel shaft, and I am therefore compelled to accept the chemical action alone as the inducing factor in all these fractures. Of course, at the present time we cannot overlook the fact that many vessels are being sent across the Atlantic in ballast trim, and many of us, who have had engine-room experience in crossing the Atlantic in winter time, well know the terrific strains the engines are subject to, owing to excessive racing, and little wonder that with such vessels the propeller shaft has given way after only a few months' work, and this, we must admit, is entirely outside the chemical action above referred to, and can only be remedied by properly ballasting the vessels and fitting the most approved governor. And this brings us to another part of the question, and that is the method of fitting the propeller. In many cases we find the propeller boss has no recess, and the space between boss and end of liner has to be lapped or fitted with an india-rubber ring, and is very often never watertight. This is bad practice, and, in my opinion, should not be allowed. The better plan is to have a deep recess in the boss, and to fit it some distance on to the brass sleeve, the intervening space to be run up with melted wax or tallow; this would materially strengthen the shaft at this part and the wax or tallow would effectually keep out the water.

I may now refer to the remedies suggested by Mr. Aisbitt. First: A short tube is suggested and the peak bulkhead cut and stepped back so as to give the engineer access to the gland. This, in my opinion, is not satisfactory, as it is never satisfactory to step a bulkhead, more especially at the after end of vessel. I understand where this arrangement has been adopted that the proportion of failures of shafts has been just as heavy. Second : Lining the bush with white metal and adopting some method of oiling.

I have had no experience with this method, but from inquiries I have made, the whole thing depends on the efficiency of the outer gland in keeping in the oil, and, as we all know, this will require very careful attention, and which can only be attended to when a ship is in dry dock. Mr. Aisbitt reminds us of the experience we have already had with white metal for main bearings, but we must not forget that the conditions of working are very different as between the crank shaft and the propeller shaft. Third: The method of protecting the tail shaft between the liners by means of lapping with marline canvas, etc., is anything but satisfactory, as many of your members may have heard of a case where, after many attempts to draw the tail shaft, the stern tube had to be cut to release the marline, which in this case had got loose and jammed the shaft in the tube.

Another case of this sort came under my own notice only last week, where the shaft had been parcelled with canvas and marline at the fore end of the after liner, and owing to this getting loose it was only with great difficulty that the shaft was drawn.

Many years ago the Scotch practice was to fit a short tube in the after peak secured to a short bulkhead, with a stuffing-box and gland at fore end of the tube with a gland and stuffing-box, but independent of the tube proper, on peak bulkhead. Some time ago there was patented a similar arrangement, but with an improved short tube and a new method of fitting the lignum vitæ; this had some good points about it, and part of the shaft was certainly left free from the action of the water, but the rigid support given by the old style of stern tube to the peak bulkhead was here lost.

I have come to the conclusion that any method to overcome the chemical action at the ends of the brass liners to be perfect must absolutely prevent the access of the sea water to the shaft, besides retaining all the advantages of the old style of tube, viz., a good support to the after peak bulkhead. I may now be excused if I draw attention to the improvements that I have patented for this purpose. I adhere to the long stern tube, but by enlarging the tube at about its middle part, and fitting a stuffing-box and gland at some 5 to 6 ft. from post, leaving the tube open at each side, access is given to the gland for packing, and the portion of the tail shaft —where all the trouble occurs—is free from the action of the sea water and accessible at any time for examination, cleansing, and painting. The usual stuffing-box and gland forming part of the tube is fitted at fore side of the bulkhead. The advantages of the old style of tube is retained, viz., a rigid support to the peak bulkhead. Another advantage gained to the shipowner by the adoption of this method is getting the peak measurement allowed in as part of the propelling space. This tube has now been fitted to eleven large vessels trading to all parts and has given every satisfaction. I herewith send a tracing of the tube as fitted to the Austrian Lloyd's steamer *Moravia*, and which will more fully explain the method.

P.S.—Since writing the above I have been favoured, by the kind permission of Messrs. Charlton and Thompson, managing owners of ss. *Brantwood*, with the perusal of a letter from the chief engineer with reference to my improved stern tube after three years' use. He says:

"As regards the shafting, I had the door of peak tank taken off, and thoroughly scraped all dirt and paint off while the *engines were running*, and saw for myself that shafting and tube was, as far as I could see, in perfect order—in fact, the captain also had a look. I then gave the shafting a good coat of white paint, and particularly in about the part nearest to brass liners, and I may add that the general appearance of the shaft between the liners is a treat to see."

The PRESIDENT (Professor A. C. Elliott, D.Sc.) said that chemical and mechanical actions were mixed up, and no one ever saw an electrical action of the nature under notice that did not partake of chemical and mechanical or carrying action. He thought Mr. Evans had proved that corrosive action was due primarily to electrical action. To prevent it, they could do away with the brass or keep out the acidulated water by means of oil, as had been suggested, or they could oppose an electrical couple acting in the opposite direction. In other words, it might be possible to wear away the brass instead of wearing away the steel shaft. As to failures of tail shafts, he agreed with Mr. Gibson that the principal causes lay in the fact that they were not made strong enough; the peculiar circumstances under which they worked were too often under-estimated, to the extent of 20 per cent. The forces acting upon the tail shaft were many. There was the driving couple, which of course extended throughout the length of the shaft. It might be, and was, greatly exaggerated above its regular value owing to the racing of the engine and the subsequent plunge which the propeller took into the water. That was to be allowed for, and some rough-and-ready allowance had sometimes been adopted. Then there was the over-hang of the propeller, which was a matter for calculation. But there was more than this. There was the bending moment, due to simple inertia, and in taking out this, together with that due to weight, a rough rule was to double the weight of the propeller and multiply it into the leverage, and the result was the bending couple due to weight and inertia.

There was another force—the gyrostatic action. The propeller was a huge gyrostatic top, and to move it when the vessel pitched heavily they required a considerable couple, and, curiously enough, the couple was not in the plane in which they applied the pitching motion, but at right angles thereto. When a ship was plunging with her bows down she usually yawed to port; when rising by the head, to starboard. That was the gyrostatic couple acting on the screw. The gyrostatic action was a maximum when the ship was in the middle of her longitudinal vibration; the simple inertia effect was, on the other hand, maximum when she was at the end of her swing, either up or down. When she was coming up by the stern they had this inertia force to add to the weight of the propeller. No proper allowance has hitherto been made either for simple inertia or for gyrostatic action. Some rough allowance was sometimes made in an indefinite manner for racing and heavy weather, say, 10 per cent. for a vessel crossing the Atlantic, but when they added to this the 10 per cent. for each of the actions to which he had referred, they came to the conclusion that the tail shafts of the present day fitted to the springy ships of the time were at least about 20 per cent. lacking in the necessary strength. Concluding, the President said it had been a real personal pleasure to him to be there that night, and to hear the words of warm appreciation that had fallen from members of Mr. Aisbitt's paper, which had been an exceedingly successful paper, whose career was not yet ended—(applause). Replying to a question by Mr. Reed, he said that in his opinion the point of greatest weakness in a tail shaft depended largely on the over-hang, that was to say, how far slackness in the nip at the after-end permitted increase of the effective length of over-hang.

Replying briefly on the discussion, Mr. AISBITT touched upon the various points raised. He observed that although several speakers had declared their disagreement with him, yet the trend of their statements was to support his contention as to the chemical origin of shaft defects—(murmurs of dissent and "No, No"). He denied that blame for fractures of shafts could be attached to the triple engine, contending that the strain upon a shaft in a compound was infinitely greater than in the case of the first power divided into three. He would rather say that the triple engine preserved the shafts. As to shafts without liners not corroding, he should like to ask Mr. Evans if he ever found in those shafts which were swelled a fracture in front of the liner.

Mr. EVANS replied in the negative. The only thing he had found were these longitudinal marks, but nothing at the end. The swelled part was not more than a $\frac{1}{4}$ of an inch or $\frac{3}{8}$ths of an inch, and it gradually tapered away.

Mr. AISBITT continued his reply. As to Mr. Walliker's remarks, if they had not yet been able to design a proper shaft it said little for them, but he presumed Mr. Walliker meant that the weakest point was the brass liner. Well, the thing to do was to dispense with the brass liner. As to the importance of scale, he considered its presence the best evidence of galvanic action. As to vessels being lighter than formerly, he believed that ships being a good deal lighter, chemical action was set up by air being forced along the tube into the shaft. There was undoubtedly more air admitted in the present type of steamers than in the old type, whose engines hardly ever raced. Mr. Nisbet's theory of harmonic action was most interesting, but it did not go sufficiently far to "disestablish" chemical action. Then much depended upon the component parts of the brass liner. The quality of a brass liner had undoubtedly an effect upon the shaft, and went far to explain the difference between shafts. As to the observations of Mr. Strong, it was rather curious they did not find the same action on the iron pins and brass bushes of the paddle-boat as on tail shafts. He could not state the reason, but it was a fact. Mr. Donovan spoke of the danger of allowing the engineer to go right aft. A good deal of shipbuilding and engineering was carried on upon traditional lines; but there was not the slightest reason why a man should not walk to the stern of a ship and examine it. They could make a perfectly water-tight floor and keep the water above the man just as well as keeping the man above the water.

On the proposition of the President, seconded by Mr. Gibson, a vote of thanks was accorded to Mr. Aisbitt by acclamation.

A vote of thanks having been passed to the President, the proceedings closed.

DISCUSSION

ON

CERTAIN DEFECTS FOUND IN PROPELLER SHAFTS.

AT

58 ROMFORD ROAD, STRATFORD,

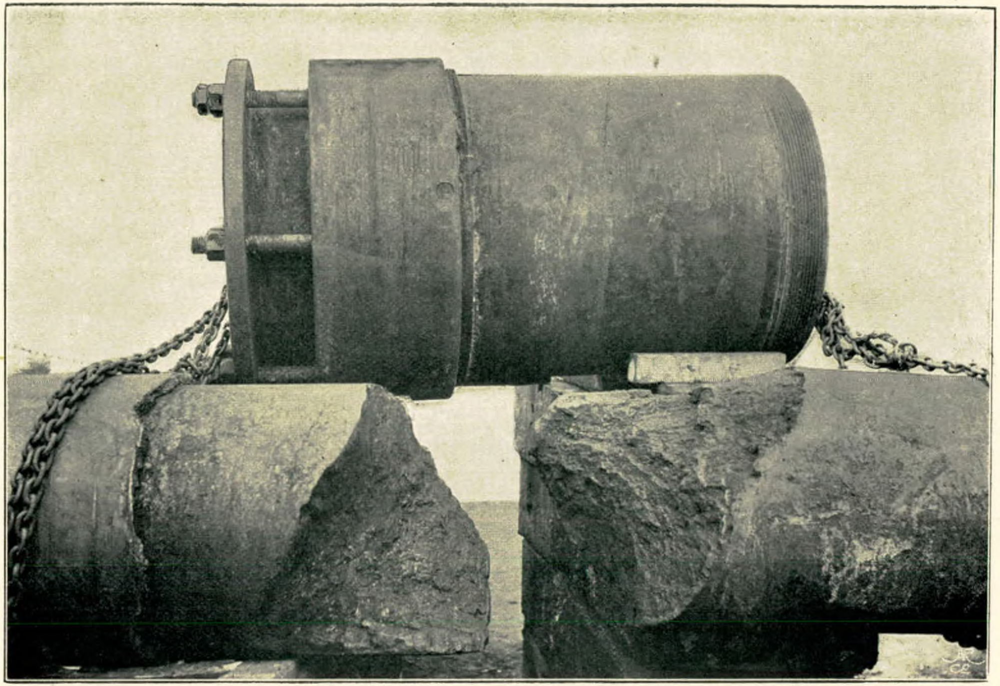
MONDAY, JANUARY 10th, 1898.

CHAIRMAN:

MR. J. H. THOMSON (VICE-PRESIDENT).

The CHAIRMAN: We are assembled to-night to hear a paper by Mr. M. W. Aisbitt, "On Certain Defects found in Propeller Shafts," and I am sure that you will all be disappointed to learn that Mr. Aisbitt is not able to be here this evening to read his paper. You will also, I know, be sorry to learn that Mr. Flannery, our president, is unable to be present. The subject of this paper is one that we as marine engineers are all very much interested in. The fracture of a propeller shaft is often a question of life or death to those on board, and it is therefore of the greatest importance that we should obtain every possible information as to the causes of defects in these shafts and the best remedies. In the absence of the author, our honorary secretary will be kind enough to read the paper, and I would remind members that they are expected to take notes of any points that may occur to them during the reading of the paper, so as to be able to take part in the discussion.

The HONORARY SECRETARY: In addition to what our chairman has said I may mention that Mr. Aisbitt



SS. "TOKO-MARU."

Broken Propeller Shaft and short after-peak stern tube used to bring the ship home, after fitting spare shaft.

The report of the circumstances as given in the *Shipping Gazette* is as follows :

"UNDERWRITERS AND BROKEN SHAFTS.

"INTERESTING PRESENTATION.

"Heavy salvage awards in connection with loss of propelling power have become so frequent of late that the plucky conduct of the captain, officers, engineers, and crew of the steamship *Tokomaru* in surmounting the difficulties associated with a serious breakdown in the South Atlantic has naturally attracted attention. The circumstances of what is regarded as a unique achievement are detailed in the speeches which were made at a pleasant gathering of underwriters, held yesterday afternoon at the offices of the London Salvage Association, when Captain Joseph Maxwell and his chief engineer, Mr. Charles McEachran, were the recipients of a substantial acknowledgment of the resource and skill they displayed. The chair was occupied by Mr. Leonard C. Wakefield, and among those present were Mr. H. Buckland (Thames and Mersey Insurance Company), Mr. A. Price (Ocean), Mr. Douglas Owen (Alliance), Mr. F. J. Timms (London), Mr. T. Davis (British and Foreign), Mr. T. A. Clark (Union), Mr. W. P. Shepard (Royal Exchange), Mr. H. Ellis (Indemnity), Mr. A. E. Raynes (Commercial Union), Mr. H. Worsley (Sea) ,Mr. A. B. Rose, and the following members of Lloyd's : Mr. M. H. Brooking, Mr. T. L. Forbes, Mr. W. G. Ardington, Mr. E. Beauchamp, Mr. J. W. Robinson, Mr. J. Franklin-Adams, Mr. C. A. Hardman, Mr. E. E. Cooper, Mr. J. E. Street, and Mr. S. Smith. On behalf of the Shaw, Savill and Albion Company, the owners of the *Tokomaru*, Mr. Popham was present, and Mr. J. Lowrey (secretary of the London Salvage Association) also attended the gathering.

"Mr. WAKEFIELD having briefly explained the object of the gathering, which he said was to do honour to two typical British seamen, and to present them with a substantial mark of the underwriters' appreciation of their plucky action,

"Mr. H. BUCKLAND made a statement detailing the circumstances. The *Tokomaru* (s) was bound from New Zealand to London *via* Teneriffe, with frozen meat and general goods, and sailed from Wellington on August 28, 1897. On September 22, when in the South Atlantic, and distant some 472 miles from Rio Janeiro, and 3,900 miles from Teneriffe, the tail-shaft broke on the fore side of the stern-post, and the propeller went out against the rudder-post, leaving just enough of the shaft in the stern-post to fill up the hole, so that the pumps were able to keep the water down. The after-bulkhead was patched up so as to confine the water to the after-peak, and on the following day the chief engineer conceived the idea of gripping the broken end of the shaft with a Thompson's patent coupling which they had on board; but to enable them to fit this on the shaft they had to cut and drill off from the broken shaft for a length of 9 ft. 6 in. the stern-tube of cast-iron $2\frac{1}{2}$ in. thick and from $2\frac{1}{2}$ to 3 tons in weight, as well as the brass liner. This work was effected in a very confined space, the men standing in the water, which was kept down by the pumps, but at the risk of the propeller falling away, in which case the after-peak would have been instantly flooded. As a fact, on two occasions the men had to beat a precipitate retreat when the pumps became choked. The stern-tube and brass liner having been removed, the coupling, weighing 30 cwt., was taken along the tunnel, by rigging purchases and gear, a distance of 170 ft., then hoisted up through the engine-room on to the deck, then carried aft, and lowered through the lazarette hatch to the after-peak, the man-hole having been enlarged to enable them to do this. The coupling was fitted, but would not revolve in the limited space, and the ship's frames in the vicinity were cut away as necessary. This work was continuously proceeding under great difficulties for eight days and nights, and while in operation, on September 29, the steamship *Gulf of Guinea* passed close and offered assistance, which was declined with thanks. On October 1st the engines were started, and on the 4th the *Tokomaru* anchored in Rio Bay. She was there tipped, and the engineer fitted a short stern-tube and gland immediately inside the stern-post, instead of inside the after-bulkhead. With this repair she proceeded, and arrived safely in London on December 12, having encountered a gale in the Bay of Biscay which caused considerable anxiety, owing to the pitching of the vessel and the racing of the engines. That was the story of the services, which he thought spoke for itself, and needed nothing in the way of amplification. He believed those present would agree with him that it was an instance of duty splendidly done—(cheers). The underwriters, at a meeting held to consider the subject, came to the conclusion that the case was one for special recognition, and resolved to award a sum of 850 guineas. Of this amount 150 guineas was awarded to Captain Maxwell, and a like amount to Mr. McEachran, the chief engineer. In addition, the captain would receive a letter, signed by the chairman of the meeting of underwriters, which set forth the merits of his services, and conveyed the thanks of the underwriters to him. They thought he might like to possess such a document, as it might be of use to him in the days to come. As the service was peculiarly an engineering service they had determined to present to the chief engineer, in addition to a sum of 150 guineas, a gold watch and chain, with a suitable inscription, which would serve as a record of his valuable work. They had endeavoured to arrange a meeting at which all the men engaged in the service could meet the underwriters, and it was originally suggested that they should go down to the ship and make the presentation there. That, however, was found impossible at this busy season, and accordingly the present gathering had been brought about. It was a matter of regret that they had not been able to see all the men, but he had no doubt that the owners would do all that was needful in the way of expressing thanks to them. The apportionment of the rest of the amount among those engaged in the service was, of course, a matter of some difficulty and delicacy, but thanks to the assistance rendered by Mr. Popham, of the Shaw, Savill and Albion Company, an equitable distribution had been made, and he trusted the men would be satisfied with the sum awarded them. He would now ask the chairman, on behalf of the underwriters, to make the presentation, and would add that they were glad to have the proceedings presided over by a gentleman of such high standing and experience as Mr. Wakefield—(cheers).

" Mr. WAKEFIELD, in making the presentation, said that Mr. Buckland had shown that the service was rendered at the risk of life, and that it could not have been accomplished unless the engineer had possessed very great professional ability, as well as the full support of his captain, in what he (Mr. Wakefield) believed was an unprecedented feat. He was very glad to be the medium of making a substantial recognition of so gallant an action, and he was sure the underwriters had had great pleasure in awarding it. They felt that not only would this proceeding form some acknowledgment of a great service, but that it would encourage masters and engineers who might be similarly situated to do their best, first from their sense of duty, and secondly from the feeling that there were less grateful men in the world than underwriters—(hear, hear). He might add that in this instance the property at stake amounted to close upon £200,000, and that the claim under the policies was merely nominal in consequence of the action which was taken —(hear, hear). The speaker then handed a cheque for 150 guineas and a handsome chronometer to Mr. McEachran, and a cheque for the same amount, together with the following letter, to Captain Maxwell:

" Dear Sir,—In presenting you with a cheque for

150 guineas, I am desired on behalf of the underwriters of the steamer *Tokomaru*, her cargo and freight, to place on record their sense of the meritorious service rendered by you and those on board under your command on the occasion of the breakage of the tail shaft of the vessel in the South Atlantic on September 22 last. The underwriters appreciate highly the resource, skill, and energy which enabled you under circumstances of great difficulty and danger, and without assistance, to take the vessel to Rio Janeiro, and when there to effect further temporary repairs, under which, notwithstanding bad weather in the Bay of Biscay, you brought her safely to London, having incurred only the minimum of expenditure. The conduct of all concerned is regarded as especially meritorious by the underwriters, and I am desired to express to you their best thanks and hearty wishes for a prosperous future.

"I am, dear Sir, yours faithfully,

"H. BUCKLAND,

"*Chairman of the Meeting of Underwriters*

"Captain MAXWELL, in response, expressed the hope that he would not be expected to make a speech. He trusted they would believe him when he said that for this very substantial award for their services he and those under him were heartily and sincerely grateful —(hear, hear).

"Mr. McEACHRAN, in reply, said that he, in common with a good many more sailors, was not very competent to express his feelings with regard to the handsome recognition of their endeavours to bring their vessel into port. There would, at all events, be something for him to look upon with pleasure and satisfaction during the remainder of his life, while he could but think that the presentation would act as an encouragement to those who might be placed in a similar position, by assuring them that if they could possibly save expense their action would not be forgotten by the underwriters—(hear, hear). He thanked them for this recognition of his endeavours to do what he considered to be nothing more than his duty—(hear, hear).

"Mr. WAKEFIELD said he had had very much pleasure that morning in bringing Captain Maxwell's conduct to the attention of the Committee of Lloyd's. As Captain Maxwell might be aware, the committee granted medals for exceptional services such as he had rendered. There was but one feeling, after hearing the plain, unvarnished tale of what Captain Maxwell had done, namely, that he amply deserved the medal in question —(hear, hear). He had now the pleasure of presenting that medal both to Captain Maxwell and to Mr. McEachran, and he was sure they would value it all their lives. Lloyd's was a body known all over the globe, and he was confident the recipients would be able to point with pleasure to the medals they had received from the oldest assurance association in the world, as showing that what they had done had been appreciated in London—(hear, hear).

"Captain MAXWELL and Mr. McEACHRAN tendered their acknowledgments, and before the gathering broke up received the personal congratulations of most of those present.

"The presentation of 500 guineas to the rest of the officers and crew of the *Tokomaru* took place yesterday afternoon at the Royal Albert Docks."

The HONORARY SECRETARY continued: In reading over this account I was reminded of a sentence in an address by Earl Stair on the relations between employers and employed, which is as follows: "No separate interests can subsist between employers and employed. If you thrive, I thrive. On your well-doing will depend my comfort, my honour, and my character, for I shall stand high or the reverse, as I act justly or unjustly by you." That sentence seems to me particularly *apropos* of much that was said in connection with this presentation to Mr. McEachran.

Mr. McFARLANE GRAY (Vice-President): While this statement by Mr. Adamson is fresh in our minds, I would propose that a board or tablet should be placed in this room bearing some brief but permanent record, printed in gold letters, of any specially meritorious service of this character by one of our members. It is an honour to the institute, and it would inspire many of our members with a wish to have their names similarly honoured.

Mr. F. W. SHOREY (Member of Council): We must also consider others who have performed specially meritorious feats. This record will be entered in our "Transactions." Engineers are constantly doing things worthy of special recognition, and if we begin to put these records on the walls we shall soon have our walls covered.

Mr. J. G. HAWTHORN (Member): As an amendment I would propose that Mr. Gray's suggestion be remitted to the Council for them to act in the matter as considered best in order to carry into effect the views expressed.

The CHAIRMAN: The suggestion is one which may be worthy of consideration, but it is necessary, it seems to me, that we should get some information about other special services that have been performed, and which have not been recognised by underwriters. It seems to me also that if anything of the kind is to be done it should be something more substantial than a picture board.

After some further conversation the matter was referred to the Council in the terms proposed by Mr. Hawthorn.

The CHAIRMAN having invited discussion on the paper,

Mr. HAWTHORN said he had read Mr. Aisbitt's paper very carefully, and there was much in many of the points which the author had brought forward as to the causes of corrosion in tail shafts, but the author appeared to have overlooked one cause, and that was the action of the air admitted to the stern-tube when the engines were racing. They all knew that the surface of the water was thoroughly impregnated with atmospheric air, about 15 cubic feet of water containing one cubic foot of air. It was possible that as the result of the churning of the water in the stern-tube this air might be eliminated, and there was no doubt that it might be in contact with the iron of the shaft sufficiently long for the air to become decomposed. The oxygen entered into chemical combination with the iron, and they would thus get rust—the beginning of the trouble; and they all knew that sea water was the second best of all liquids by which a current of galvanic electricity could be conveyed. The iron rust being electro negative to the iron's electro positive, they thus had very powerful elements to assist corrosion. He could not agree with the author in thinking that mechanical action might be left out of consideration altogether as one of the causes of corrosion and trouble in tail-end shafts. Mr. Hawthorn gave figures illustrative of the enormous strain brought upon a tail shaft in a seaway, taking for illustration a 12-in. shaft, transmitting, say, 1,800 horse-power when running 60 revolutions; this twisting moment alone, he said, would give about 9,000 lbs. stress per square inch in torsion. The bending moment with a 6-ton propeller, wholly immersed, would at a distance, say of 24 inches from the stern-post, give a bending stress of about 1,600 lb., and the equivalent twisting moment, with these combined, would result in a stress of about 10,500 lb.; and then imagine the ship's stern to lift, so that 75 per cent. of the weight of the propeller was suddenly lifted out of the water; the bending moment would be that due to a weight of about four tons suddenly applied, and this would result in the bending stress tension on the upper surface and compression on the lower surface, of three times the original amount. And these increased stresses being suddenly changed, upon the ship suddenly dipping her stern, would no doubt fatigue the metal very much on the forward side of the after liner, and would account for some of the flaws found there. He then sketched his reasons for believing that the twisting moment was equivalent to a stress of 15,000 pounds per square inch. There was another point that occurred to him, and that was that stern-tubes were not always full of water, and that the action of the shaft had a tendency to create a vacuum immediately next to the shaft. If he was correct in that view, and the air only remained sufficiently long to set up the air-cones, they had the beginning of rust. As a precaution against corrosion he strongly recommended the use on tail shafts of a paint or composition containing a large proportion of zinc. He also thought the plan of running the shaft in white metal and oil was a good one, and mentioned the plans of one manufacturer, who fitted the stern-tubes so that the parts between the two liners was get-at-able. He considered further that there ought to be some means of shutting off the stern end altogether, and thoroughly draining the stern-tube in port, for his opinion was that the corrosion was much more active when the ship was in port, and the stern-gland nipped up; the water then was more stagnant. He thought it a barbarous method to carry water in the stern-tube at all, and did not see the necessity for having stern-tubes so long as was usually the case.

The CHAIRMAN: Some of Mr. Hawthorn's remarks point to the idea that the weight of propeller shafts is cut rather too fine. It is well that we should keep down the weight of a shaft as much as possible for a given power; but I think the practice of some of the larger companies in making their shafts a good deal in excess of the Board of Trade requirements has been a great safeguard. It has really been a question of weight versus safety.

Mr. MCFARLANE GRAY: The chairman made a

remark with reference to the Board of Trade requirements, and, as the Board of Trade rules have been referred to, it ought to be understood that they prescribe the *least* that will be allowed—the *minimum* that is considered permissible.

The CHAIRMAN: It is something like the victualling scale on board ship. There is a minimum scale, but there is no reason why you should not double it.

Mr. MCFARLANE GRAY: It shows the danger of having rules laid down for everything by a government department. It is just the same thing with the load line rules. A minimum freeboard is prescribed in each case, and if there was no load line prescribed at all vessels would probably have more freeboard than they have now. It is the same with shafting and everything dealt with in that way.

Mr. HAWTHORN asked if any gentleman could inform him when the rudderpost bearing for tail shafts was abandoned—(A MEMBER: 15 or 20 years ago). His own opinion with regard to this abandonment was that the remedy had proved worse than the disease. It had given more liberty of action, but the fractures of shafts had become much more frequent. When they had rudderpost bearings the tail shafts were not so likely to break in a heavy sea as now, and with the powers that were now being put into steamers he was afraid they were cutting things too fine. He thought more weight ought to be put into these shafts. Another inch, or half an inch, in diameter would not add much to the weight, say, with a 12-in. shaft increased to 13 in., remembering that the resistance to torsion and bending varied as the diameter of the shaft cubed. Therefore, the 12-in. shaft would have 27 per cent. more power of resisting these excessive strains, and the strength would be increased enormously.

Mr. H. M'LACHLAN said he believed that the patent stern-tube referred to by Mr. Hawthorn was fitted into one of the China steamers some years ago, but gave serious trouble, and had to be taken out and an ordinary stern-tube substituted. He had had experience of a similar accident to that which Mr. McEachran had to deal with, the tail-end shaft breaking in the same place, but much farther in. He conceived the same idea as Mr. McEachran, but owing to the ship having such very fine lines it was impossible to carry it out. The shaft was examined in Antwerp before the ship left that port, and was found to be in beautiful condition. The shaft was fractured in the same way as they would break a tap. The liner of that shaft was tapered away, and there were no signs of corrosion whatever, from which he concluded that the cause of corrosion at the end of a liner was entirely due to the sawing action of the water.

Mr. A. BLAIR (Member of Council) said this was a paper that would interest all marine engineers very much indeed, because tail shafts and propeller shafts had been a source of very great trouble during the last two or three years. He had had a good deal to do with shafts, both when engaged with a large repairing firm in London and since he had been in his present position as a superintending engineer, and this action that went on at the back of the liner was, he thought, well-known to every sea-going engineer. When the liner came sharply out there was this cutting action at the end of the liner, whereas by tapering the liner away and rounding it off the cutting action was pretty well avoided. Instances had occurred where the liners had been thinned away, and after a while found to be loose, and having been cut off, it was ascertained that corroding action had been taking place under the liner. Perhaps this was due to the fact that the liner was cut away too thin in the first instance. Of course, the great point was to find a remedy for all these mechanical and other troubles that had been referred to, and he did not know that they had yet arrived at the right conclusions. He had tried the practice of protecting the shafts with marline and they never gave any trouble. During the last twelve months he had to condemn four shafts through this eating action that had been going on at the ends of the liners, and they were all of larger size than required by Lloyd's rules. They had increased the size over half an inch in excess of Lloyd's requirements to guard against this trouble of the shafts cutting away. Mr. Hawthorn was, he thought, quite right when he said that a great cause of trouble was the taking away of the outer bearing of the tail-end shaft. There could be no doubt in his mind that the abandonment of that outer bearing was a great detriment to the shaft. This outer bearing in the rudderpost was a great assistance to the life of a shaft, and when a ship was surging in a seaway the action of the propeller must involve a tremendous strain on the shaft.

The HON. SECRETARY read a letter that had been received from Captain Blackmore, who wrote :

"I am sorry the state of my health prevents me from going to a distance from home at night. I should much like to have heard Mr. Aisbitt's paper on 'Certain defects found in Propeller Shafts.' Without seeing the paper I cannot, of course, know to what kind of defects he has referred; whether original defects or those caused by wear, vibration, racing, etc. As I am of opinion that many broken propeller shafts are due to certain classes of steamers being sent on oversea voyages insufficiently ballasted, and with propellers not sufficiently immersed, I should be glad to see any evidence confirmatory of my idea, and to know what the ideas of sea-going engineers are upon that surmise."

Mr. W. McLaren (Member): Did I understand Mr. Hawthorn to say that he would prefer the shafts to have a special coating of paint?

Mr. Hawthorn: I said I thought it would be desirable to make a paint containing zinc, or take some zinc composition and coat the shaft between the two liners, which would tend to prevent a great deal of the surface corrosion. My idea was to prevent corrosion in the first place if possible. I see no means of avoiding the effects of the mechanical strains, except by increasing the weight.

Mr. W. McLaren spoke of the great strain that was brought on tail-end shafts by the manner in which the propellers were often wedged off in dry-dock, and suggested that junior engineers should be afforded every opportunity of enlarging their knowledge and experience whenever a tail-end shaft was to be drawn. He thought it would be a great advantage if superintending engineers would afford their juniors every assistance in this respect. In the course of the paper Mr. Aisbitt spoke of a method of using red lead in connection with the sleeve just inside the propeller, but he (Mr. McLaren) had tried another way of attaining the same object by putting in a rubber-ring, which had had a very good effect in keeping out the water.

Mr. F. W. Shorey: I do not think that I have much to add to what has been said. Mr. Aisbitt has certainly treated the subject very well. He has described some of the defects, and his methods of remedying them. We know that shafts break, through many causes, but he has not gone so much into descriptions of the breakages of shafts as the defects. I think myself, when we find those rings close to the liners, that they are caused chiefly by galvanic action. What we want to do in the first place is to exclude the air. Mr. Aisbitt says that Mr. Mudd introduces a rubber sleeve; but I should not think that that would answer very well. Our friend Mr. McLaren has spoken about fitting a rubber ring, but that would be very objectionable for this reason :—Nothing will attack iron more than sulphur, and there is scarcely any rubber made up which does not contain sulphur. You will find that it will eat away every kind of iron. I believe that some of the large companies protect their shafts with a good coating of some composition made by the people who cover the bottoms of the ships, and one of them told me that when they warmed a shaft and put this coating on, and, after the ship had been running for some time, scraped it off again, they found the shaft as clean as when it was put on.

Mr. HAWTHORN said that a friend sitting near him had mentioned two cases of propeller shafts breaking immediately after the first dry-docking when the propellers were taken off ; and it had occurred to him that the barbarous method adopted in taking off the propellers might have had a great deal to do with the breakage of the shafts in these two cases. The manner in which propellers were often taken off in dry-dock or on a slip set up great longitudinal strains which was very likely to cause a slight fracture that might not be noticed at the time.

The CHAIRMAN then proposed a hearty vote of thanks to Mr. Aisbitt for his most interesting and instructive paper, and said he thought they had much valuable food for discussion at the next meeting on January 24th, to which date the discussion on the paper would now be adjourned.

Mr. F. W. SHOREY seconded the motion, and Mr. JAMES ADAMSON in supporting it expressed regret that Mr. Charles McEachran had been unable to attend the present meeting, his ship having sailed at the end of the previous week. He hoped that in addition to the photographs from Cardiff he would be able to obtain a photograph of the broken shaft of the *Tokomaru*, and show these by means of a lantern and screen.

The meeting terminated with a vote of thanks to the chairman.

DISCUSSION CONTINUED

AT

58, ROMFORD ROAD, STRATFORD,

ON

CERTAIN DEFECTS IN PROPELLER SHAFTS,

MONDAY, JANUARY 31*st*, 1898.

CHAIRMAN:

MR. JAMES ADAMSON (HON. SECRETARY).

The CHAIRMAN: Our meeting should have been held in the ordinary course last Monday night, but, as you are aware, we have lost one of our most valued and esteemed members, Mr. John Henderson Thomson. As most of you know, he was here at the Institute on the Saturday evening, taking a very active interest in the arrangements for the lantern views in connection with the adjourned discussion on Mr. Aisbitt's paper for the following Monday evening, and on the Sunday morning he was found in bed by his aged mother, quiet and still. He had died during the night, and had evidently passed away in his first sleep. There had been no disturbance of the bedclothes, and when, in response to a message from his mother, I went down to the house and saw the body; his face wore a smile of perfect peace. Personally we feel his loss very deeply, but his loss to the Institute is incalculable. He was one of the originators of the Institute, and was one of our most energetic workers. At a meeting of the Council on Friday last a resolution of condolence with his family and friends was passed, and at the last meeting of the Bristol Channel Centre at Cardiff—where he was known personally to several members—a resolution of condolence was also passed. The funeral took place on Saturday last, and was attended by a large contingent from the Institute. Notices have appeared in several papers attesting to the respect in which he was held and placing on record a tribute to his memory. It was meet to commence our proceedings this evening with this reference to his death, and in such a reference I know your sympathy is heartily with me. Our meeting to-night is called to continue the discussion which was commenced on the 10th instant on Mr. Aisbitt's paper, "On Certain Defects Found in Propeller Shafts"; and the views which Mr. Aisbitt had prepared, and which were shown when the paper was read at Cardiff, are with us to-night. We have a lantern, and the gases and lime-light, by means of which these views will be shown upon the screen; and I am pleased to say that we have also obtained two very good views, which will afterwards be thrown upon the screen, showing the broken shaft of the *Tokomaru*. With reference to the proposal made at our last meeting that some permanent memorial should be placed in the Institute to record specially meritorious work done by members, as in the case of the *Tokomaru*, I may state that at the Council meeting on Friday it was agreed that an enlarged photograph should be taken of this broken shaft and framed, with an inscription recording what was done, to be hung up on the walls of the Institute. We thought that that would be the most fitting and the best way, so far as the Institute is concerned, of recording the particular work that was carried out in this case.

Views of the various shafts referred to in the paper were then shown upon the screen, and Mr. Ruthven, the convener of the Papers Committee, read the descriptions and explanations of the same furnished by the author. Two views of the broken shaft of the *Tokomaru* were also exhibited.

The CHAIRMAN: In addition to the views that have just been shown, we have received from Mr. J. W. Donovan a copy of a communication that he has addressed to the Bristol Channel Centre on this subject, and he asks that it may be read here. Perhaps Mr. Ruthven will kindly read Mr. Donovan's contribution, which in the *Transactions* will appear under the Cardiff discussion.

Mr. WM. MCLAREN (Member): I am rather disappointed with the remedies recommended by Mr. Aisbitt in the paper, and think it likely that Mr. Donovan's plan would give the best results. With regard to the troubles arising from chemical action, why should we not use nickel steel for propeller shafts? We could then do away with the brass liners altogether, and work the nickel steel in the white metal. A spare length of nickel steel shaft was fitted in the *City of Paris* with a tensile strength of about 95,000 lbs., probably 25,000 lbs. more than any British or German steel shaft. In a paper which he read before the Institution of Engineers and Shipbuilders in Scotland, in March, 1896, Mr. William Beardmore said: "These experiments proved nickel steel to offer greater resistance to breaking, after being nickled, than carbon steel, but they also prove something else. Whilst the carbon steel broke off short, the fracture of the nickel steel, as in the case of the rivets, was fibrous. From this we may reason that if a crack were to appear, say, in a propeller shaft made of nickel steel, it would not develop so readily as in a shaft forged from carbon steel. The importance of this fact to marine engineers is obvious." I have seen it reported that some 1,500 nickel steel shafts have been fitted in steamers, and two-thirds of these were said to be screw shafts. This shows the progress being made and the direction it is taking, but it has not been shown whether or not the usual brass sleeves were fitted. We should, however, be able to dispense with the brass sleeves altogether, and work in the white metal.

Mr. J. E. ELMSLIE (Member): All will agree with Mr. Aisbitt as to the importance of the matter dealt with in his paper.

The failure and breakage of shafting is a matter of the first importance to the sea-going members of this Institution, for though the losses and delays caused by the failures of shafting are undoubtedly serious to owners and underwriters, still the owner is to a large extent covered by insurance, and the underwriters should by this time have adjusted their premiums to fit the case. The sea-going engineer, however, frequently goes with his shaft.

Of late years the failure and breakage of shafting has been so frequent as to rather suggest that there is a screw loose somewhere, viz., that the failures are due to preventable rather than to accidental causes.

If it were possible for this or some other Institution to collect and tabulate all the failures of shafting over a period, of, say, three years, showing the nature of the failures, the dimensions, the material and age of the shafting, the class of ship to which fitted, and condition of lading, etc., at time of failure, I think we might learn something about the matter.

Mr. Wm. Beardmore in a paper on nickel steel read before the Institution of Naval Architects last April, gave from a then recent return made by Lloyd's the following rather startling figures: that during the previous two years 1,506 new shafts of all kinds had been made at the principal ports for old classed vessels; of the 1,506 shafts mentioned, about two-thirds were screw shafts, 400 were crank shafts, and 100 were thrust or intermediate shafts—giving an average of about 125 in two months, and that, taking the many new shafts fitted in foreign ports, the average number was probably 140 to 150 per two months.

As a result of this state of things, Lloyd's Register issued a circular letter to the forge masters calling attention to the frequent failures of shafting, and asking them to explain their views of the matter. With what result I do not know. Perhaps some other member can give us some information as to the result of this inquiry.

Though probably in the majority of cases the failures are due principally to some defect of the shafting, or the corrosion of the shafting round the fore end of the after liner, the defect principally dealt with by Mr. Aisbitt, nevertheless my opinion is that a large amount of the failures are as much due to the ship in which the shafts are placed as to any other cause; and I entirely agree with the views expressed by Mr. Aisbitt in the second paragraph on page 8 of the paper.

In the present day the shipowner requires the utmost deadweight that can be carried on given dimensions, in the cheapest possible ship that can be produced, with the result that (1) all weights of hull are cut down to the last pound; and (2) the form of hull is such that sea-going qualities in anything more than moderate weather are of a very second-class order. The effect of the first is that you have a rigid shaft of great length, subject to a large amount of vibration, with a heavy propeller on the unsupported end of the shaft. You thus produce something very like what is commonly called the fatigue test in a testing laboratory, viz.: a bar is placed in a machine and made to revolve with a weight at the end of it, the bar eventually breaking from the fact that as it revolves the fibres of the material are alternately exposed to plus and minus stress. This is, I think, very much the case with the shaft; in addition to which, the vibration rapidly deteriorates the quality of the steel, causing it to become crystalline.

The effect of the second, viz., the form of the ship, being that in bad weather these vessels are almost unmanageable. In steaming against a head sea the tremor caused by the seas striking the ship and the racing of the propeller must throw very great strains on the shafting.

No doubt in all cases of failures the shafts have been made to the dimensions required by the rules laid down by the Board of Trade or Lloyd's Register, which Mr. Macfarlane Grey has reminded us are "minimum" dimensions, but everybody knows that owners and builders of cargo tramps seldom exceed the requirements of either the Board of Trade or Lloyd's Register.

Also, it must be recollected that the rules for the dimensions of shafting laid down by the Board of Trade and Lloyd's Register were calculated for a normal condition of things, and not for the condition of things you get with a big tramp making a sea voyage in water ballast in bad weather, with a heavy cast-iron propeller of large diameter only partially immersed on the end of it, which is doing its best to shake everything to pieces, including the shafting. You get stresses that the rules for the dimensions of shafting were never intended to allow for, and which no rules can ever calculate.

Now, do we find the same condition of shaft failures all round? I think not. Last July Mr. Manuel read a paper on "Crank and other Shafts used in the Mercantile Marine" before the International Congress of Naval Architects and Marine Engineers. He stated that in the P. and O. Company from 1880 they had used mild steel shafting. The percentage of strength above Board of Trade rules being, in 1881, 24 per cent.; 1887, 14 per cent.; 1892, 11 per cent.; 1897, 6 per cent.; and summed up his experience as follows: "After an experience of sixteen years I have neither flaws nor breakages to report, while gradually reducing the margin of safety of these steel shafts from 24 per cent. to 6 per cent.

If we take the leading steamship companies that have passenger trade, we shall find, take them all round, that though there may have been a broken shaft here and there, the experience of their superintending engineers is not very different from that of Mr. Manuel's company, and all these companies now have large cargo steamers.

This being so, it seems to me that shipowners have the matter a good deal in their own hands; that to a large extent the failures of shafts are due to the competition to get the cheapest possible ship as regards first cost that can be produced, with weight cut down to the lowest possible point, and which are not constructed with due regard to the work they have to perform. If they were we should hear less of shaft failures.

As regards shafting, nickel steel would be superior to anything else. It is a very reliable material, and while possessing a higher tensile strength than mild steel—about forty tons—it also possesses increased ductility and toughness, and should a crack appear it will not develop as in carbon steel. As compared with wrought-iron or mild steel, it is nearly incorrodable. And while steel shafting once cracked may break short off, the nickel steel is *fibrous*, and tears gradually.

Mr. Edison, speaking of this material, said: "Steel will crack, nickel steel you cannot crack."

Nickel steel shafts have been made for some large German ships.

The price of this material is higher than that of the best mild steel—in fact, too high for the ordinary shipowner. Probably for the present, shipowners had better follow Mr. Manuel's lead, and use mild forged steel made by the best English makers, which again means L.S.D.

I take it that Mr. Aisbitt's paper principally dealt with cargo tramps; in these I would use the best class of mild steel shafting the owners would pay for. Keep the tail shaft as large as possible, and the propeller as light as possible, consistent with the necessary strength. If the stern tubes were longer the tail shaft would be better supported.

Mr. HUGH MCLACHLAN said he thought it an objection to Mr. Donovan's system that it would diminish the water ballast tank capacity. He considered steel shafting most objectionable unless it was nickel steel. There was one thought that had occurred to him as a possible explanation of some of the trouble in propeller shafts, which he had never yet heard mentioned, and that was, that in a ship sailing from north to south, or from south to north, whether the magnetic action which took place in the shaft due to the hammering had anything to do with the separation of the molecules in the steel shaft to a greater extent than in iron. It might appear to be a strange idea, but perhaps there might be something in it.

The CHAIRMAN: I have had brought under my notice the case of a propeller shaft which was covered right through the whole extent of the stern tube with brass. The brass running in the water between the bearings got incrusted with scale, and when the attempt was made to draw the propeller shaft it was found impossible to get the shaft out without dealing with the stern tube as well. That is the great danger involved in wrapping the shaft with marline or other substance.

Mr. A. SCOBIE (Member): The case of the shaft referred to which was covered with brass, reminds me of a similar instance where the shaft was all iron right through, without any brass at all. When we attempted to draw it we found that we were unable to do so. We drew it out a foot or two, but then it stuck, and we could get it neither out nor in. We could not drive it back even with a ram. It was only a 12-in. shaft. We then bored small holes through the stern tube, and poured vitriol through the holes to soften the rust, and in the result it took us ten days to get that shaft out. The shaft had been running previously for about eighteen months. That was my experience with a propeller shaft. It took place some years ago, when they did not put brass on all shafts, but made them iron all through.

Mr. C. NOBLE (Member): Many defects and failures of propeller shafts are due to the construction of the hulls of steamers. One particular case came under my notice when fitting a new propeller shaft in one of the Western Ocean steamers. This propeller shaft had a collar on the fore part of the bearing, between the collar and the face of the bearing. The old shaft had $1\frac{1}{4}$ in. clearance, and the new $\frac{7}{8}$ in. The chief engineer on examining it said he should have to shift the bearing further aft, or else the shaft would shift it for him during the voyage. I remarked that it was impossible for the working heat at each bearing to expand the shaft to that extent, but the chief engineer said it was entirely due to the structure of the vessel, which changed so much with the nature of the cargo carried that the friction of the collar on the fore end of the bearing was so great at times that it often heated up. If the hull of a ship changed so much under ordinary circumstances, what must the effect be on shafting with a ship of that description in a heavy sea? When we consider the severe conditions under which shafting has to work: firstly, from the varying stresses which occurred through racing; secondly, the bending strain caused by the pressure on the different parts of the hull; thirdly, the twisting strain due to suddenly stopping and reversing the engines; together with bad material and a certain amount of carelessness, it was perhaps surprising, with shafts working under these conditions, that the percentage of breakdowns was so small. A propeller shaft carefully sheathed with gun-metal of proper size, and made of best iron, seldom gave trouble. With regard to corrosion or water-marks, I remember seeing a very bad defect, found abaft the gun-metal liner in front of the propeller, to the extent of $\frac{5}{8}$ in. deep, $\frac{5}{16}$ in. broad at surface, tapered down all round the shaft, as if it had been cut with a tool. We would say that such a defect was due to chemical action assisted by the rotation of the shaft. I have never noticed chemical action to any extent take place when zinc plates have been fitted near the parts which are likely to be effected.

The CHAIRMAN: *Apropos* of Mr. Elmslie's remarks about the Board of Trade rules prescribing the minimum requirements, we find that those minimum requirements are generally adopted as far as possible in other directions than propeller shafts. I think the practice in most large companies is to have the shafting about 5 to 10 per cent. stronger than required by the Board of Trade rules. Mr. McLaren has suggested running nickel steel in white metal, but the question occurs to one how far white metal and nickel steel will work together in salt water? It would be of interest and value to have the result of experience on this.

Mr. J. R. RUTHVEN: It seems to me that in view of Mr. Manuel's experience that a strength of from 6 to

10 per cent. above the Board of Trade minimum furnishes a proper margin of safety. It should be possible to whisper to the Board of Trade to increase the minimum to that extent, so that everybody should stand on the same footing, instead of penalising the large steamship companies as at present. Let the Board of Trade rules provide for such a safe minimum that shafts will not break in such large numbers as they do now. Another point that occurs to me is the additional strain thrown upon shafts owing to the very powerful reversing gear now used. If any practical result is to come from this paper we should be prepared to suggest to the Board of Trade that the minimum should be raised to such a standard as in the experience of the majority furnishes a safe margin. Let every owner who sends a ship to sea be on the same footing as the great steamship companies in respect to the safety margin.

The CHAIRMAN: Do I understand Mr. Ruthven to propose that we shall approach the Board of Trade on this subject?

Mr. RUTHVEN: I leave that for further consideration, but I have no doubt that if we did suggest something of that kind to the Board of Trade it would have some effect.

Mr. M'LAREN: In reply to the Chairman's inquiry as to whether white metal and nickel steel would work together in salt water, I can give my experience with four rudder pintles around which white metal was run. The ship thus fitted made a voyage from Rio to the United Kingdom, the run occupying thirty-eight days, at the end of which time these pintles were found as fresh as when the white metal was put in.

Mr. C. NOBLE: There is another point that occurred to me; the space of shafting between the liners suffers considerably through the twisting strain, because the liners shrunk on the shaft bind it and add considerably to its strength. In one ship a Thompson patent coupling for convenience was fixed on the shaft, and when the engines were stopped suddenly it could be seen very plainly, on looking along the tunnel way, the effect of the twisting strains and the flexibility of the shaft.

The CHAIRMAN: Some years ago a steamer arrived, and it was found that from the Bay of Biscay home the whole of the lignum vitæ had come out of the after bearing of the stern tube, and when the wedge was tried in dry dock in the usual way it showed a clearance of an inch and a half; and although the propeller shaft had thus been working from the Bay of Biscay to London, it came out all right, and did not appear to have suffered much from the infliction.

Mr. RUTHVEN: With regard to the question of cost in this matter, it would be interesting if those who know the figures would tell us whether it is cheaper or dearer to make a good shaft than a bad one. I am inclined to think that cutting a shaft down to the finest dimensions is the dearest thing all round for everybody. If the loss and the cost of detention were calculated I think it would be seen that to do the think well is the best plan. This is a question of money, and if you are tied down to the last farthing you must take the consequences.

Mr. A. H. MATHER (Member): I should like to ask, Mr. Chairman, whether the shaft which had been working with a clearance of an inch and a quarter or so was put back into the ship again, and if so with what result?

The CHAIRMAN: The spare shaft was fitted, not, however, because of any flaw from the conditions being so severe, but on account of the reduction in diameter between the liners due to corrosion. A new bush was also fitted in the stern tube, with the lignum vitæ fitted in separate grooves in place of being fitted like the staves of a barrel and a keeper key, as the bearing was fitted originally. During my experience in the company with which I am connected we have not had a broken propeller shaft.

Mr. RUTHVEN: What were the dimensions of the shaft you cited, Mr. Chairman, over the Board of Trade minimum?

The CHAIRMAN: It was about 6 per cent. over the Board of Trade requirements.

Mr. RUTHVEN: That shows that a margin of 10 per cent. above the Board of Trade minimum is a safe margin.

The CHAIRMAN: It think it would be very interesting if Mr. Ruthven, when he raises the question of cost, would say whether he means from the shipowner's, the underwriter's, or the engineer's point of view, because these interests are not always identical.

Mr. RUTHVEN: My idea was from the repairs point of view. My idea is that it is a question of a national loss, and that when a shaft breaks and a ship goes down we all have to pay for it in some form or other. That is the point where I think the Board of Trade should come in and protect everybody. If increasing the minimum by 6, or 10, or 12 per cent. had the effect of saving 50 per cent. of the present breakages it would surely be a matter worth consideration.

Mr. T. F. AUKLAND: One or two remarks have been made in the course of this discussion in which underwriters have been mentioned. It is the duty of the underwriter when he has a risk submitted for his acceptance to judge whether it is a risk to be guarded well or otherwise, and he has to arrange accordingly, so that after all it does not matter to the underwriter whether the risk is relatively good or otherwise. If a loss occurs he has to pay, but if he knows his business he does not write that risk again unless he has more money for it, so that somebody else has to pay for it and not the underwriter. It has been stated that a frequent cause of the breakage of propeller shafts is to be found in the fact that steamers are sent across the Western Ocean in ballast, and the suggestion has been thrown out that it may be neccessary to have a load-line for ballast trim. I think the suggestion a good one, so as to prevent the racing of engines, which must facilitate breakages when the vessel is only half immersed.

The CHAIRMAN: As there appears to be no desire to continue the discussion, I have to intimate that our next meeting will be held on the second Monday in February, this night fortnight, when Mr. Keay is expected to read a paper on "The Thermodynamics of the Steam Engine." This paper of Mr. Aisbitt's has provoked a good deal of discussion both here and at Cardiff, and out of all that has been said we ought to find something that will be of permanent value, both to us and to the country at large.

The CHAIRMAN was awarded a vote of thanks, which he acknowledged.

RESUMÉ,

BY

THE AUTHOR OF THE PAPER.

After having perused the opinions of over twenty gentlemen who have taken part in the discussion on this subject, both here and in London, it is evident, I think, that the subject in merely its engineering aspect is one of great importance and interest to the profession generally, and that the discussion has revealed that the importance of the subject and the ultimate effects of defective propeller shafts is of far reaching and vital importance to others besides marine engineers and surveyors, viz., to shipowners and underwriters generally.

My reasons for saying so are that in a discussion at London Mr. J. E. Elmslie stated that in two years 1,506 new shafts had been certified by Lloyd's Registry to have been supplied to old or modern vessels not new, registered in their classification, of which number about 506 were for crank shafts, tunnel, and thrust shafts. This equals 500 defective propeller shafts per annum for vessels classed in Lloyd's Registry only, leaving out those which may have been fitted to special vessels unclassed, having Board of Trade passenger certificates, as also those which are classed in the Bureau Veritas, British corporations, or foreign registry societies.

Now, as I have found from my own experience that, out of the sixty or seventy shafts which have come under my notice as being condemned per annum, only about ten per cent. have been actual *bona fide* fractures, in which there has been no chemical or electric action, etc., it must be apparent what an enormous annual loss to shipowners, underwriters, and the country generally this replacement of defective shafts means; but, taking Lloyd's figures only of 500 shafts per year at an all round sum of £200 per shaft to cover their cost and contingent expenses and renewals, this represents a sum of £100,000 a year, without taking into consideration the question of salvage and other expenses.

I have carefully analysed the interesting discussion which has taken place both here and at London, which has, I think, proved the following facts:

Of eighteen gentlemen who discussed this matter, including Mr. Gravell, who wrote a paper some time ago on this subject, eleven are of the opinion that chemical or galvanic action is either the primary or subsidiary cause of the defects as found at the fore end of the after liner;

Six are of the opinion that the shafts as now fitted with brass liners are mechanically of defective form;

Six also are of the opinion that shafts, whether fitted with brass liners or without, are best run in oil or grease as a lubricant;

Eight are of the opinion that it is best to run the shafts on white metal in the place of lignum vitæ, dispensing, of course, with the brass liner;

Five that the present diameters of the shafts should be increased;

Three that the material of the shafts should be nickel or other good quality steel.

Finally, several gentlemen have suggested that some of the troubles which we have discussed are caused through the structure of the vessel working and causing the shafts to bend. This, I think, is untenable, seeing that from the formation of that particular part of the hull at the extreme stern, and also from the fact of the propeller shaft being enclosed in a rigid cast iron stern-tube, it would be impossible to exercise a bending strain on the shaft without showing very plainly signs of straining in the hull and fracture in the cast iron stern-tube.

Undoubtedly, the hulls of many of our steel cargo boats are unduly flexible, but that is a subject entirely irrelevant to the present matter under discussion, and, although of great importance, is one which is better treated separately.