INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1900-1901.

President—COLONEL JOHN M. DENNY, M.P.

DISCUSSIONS ON

THE NINETIETH PAPER

AND

THE NINETY-FIRST PAPER

(OF TRANSACTIONS).

PROPELLER SHAFTS:

AND

SOME REASONS FOR THE INCREASED NUMBER OF DEFECTIVE TAIL SHAFTS SINCE THE INTRODUCTION OF THE TRIPLE EXPANSION ENGINE.

READ AT

3 PARK PLACE, CARDIFF,

ON

WEDNESDAY, APRIL 4TH, 1900,

AND AT

58 ROMFORD ROAD, STRATFORD,

ON

MONDAY, SEPTEMBER 24TH, 1900.

PREFACE.

58 Romford Road,

Stratford,

November 12th, 1900.

A meeting of the Institute of Marine Engineers was held here this evening, presided over by Mr. S. C. Sage (Member of Council), when the discussion on the subject of "Propeller Shafts," introduced by papers contributed by Mr. E. Nicholl, R.N.R. (Member), and Mr. G. F. Mason (Member), was concluded.

The papers were read before the members at the Bristol Channel Centre, on Wednesday, April 4th, when Mr. T. W. Wailes (Local Vice-President), presided. They were afterwards read at 58 Romford Road, on Monday, September 24th, when Mr. A. Boyle (Chairman of Council) presided.

The discussions which ensued will be found in the following pages.

JAS. ADAMSON,

Hon. Secretary.

INSTITUTE OF MARINE ENGINEERS

INCORPORATED.

SESSION 1900-1901.

President—COLONEL JOHN M. DENNY, M.P.

PROPELLER SHAFTS.

DISCUSSION.

58 ROMFORD ROAD, STRATFORD.

MONDAY, SEPTEMBER 24th, 1900.

CHAIRMAN:
MR. A. BOYLE (CHAIRMAN OF COUNCIL).

THE CHAIRMAN said the subject for discussion was two papers on "Propeller Shafts," by Mr. Edward Nicholl, R.N.R. (Member), and by Mr. G. F. Mason (Member). Both papers had been read and discussed by the members at the Bristol Channel Centre premises, and in order to draw attention to the points in the papers he asked the Hon. Secretary to read them.

MR. JAMES ADAMSON (Hon. Secretary) said the authors of the papers were unable to be present, but would be pleased to reply to any questions asked in the course of the discussion.

The papers having been read, the CHAIRMAN remarked that they were most interesting and valuable and the authors had very clearly stated their views as to the cause of the very large number of failures of propeller shafts, especially of recent years.

Mr. W. LAWRIE (Member of Council) said the arguments followed in the two papers were somewhat different, and it would be confusing to go from one to the other. The remarks he had to make would not add anything to the information they already possessed on the subject, as he had not had a propeller shaft under examination for a large number of years, and his experience had been wholly derived from steamers whose propellers had been fully immersed, at any rate when they were in still water. The writer of the first paper (Mr. Edward Nicholl) confined himself wholly to cargo boats, usually engaged in trade, the exigencies of which required that they should steam long distances in ballast trim, with their propellers partly immersed. He thought it would have greatly assisted the discussion, or at any rate the engineers who had had any experience of this class of steamers, to show the nature and extent of the defects Mr. Nicholl referred to. He took it they would be very similar; but they developed in the other classes of steamer, still their development may have been more rooted owing to the conditions under which they had been working—that was, under light draught. The most acute troubles he ever experienced with propeller shafts had been all due to circumferential fracture, which always occurred close to the gun-metal liners, and all the shafts he had ever condemned had been put aside from that one cause. The wasting of the uncovered part of the propeller shaft in the tube was a trouble that could be very easily dealt with, and had never been a serious matter. Engineers were divided on this question. Some thought it was due to mechanical and others to chemical causes, but if they examined the cracks found in propeller shafts, or, at any rate, the circumferential fractures, they would find that they began from the outside and worked into the solid part of the shaft with a very fine line. In fact, it was so very fine at times that it was almost undiscernible, and if they looked at the location and the nature of the crack, it had always seemed to him to be the result of a bending action or bending stress on the shaft. His observations led him to think the fracture was due to the overhanging weight of the propeller, accentuated by the constant blows received during the "racing" in heavy weather, and he did not see anything inconsistent in thinking that the fracture might have been assisted by corrosive action. At any rate, it did not seem to him to matter much which of the two was the greatest sinner or which was first in the field. The theory regarding the centre of resistance being below the centre line of the shaft in the position with the propeller partly immersed seemed to him to be correct, and it was of course the opposite when the propellers were fully immersed, with the result that the fractures developed more quickly in the one case than in the other. Mr. Nicholl said: "The great majority of failures took place at either the inner end of the outer liner or between the propeller boss and the liner." His own experience had been that failure occurred more often at the forward end of the after liner than at the after end of the same liner, and he had also seen a very serious fracture occur at the after end of the forward liner, but he had never seen a fracture occur at the forward end of the forward liner, at the forward end of the bulkhead. The reason he made this remark was because he saw an illustration accompanying a paper read by Mr. Manuel at a meeting of the Institute of Naval Architects in 1897, where he had noted a fracture at all four points of the two liners. This he (Mr. Lawrie) had never seen before, and it was just possible that Mr. Manuel, from his greater experience and closer observation, might have seen this flaw at the forward end, and it might have escaped others. He wondered if any of the members had ever seen such a fracture. He was not sure whether these steamers that ran with light draught such as had been taken by Mr. Nicholl were fitted with twin screws, but there were many vessels in regular lines that were fitted with twin screws, and he wondered whether the life of a shaft was increased in the case of twin screws as against the single shaft. As to the remedies to be applied, Mr. Austin said, "improve the trim of the ship"; Mr. Nicholl said, "either propeller shafts must be considerably increased in diameter or the ships must be put down deeper in the water." Mr. Austin's view, he thought, was the correct one, and would meet with most approval from marine engineers. He would like to hear more about metal liners that extended the full length of the stern tube. Mr. Nicholl thought it only intensified the strain at the after end of the liner, and he would like to know the opinion of the members. Linerless shafts had been tried and failed, and the reason of their failures seemed to puzzle him. Mr. Nicholl showed a plan for lubricating, which had been fixed to two 6,000-ton ships, but he (Mr. Lawrie) could not see how he expected to get good lubricating from the method. Why lubricate from the upper deck, with yards and yards of piping? Why not do it from the engine-room, where the lubricating medium would be under the control of the engineer, and the thing could be done in the automatic fashion that seemed to him to be the correct way of going about the lubricating of these shafts. He was of opinion that many of the failures in these linerless shafts had been from want of proper lubrication much more than the want of good material for running the bearing in. Mr. Nicholl asked for the views of the Institute on three particular points—first, linerless tail shafts; second, shafts of larger diameter; and third, shafts made of better material. He did not think they would be unanimous on all the points, and the most Mr. Nicholl could hope for was the expression of individual opinion. As to the linerless shafts, he thought, although he had had no experience, they were the correct thing. If they could get a uniform section right throughout it would strengthen the shaft very much, and he did not see any reason why they should not be made to work as successfully as any other bearings. He granted they were out of the way, but that could be easily overcome. As to the question of increased diameter and improved material, it seemed to him that the most improved material was nickel steel, and if nickel steel was adopted he did not see much use in increasing the size and diameter of the shaft. On this point he thought it would be well to read up the paper by Mr. Beardmore, read in 1897, and in his opinion if nickel steel was used that would certainly be all that was required.

Mr. J. T. SMITH (Member of Council) said if it was possible for the authors of the papers to get the names of makers of bad shafts, the names of the ships in which shafts had broken and the makers of those shafts, they would be getting at the root of the matter, and people would know where not to go for shafts. The linerless shaft with oil lubrication was a very tender point, because they could not get at the stern tube to see how it was going on. If they had oil in the thrust or any other bearing they could watch it, and when getting lower than usual take steps to see it attended to, but in the stern tube they could not do this, and if the shaft was so fitted that it was entirely to be lubricated by oil, a hundred things might happen to admit a little water; and if they churned oil and water in the stern tube in a short time they would find it in a state more like a bath of soap than anything else, and something serious might happen. He thought this a very serious drawback in linerless shafts and oil lubricating.

Mr. S. C. SAGE (Member of Council) said this question was a very interesting and important one to marine engineers, and it seemed to him that while various theories had been set up as to the cause, the only true one was that advocated by those who ascribed all these failures to an insufficient draught of the vessel, and to the "thrashing" which occurred in consequence. In his experience the place where the fracture nearly always occurred was at one end of the after liner or the other; in some cases clean off by the liner aft, and in other cases clean off by the liner inside, and in ninety-nine cases out of one hundred the fracture was clean across, as if the shaft had been made of cast iron. In many cases he had seen the condition of the iron such that it might be thought to be pig iron. He was speaking of shafts that had been broken to see how far the fracture had gone in. The fractures were nearly always circumferential, and had developed across. He did not think the chemical or galvanic action had anything to do with the origin of the crack; they only tended to make the fractures which existed more clearly visible. In no case had he seen these circumferential fractures extend more than $\frac{5}{8}$ in. or $\frac{3}{4}$ in. into the shaft. Having spoken of two ships he had had experience of, Mr. Sage said that if they looked at the fibre and texture of the iron which contained these fractures they would find that the continuous concussion that went on tended to make the material revert to its original state. In no case had he seen a fracture that had had the slightest fibrous grain; it had all been highly crystallised, and he thought the liners or any variation in the form of the shaft tended to accentuate the concussion and the vibration. In the old days they used to have a plain straight shaft, and the propeller was generally set up with a tail key, and they used to run with cast-iron bushes. The only difficulty they then had was to keep the stuffing-box tight, because it would become a little reedy, and tear the packing out. Every twelve or eighteen months the shafts used to be drawn in and the bush replaced, and then coupled up again. He had a considerable experience with a firm that did a good deal of bushing, and it was the exception for any of these ships to have broken tail shafts, but in those days the ships were loaded out and home, and if they went a ballast voyage it was simply to some northern port. There had been many advocates of the linerless shaft, and he pinned his faith very much to that, and he did not see why the wrought iron or wrought steel shaft should not run in bearings properly lubricated as well as the crank shaft. He had just completed a vessel in which he had altered the stern tube and the stern shaft to run in this manner. The tube was bored the whole distance, and at the outer end there was a Parson's white metal bush, with a ring at the end. A little solid lubricant was forced into it, and by the time it reached outside the stern bush they had a thin collar of lubricant exuding from the stuffing-box. He hoped to bring the result of this trial before the members of the Institute. He felt certain that if they took some of the shafts and tested them and tried them when they were new, and then after a fracture—subject them to the same test—they would find that the strength of the material had very much deteriorated from one cause or other. By the look of the section he felt certain that no forging or hammering would have left them in such a crystallised manner as he had seen.

Mr. G. W. NEWALL (Member) drew attention to an engraving of a new ship, the *Ivernia*, and spoke of the action of the sea upon the different parts. When a sea struck a certain part the ship "wriggled," and it was this wriggling that destroyed the shafts. The whole business of the papers, which was very important, seemed to be to tell them they did not know their business. Two ships every week were breaking their propeller shafts, and several shafts were condemned every week, and they had to see whether they could not get round all these troubles, which were more prevalent than they had ever been. He advocated that no part of the iron shaft should ever come in contact with sea water. It should be treated as a special detail and isolated from sea water, because it appeared from these papers, and from others, that corrosion took place from some cause not understood, and ate away the shaft in places. To prevent that they should put a bonnet over the nut at the end of the shaft, and fill it up with melted fat or tallow, and if the propeller boss was open to the water it should also be filled with melted tallow. A great many ships had broken their shafts through corrosion between the forward part of the propeller boss and the after part of the liner, and he suggested that all propellers should be supplied with a pipe piece projecting slightly over the first liner, and insulate the cavity with an alloy of antimony and lead, or pitch and resin, which would bring about the sealing of the place. Inside they could bind a gutta-percha strip closely round the part to be guarded against corrosion. He believed they made a great mistake in fitting the thrust-block where it was. The thrust-block should be fitted on the first tunnel-block in the ship, where all the work was. There was another point, and that was that the shafting that immediately followed the single piece of tail shafting should be built up in such a way that wherever a bearing comes it should be swelled slightly larger; and, further, what was most important, not one inch of tunnel shafting, except where the bearings fitted and the coupling came, should ever be turned. They hammered iron to drive the molecules in it closer together, and yet after they had done that they put it into a lathe and turned a large part of it off again. Many a shaft would work much better if they only left it as the hammer had left it.

The discussion was adjourned for a fortnight, and a vote of thanks was accorded to the Chairman for presiding.

DISCUSSION CONTINUED.

58 ROMFORD ROAD, STRATFORD.

MONDAY, OCTOBER 8th, 1900.

CHAIRMAN:

MR. G. W. MANUEL (PAST PRESIDENT).

THE CHAIRMAN: The subject for discussion this evening is comprised in the two papers on "Propeller Shafts," read at the Bristol Channel Centre in April last and at the Institute premises here in September. A goodly number of papers have been written on this matter, and I regret to hear that, after all, propeller shafts still break, and even a little faster than formerly, in spite of all that has been said and done to prevent such accidents, bringing loss of life and danger to ship and all concerned. As you are aware, I have taken a great interest in this subject on account of the position which I hold, and also a desire for better things. I read a paper on the question at this Institute eleven years ago—I think it was the second or third paper read at the Institute. I also read an extended paper of my further experience at the Imperial Institute, before the world's principal engineers and shipbuilders in the Jubilee year. It is certain that the attempts at prevention have been very little, and in many cases very meagre. I think it does one good to look back and study your own sayings of byegone years. The result may be refreshing or not, or it may seem prophetic, according to the statements made. Members of Parliament have to beware of the lookers back over their sayings. Many of the causes of broken shafts cited in these two papers have become truths in my own experience. Some have not borne the crucial test of practice, which after all is the true test. The difficulty, I find, which prevents advice honestly given from being carried out is the opposition from trade and other interests. From my own experience there can be no necessity for such records of broken shafts as have lately been referred to, and I have no such record to lay before you. I have to congratulate the members of this Institute on having such useful papers read at Cardiff and here, and the opportunity they have of discussing them—or hearing them discussed—especially the young members, is one of the principal purposes for which this Institute was founded, and one which especially deserves the notice of our shipowners in the way it is carried out. To the younger members this training is invaluable in aiding their future efficiency as marine engineers; in fact, the amount of your income depends on your practical and theoretical knowledge combined more than ever in these days of progress. I was much interested in reading last week this advertisement in an American engineering paper, showing the manner in which the benefits of this kind of education are put before the students over there. The advertisement is headed "Salary raising education," and it says: "$12 to $70 in small monthly instalments pays for a salary raising education in marine engineering, mechanical engineering, electrical engineering, English branches, etc.; course in lake navigation in preparation. Established 1891. $1,500,000 capital. Write for circular and local references," etc. That shows you the aim or the direction in which education is pointing—salary raising, that is to say, money making. The Americans are great people for money making and amassing wealth, but looking at what the young men in America have to pay, you will see that we beat them in regard to the cheapness of this kind of education. The Americans are making great strides in marine engineering, and will presently have a magnificent fleet of merchant steamers of their own construction. The Germans now have the fastest steamers across the Atlantic, but this is no discredit to our engineers, the circumstance depending not on skill, but on finance—on the margin between profit and loss to compensate owners for the enormous increase of weight and the consumption of fuel for these high speeds. This is a matter in respect of which it is for members of Parliament to obtain for shipowners more money assistance from our Government, and so enable them to keep the pace with foreign nations instead of cutting and minimising their profits with vexatious systems, seeing that we are more dependent on our maritime commerce than any other nation in the world. I take this opportunity of congratulating you on the happy selection as your president of Colonel John Denny, M.P., who, I am sure, will do all he can, both in and out of Parliament, to advance your interests. I need not delay longer the resumption of your discussion on propeller shafts. I ask you to bear in mind the direction taken by Messrs. Nicholl and Mason, namely, after going into the matter they consider that the many breakages which have taken place in these shafts are preventible. It is for you to give your opinions on the means they recommend for their prevention, and any further light you can throw on the subject that will tend to their prevention. I am quite of opinion, from my own experience, that they are preventible.

The HON. SECRETARY (Mr. James Adamson) then read a communication that had been received by a member from Mr. J. M'Millan, an engineer engaged on the Australian coast, who wrote *inter alia*:

"The subject of the relationship between a leaky dynamo and the active corrosion of a propeller shaft is one which has to me much interest. Is there any such relationship? If so, to what extent; and is there any remedy? You will possibly pass the subject over, as others have done, by saying that tail shafts corroded before ever electricity entered as an active agent on board ship. However that may be, I shall give you my experience during my time on board one steamer, and if after that you think there is anything in it, you can gain information from those now in charge on board the same steamer. What first drew my attention to the subject was the steamship *Perthshire* breaking her shaft, others following, and then the *Fazilka* coming to grief through the same cause. My experience is as follows: About six months after I joined the steamer she went into dock for an overhaul. The tail shaft was drawn out for examination. I may here state that I was told the shaft had been in for twelve years, and had only been taken out for examination at stated intervals. It was found to be corroded a good deal. The surveyor ordered that at the end of six months the spare shaft must be put in. At the end of that time the spare shaft was put in, the old shaft having corroded considerably during the interval. At the end of two years the propeller shaft was again drawn out for examination, when it was found to be in as bad order as the old one, and no spare shaft being available, the same one had to be put back again till another one was got ready. The engineer-surveyor cut into the shaft three-eighths of an inch on each side of the diameter, close to the forward end of the after liner, and then was not at bottom of the score in the shaft. The part cut into was filled up with red lead, putty, and marline for about six inches on the length of the shaft. A new tail shaft was afterwards fitted, and on examination No. 2 shaft was found in a worse condition than No. 1 had been. Being curious to see if any action had taken place where covered with the marline, the lapping was cut off, and the metal was found to be as bright as when cut with chisels. Naturally, broken shafts being freely spoken about, I considered what could be the cause of our shafts corroding so fast, and it suddenly dawned on me that there might be something in the dynamo causing the action. I then remembered that there was a leak from the dynamo, as I could get a spark from any part of the hull if I connected a wire between the two. I also remembered that when the original engine was removed and the substitution made of an engine driven by belt, that the dynamo was bolted direct to the ship's frames, although sitting on a wooden block, and to all intents looked as if it was fixed in the proper manner. The dynamo is still fixed in that way if not altered since. I am at a loss to explain how the action takes place, yet I believe that it does exist. There are two ways which appear to me. The first is to suppose the ship's hull to be a huge field magnet, stern tube included, and the shaft working as an armature, if the lines of force (magnetism) were slight under ordinary circumstances, and a leak from the dynamo was added to it, don't you think that would cause the extra active corrosion? The second is that the stern tube is a battery, and the leakage from the dynamo excites the water held in the stern tube in a greater or less degree, causing the action. If my contention is correct, that the relationship does exist, how is it to be remedied? This is the point at which I must give up. The subject seems worthy of discussion, and perhaps some engineers may be able to trace and explain the cause and effect, and perhaps lead to some experiments being made to test the cause."

Mr. W. LAWRIE (Member of Council): I see that Mr. Nicholl claims some originality for his paper in that it is the first to publicly advocate very much larger shafts and also opens up the question of the material used in the manufacture of propeller shafts. He also asks for the approval by this Institute of three proposals—linerless tail shafts, shafts of larger diameter, and shafts made of better material than questionable scrap iron. I see also on page 53 that in reply to some of the criticisms on his paper at Cardiff he stated that his present formula for all the trouble mentioned would be "submerge the propeller" when he believed the best part of the difficulty would be overcome. This last formula is no doubt somewhat drastic, and so far as my memory serves me I do not think that Mr. Nicholl followed out that point in his paper. I suppose he does not care to advocate any idea that would cause an appreciable difference in the first cost of the vessel. But in asking the approval of the Institute for shafts of larger diameter and of better material, I think the author is somewhat premature in asking for larger shafts until he has decided what material he proposes to adopt in lieu of the material at present used. It seems to me that if you could get a material much stronger and much more suitable for the work than that now employed there would be very little need for increasing the size of the shafts. I agree with what the Chairman has said that these breakages which now occur so frequently are preventible, because in the experience of lines such as that the Chairman is connected with and many others, they are practically unknown. The cases more immediately dealt with by the author of the paper are, I think, rather extreme cases. Good scrap iron is a material that has served very well for shafts in times past, but it would seem that good scrap iron is not now to be had. For instance, Mr. Nicholl says: "Shafts made of the best scrap iron are generally stipulated for now, but this seems to be a very vague term, as often, and especially in our local yards, scrap steel is sold and bought and treated like scrap iron, and I should say a shaft made up of a mixture of scrap steel and iron would be the most unreliable thing you could possibly have." When Mr. Nicholl speaks of "our local yards" I suppose he refers to yards in the neighbourhood of Cardiff, but if the same practice obtains elsewhere I do not see that it is much use looking for good scrap iron. At any rate I think we shall all be agreed that as time goes on it will become increasingly difficult to procure good scrap iron. We should therefore look ahead and see what better material can be found, and experience almost forces us in the direction of nickel steel. Mr. Nicholl inclines towards nickel although he does not advocate it very strongly, and to me it is one of the disappointments of this paper that it gives no information as to whether nickel steel has been tried for propeller shafts, and if so, with what success. My view is that shafts of nickel steel ought to have a fair trial. Of course in dealing with these vessels that are frequently running about with their propellers only partly immersed we must try to meet those extreme cases, but I do not think that it would be altogether the thing to expect Lloyd's Register and the Board of Trade to make special rules for these special steamers. I know that in the paper which he read in the year 1897, our Chairman stated that the cargo steamers under his supervision experienced no particular difficulty in this respect and that their shafts ran without breaking. If that is so I do not know why the same thing cannot be done in connection with the particular steamers brought under our notice in the paper. In the second paper under discussion Mr. Mason takes up a somewhat different view to that put forward by Mr. Nicholl, and he appears to trace all the trouble to the advent of the triple expansion engine. Four crank or quadruple engines, he says, simply add to the difficulty. His ideas, I think, are set out on page 23 where he says:

"Now, with a multi-crank job—by this of course I mean three cranks and over—directly the ship lifts her stern the engines gather way at a great rate, and although the propeller strikes the water a tremendous blow as she dips, it is not sufficient to bring the engines back to the normal speed at once, owing to the extra turning moments, and something of the following sort, I take it, happens—the heavy sudden shock and strain bring the propeller up, to a certain extent, quicker than the engine end of the shafting, causing the shafting to twist and this twist remains, so to speak, until the propeller end overtakes the crank shaft end, causing the grain of the shaft to open, giving the water in the stern tube a better chance of getting into the reeds of the metal, and this constant action keeps going on until the shaft is a mass of reeds—of course I am working on the

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hypothesis of the shaft being made to Lloyd's strength—or owing to the heavy hammering and a little slackness of stern bush, a circumferential flaw is developed or the shaft snaps off altogether."

I do not think there is much chance of a propeller shaft getting to be a "mass of reeds." If it got that far I think the shaft would be more likely to give out. But lower down the page, to prove his theory, he tells us that: "Bearing out the above I find in two instances I tested—with loaded ship and weather practically the same in each case—that in a heavy head sea with throttle valve full open and engines allowed to run to give the same revolution in each case, that is to say, both would have run at 60 revolutions in smooth water, the compound's revolutions per minute were decreased slightly, but the triple's increased about 5 per cent. Again, in each case the ordinary piston speed per second was 8 ft., in the compound it ran up to 13 ft. per second, but in the triple, went up slightly over 16 ft. per second—60 per cent. increase in the one case and 100 per cent. in the other. This means again that with a shaft $\frac{1}{2}''$ less in diameter but indicating 45 per cent. more power, the propeller struck the water with 40 per cent. greater velocity. Can it be wondered at that under these circumstances propeller end shafts have been giving out in all directions?" It occurred to me, when I read that paragraph, that in a heavy head sea, with the throttle valve full open and the engines left to take care of themselves, it would be no wonder if the tail shaft went. In fact, it would be a wonder to me if there were any engines left at all. Of course we all know that the extra turning moment in three or four cranks will give a more uniform speed and a better speed, but I do not think that any ordinarily intelligent marine engineer would allow his engines to go as fast as ever they could in bad weather with a heavy head sea. It seems to me that in a case of that kind, when the sea increased, the engineer would ease his engines down—whether it was a compound or a triple job; when it got to be a heavy head sea and the propeller got out of the water he would ease his steam down. I am afraid that that is hardly the reason why the shafts have gone. The special points to which Mr. Mason calls attention at the end of his paper are all fairly well attended to at present in any well regulated steamship company, but there is one that is not and that is the plan of running in oil, which in my opinion will materially assist the satisfactory running of propeller shafts. Instead of increasing the size of propeller shafts I think we should seek to improve the quality of the material, and if we have a good material we may well keep the sizes within reasonable limits.

The CHAIRMAN said that reference had been made to the use of nickel steel, and some time ago he was himself very anxious to ascertain the superiority or otherwise of that metal for propeller shafts. He, therefore, had a series of tests made, and the conclusion he came to, as the results of those tests, was, that having regard to its higher cost, nickel steel was not preferable to the good mild steel which had hitherto given such satisfactory results. He had been using this particular mild steel since 1881, and from that date up to the present time they had not had a single case of a broken shaft. The result of his tests was that nickel steel was stronger than the best mild steel, but very little stronger. The Germans and the Russians were now using nickel steel.

Mr. LAWRIE said the point he raised was, whether in the class of steamers referred to by Mr. Nicholl in his paper, it would not be worth while incurring the additional expense involved in the use of nickel steel. Mr. Nicholl told them of failures of shafts after only eighteen months' running, and if they had to put in a shaft every eighteen months, or even every two years, if nickel steel would stand a reasonable time, would it not be worth while using it?

The CHAIRMAN: Of course there is steel and steel. There is good steel and bad steel, and there is some very bad steel.

Mr. S. C. SAGE (Member of Council) said it was not his intention to take part in the discussion that evening, but he had been induced to rise by some of the remarks that had fallen from Mr. Lawrie. Mr. Lawrie had raised the point whether it would not be better, and cheaper in the long run, to pay the extra price for nickel steel in order to get a better article. Probably they would all have no hesitation in saying that it would be better, but there was no inducement, in the case of the steamers in which these failures occurred so repeatedly, to go to the extra expense. Large firms like that the Chairman was connected with got the best quality of mild steel that was made and they paid a correspondingly high price for it. By this means they got an article which rendered it unnecessary for them to go to the further expense of nickel steel. It was all a question of pounds, shillings and pence. Ordinary tramp steamers—and it was in ordinary tramp steamers that these frequent failures occurred—were generally contracted for at a very low price. There was no stipulation as to the material to be used, except that it was to be the best material and best workmanship, and that best material was often very ordinary at the best. The shafts were made on a commercial basis in the cheapest way possible, and the methods of forging the shafts were frequently of such a character that the virtues of the steel were largely destroyed. The idea of the forgemen was to get as much of the work of the hammer as possible on to the shaft at every heat. The shaft was brought out of the fire almost in a molten state and the hammering was continued after the iron had lost its malleable condition. The making of the shaft was probably paid for by piece work, and the price was cut very low. The shipowner ultimately got his ship which was classed at Lloyd's, and the vessel went to sea. There was no restriction on the ship as to how she should go to sea, and if she broke down and was towed into port the owner was indemnified by the underwriters. There was no inducement for the owner to pay a penny more in order to get a good material. Of late years the owners of large lines of tramp steamers had been induced to start self-insurance, and then there was no doubt an inducement to use better material and pay an extra price for it, as the large liners did. Of course the large liners examined their shafts frequently, and a shaft that was at all doubtful was removed, so that it did not come under the category of a breakdown. There was no doubt that the very light trim in which steamers were often sent across the Atlantic, and the hammering and battering to which their shafts were subjected in consequence, were responsible for a great number of the failures which occurred, and he referred to a case within his own experience in which a shaft, at least 30 per cent. in excess of Lloyd's requirements, broke off short before it was two years old. The grain of the iron where it broke was just as coarse as any pig iron would be. His theory was that the constant vibration and concussion in the shaft deteriorated the quality of the metal in the immediate vicinity of that concussion, and he felt certain that if many of these shafts could have been broken when first fitted they would have been found to consist of what might be described as good fibrous metal. The metal had been changed in character by the usage to which it had been subjected. An increase in the diameter of shafts would not prevent their fracture. It might prolong the life, but that it would prevent the fracture of shafts in ships that were constantly being sent to sea in very light trim he did not for a moment believe. In the course of his experience he had come across a number of shafts that were partially fractured, and when they broke them it was found that at the point of fracture the iron was highly crystallised and very coarse in the grain, and generally in a condition in which he felt sure they were not originally. He could not help thinking that the action of the screw, in hammering and beating in the bush when there was a little play, tended to cause the material of the shaft to revert to its original constituents. As he said at the beginning it was all a question of £. s. d. All shipowners, if they would spend the money, could get good shafts, and could run their ships as free from breakdowns as the liners did.

Mr. J. G. HAWTHORN (Member of Council) suggested that in considering the causes of the trouble with propeller shafts sufficient notice had not been taken of the wear down of the tail end shaft in the stern tube. They could easily understand what would be the effect of only a quarter of an inch of play in a light ship. Suppose a propeller weighed 14 tons, and when fully immersed 12 tons, every time the stern of the ship rose and fell, there would be a sudden blow of two tons on the shaft. He believed that this kind of thing had a great deal to do with the fracture of tail end shafts, especially when they bore in mind that a great many of the fractures took place at the forward end of the after liner. It would also be interesting and instructive to compare the number of fractures under present conditions with those that occurred when there were outer bearings in the rudder post. That these outer bearings did safeguard wearing down in the stern bush was apparent to everyone. At the same time he did not advocate that they should be reintroduced. He should also like to know what was about the average wear down of a shaft.

Mr. SAGE: I have found it to be the general rule that, as soon as the bush gets to be three-eighths down, Lloyd's will not pass it, irrespective of anybody else. Of course that is their maximum, and they like it much better if you renew when it is only a quarter down. My theory is quite in agreement with Mr. Hawthorn's, that the shocks on the shaft due to slackness in the bush are responsible for many fractures. With respect to the outer bearing, I had to do many years ago with some vessels, all of which had the outer bearing, but my experience was that the outer bearing was generally no bearing at all, and however often you lined them up, the next time you docked the vessel it was just touching nowhere, as if there was a spring upon the shaft that would not allow it to work true. The outside bearing never seemed to afford any bearing at all, but I must say that the fracture of a tail end shaft was then a rare occurrence, although they were often run under barbarous conditions and the vessels went to sea very deeply loaded. We were not particular in those days to a shaft being three quarters of an inch out of line, and it was a common thing for the stern bush to have three quarters of an inch play. But certainly the shafts were then not nearly of the strength they are supposed to be now for the power of the engines, yet the breaking of a tail shaft was a very rare occurrence. We used to have broken crank pins more than anything else, but tail shafts not so much.

Mr. W. McLaren (Member of Council) said he entirely agreed with Mr. Nicholl when he advocated linerless shafts and better material—especially better material. Some of the material that was put into tramp steamers nowadays would not stand a liner being shrunk on to it, and he was convinced that in many instances a sawing action went on at the end of the liner as the shaft revolved. With regard to nickel steel he should say from what he had read that nickel steel shafts would be the shafts of the future, and that they would be run without any sleeves being fitted. At the last meeting a question was asked about cast iron stern bushes. He was quite prepared to believe that they would be a success so far as the bearing was concerned provided that the shaft was properly lubricated, but there would be a difficulty he anticipated when they required to draw it. He did not believe that there would be the same easy drawing as there was now with brass bushes filled in with lignum vitæ. He would also recommend the shortest possible stern tube, and believed that generally speaking the stern tube was too long.

Mr SAGE said that Mr. McLaren had referred to the question of cast iron bushes. Cast iron bushes were used, to his knowledge, thirty years ago, and they were adopted for a particular trade where the white metal bushes with lignum vitæ were found not to stand. There was a very large trade up the river Humber and the Ouse to Goole. The water in these rivers was very sandy and it was found that the ordinary white metal bushes would not last more than six months, each steamer making a voyage per week. The white metal bushes wore away so very quickly that cast iron bushes were fitted in all the steamers engaged in the trade, and they were just as easy to draw provided they were not put in too tight and did not have time to get rusty.

Mr. D. HULME (Member) said he believed that many of the accidents which occurred to shafts were due to the way in which ships were often driven at sea. When a steamer got into a heavy head sea the captain would sometimes say to the chief engineer, "Can't you give her a little more?" and it was just the "little more" that broke the shaft.

Mr. MACFARLANE GRAY, being called upon by the Chairman, said he had not seen the papers before that evening and he was not then prepared to discuss them, although the discussion to which he had listened had been very interesting. He had, however, had a talk with Mr. John Corry about a particular kind of shaft that he had put into one of his vessels. He would ask Mr. Corry to put into writing what he told him on that subject in order that it might be included in the *Transactions* of the Institute.

Mr. Jas. Howie (Member) gave his reasons for holding that scrap should not be used for the manufacture of propeller shafts unless guaranteed absolutely free from steel.

Mr. Sharp (Member) called attention to the diagram opposite page 20 of Mr. Mason's paper, and said that according to this diagram the case of the triple engine was very much worse than that of the compound engine. He believed, however, that the case as put in this diagram was quite erroneous. The diagram was wrongly drawn and was not to be depended upon. In point of fact the positions of the two cases were about reversed. The position shown for the triple engine was more like what it should be for the compound engine, and *vice versa*.

After some further comments, in the course of which the Chairman sketched on the blackboard a diagram and formula which he suggested might furnish matter for thought and inquiry, the discussion on the two papers before the meeting was adjourned until Monday, October 22.

Mr. Macfarlane Gray called attention to the election to the new Parliament of two well-known members of the Institute—Sir Fortescue Flannery, a past president, and Sir A. S. Haslam—and moved that a letter of congratulation should be addressed on behalf of the Institute to each of these gentlemen.

The proposal was seconded by the Chairman and cordially adopted.

The Chairman having reminded the members that the annual dinner of the Institute would take place at the Holborn Restaurant, on the 17th inst., the meeting concluded with a hearty vote of thanks to Mr. Manuel for presiding, proposed by Mr. A. Boyle and seconded by Mr. Lawrie.

DISCUSSION CONTINUED.

MONDAY, OCTOBER 22nd, 1900.

CHAIRMAN:
MR. W. LAWRIE (MEMBER OF COUNCIL).

THE CHAIRMAN: I think that the importance of the subject dealt with in the two papers before us is a sufficient reason for the adjourned discussion this evening. Ever since I have been to sea we have had more or less trouble with propeller shafts, and I think it is generally admitted that of late those troubles have been on the increase. Failures have occurred in shafting with greater frequency than was the case some years ago. Mr. Nicholl, in his paper, at the top of page 6, makes a complaint that "in spite of all that has been written, we do not appear to have arrived at any definite conclusion as to the cause of so many shafts failing." I hope, however, with the two very excellent papers that we have before us, and the discussions upon them, that in some measure, at any rate, some of the points may be cleared up. In discussing the reasons for the great number of failures that take place, Mr. Nicholl states that the shafts have been made too ridiculously small for the work they have to do, and that unless they are considerably increased in diameter, or ships are loaded deeper, failures will go on as heretofore. That is a very definite statement which almost seems to cover the whole case, but at the end of his paper Mr. Nicholl also states that the quality of the iron or steel used in the construction of shafting would form a very suitable subject for discussion. I agree with Mr. Nicholl on that point about the quality of the steel used, but there is just this other point and that is the method of manufacture at the forge, for even if you do select a good material in the first instance, unless the best workmanship is employed in the construction of the shaft, failure is only too probable. There is another point that might be discussed in connection with the questions of material and workmanship, and that is the question of survey. It was dealt with at Cardiff, and perhaps some of our members here may be able to add something, because after all is said and done, the business of forging is a commercial concern, and they are apt to do some things, which, with greater vigilance on the part of the surveyors, they would not do. Then with reference to the question of material there is another point at the end of the paper where Mr. Nicholl says: "Many a shaft, I feel sure, is set to work with severe initial stresses in it, which are continually struggling to relieve themselves and only do so when the shaft breaks." That seems to me a very strong statement, and I should like to hear any of our members, who may be qualified to speak on the point, give us their views about it. There are many other points in the paper, but of course you can quite see that the paper deals largely with cargo steamers that make long voyages in ballast trim, and the more information we are able to get on the subject the better shall we be able to avoid these constant breakdowns.

Mr. J. R. RUTHVEN (Member of Council) said that the subject of propeller shafts had been before this Institute many times, and in a valuable paper which Mr. Manuel read some ten years ago he showed that in his experience, with a certain margin of safety above the Board of Trade requirements, other things being equal, he had a practical immunity from broken shafts. If it was required to make shafts that would not break, the conditions were well known to the majority of engineers. It was simply a question of money. If the conditions were favourable to the running of a shaft that would not break there was no difficulty in producing such a shaft; and we should not be free of broken shafts until it was to the interest of everybody concerned to make a shaft that was not liable to break under the conditions of service at sea.

Mr. JAS. ADAMSON (Hon. Secretary) said that at the last meeting the question was asked as to what was the greatest amount down—out of line—they had ever seen a propeller shaft in the stern bush. He had seen one down over an inch; it certainly did not run very long in that condition, but it spoke well for the quality of the shaft that it worked like that for several days, with the whole of the lignum vitæ gone from the outer bearing. The keep had come adrift, and the lignum vitæ had come out leaving the shaft without a bearing beyond the one next the neck ring at the stern gland. That the shaft did not break under these conditions was good evidence of its strength. The shaft in question was about $15\frac{1}{4}$ in. in diameter originally, and he dared say it had corroded down to about $14\frac{7}{8}$. This was one of the severest tests that a propeller shaft could be subjected to, and it showed that in this particular case the Board of Trade rules were quite adequate. He had seen shafts running for periods of fourteen years, and originally those shafts were only from 10 to 15 per cent. above the Board of Trade rules. During the last three or four years that those shafts were running, they had probably worked down to the Board of Trade limit. In the course of a few years the 10 or 15 per cent. margin was gone. The action that went on in the stern tube between the liners reduced the shaft down to the Board of Trade limit, and as the shafts when so reduced were still kept at work for some years his experience was that the Board of Trade limit was not too low, assuming that the shafts were made of proper material. At the last meeting Mr. Sage spoke pretty strongly about the material of some of the shafts that he had seen condemned, and at the recent annual dinner Mr. Dunlop, referring to this point, asked whether the ships by reason of their construction broke the shafts, or whether the shafts broke by reason of the stresses set up in them. During this discussion the question had been asked more than once whether broken shafts were not largely due to the flexibility of the ships. He was told recently of an iron shaft that had run in a steamer for twenty-six years, which beat all the records that he had heard of. The question of galvanic action between the brass liners and the steel in the shaft had also been referred to, and there was great difference of opinion as to the cause of the corrosion between the liners. The plan had now been adopted to a great extent of lining the propeller shaft with brass from end to end. In connection with this point, one of the members at Cardiff brought forward a theory that the mere fact of reducing the shaft between the liners was a bad thing in itself. The member held that by breaking the section of the shaft they were doing it an injury, and making it weaker than it would have been if parallel throughout, even if of smaller diameter. At their last meeting a letter was read from an engineer in Australia who referred to the action of electricity in this connection, the return current going back to the dynamo causing an action in the stern tube which led to corrosion. The writer of the letter said that the corrosion after the introduction of the electric light into the vessel was very much more active than before. Mr. Macfarlane Gray had told him of a controversy that had attracted some attention as to the active corrosion going on in a large bridge in America, and it was considered that the activity of the corrosion in the iron work of the bridge was largely due to the electric current acting on the iron due to leakage. Mr. Mason, in his paper, referred to the triple and compound engines, pointing out that with triple engines more power might be transmitted through the same size of shaft than with compound. They knew that when a compound engine was tripled they could, according to the rule, put more power through the same shaft. A smaller diameter of shaft was allowed for a triple engine than for a compound of the same power, and Mr. Mason held that was wrong, and that the triple engine should not have the advantage that was given to it by the Board of Trade rules; he illustrated his contention by saying that at certain phases in the working of the triple engine they might have two-thirds of the power of the engine thumping the blades on the water, while with a compound they could never have more than one-half. It seemed to the speaker, however, that the quality of the material used was more in question than the Board of Trade rules, and also the practice of running ships in light trim. He had taken some pains to ascertain the percentage of propeller shaft failures during about four months running, and he found that there was a broken shaft every third day. This was a heavy mortality, and surely they ought to take some steps in order, if possible, to get to the bottom of the trouble, with a view to its correction. It had been remarked by several members that the main cause might be set down to a suicidal policy of cheapness, and, in his opinion, a job that was worth doing at all, whether new work or old, was worth doing well, it was a saving in the long run, and lessened the risk of a loss of reputation.

Mr. J. HOWIE (Member) said he had read these two papers with great interest and pleasure and believed that young engineers especially would derive therefrom a great amount of useful information. But he did not agree with what Mr. Nicholl said on page 8 about the centre of resistance to the power of the engine in the case of a vessel with the propeller only partly immersed, and held substantially the same view on this point as that put forward by Mr. Younger in the course of the discussion at Cardiff. He was not quite so sure as Mr. Nicholl appeared to be that steel shafts were going out of fashion, but advocated the use of ingot steel for this purpose. Mr. Lawrie had raised certain objections to Mr. Mason racing his engines under the circumstances explained on page 23 of the paper, but this action on the part of Mr. Mason was in the nature of an experiment.

The CHAIRMAN : All I know is that if Mr. Mason or any other engineer opens his engines out and gives them sufficient steam to drive them at the rate of sixty revolutions in smooth water, and afterwards drives them at the same speed in a heavy head sea, I say that that man is not fit to take charge of a steamer's engines. If Mr. Mason did it as an experiment I say it was a wrong thing to do. It does not prove anything to my mind.

Mr. HOWIE : If you are speaking practically I agree with you, but Mr. Mason was trying an experiment.

The CHAIRMAN : An experiment to break a shaft !

Mr. HOWIE : But Mr. Mason secured his point by doing something that was wrong.

The CHAIRMAN : I do not think that any point was secured at all.

Mr. F. COOPER (Member) said it seemed to him that the question put before the Institute was, why had so many propeller shafts broken in cargo steamers as compared with the number that broke in passenger steamers ? Some said that it was because the shafts in passenger steamers were made of better material, while others said that it was because the shafts of cargo steamers were not so well looked after. But he thought the real explanation was to be found in the fact that the engines of cargo steamers were subject to more racing than those of passenger vessels. In a great many cases cargo steamers went to sea very light, so that it was almost impossible, even in a moderate sea, to keep the engines from racing, besides which they were probably not docked so often, nor was the stern bush lined up so frequently. The same rules held good, whether of Lloyd's or the Board of Trade, with regard to both passenger and cargo steamers, and he did not see that there was any necessity for increasing the size of shafts. If the same size of shaft that ran for ten or twenty years in a passenger steamer was put into a cargo steamer with engines of the same power and only lasted a much shorter period, he had no doubt whatever that it was due to the greater number of times that the engines of the cargo boat were racing, as compared with the amount of racing in the passenger vessel. He did not suppose that the shafts of passenger steamers were very much better than those of cargo boats, but as a rule passenger boats got better attention, and they were generally well loaded when they went to sea, so that they seldom met heavy weather when they were very light. But it was quite the rule for cargo or tramp boats to go through heavy seas in very light trim, with the result that the propeller shafts suffered. There was a great deal too in what had been said by the Chairman about driving a ship in heavy weather. If with the engines making sixty revolutions in smooth water a ship made, say, twelve knots, and they found on getting into heavy weather that with the same number of revolutions the ship only made eight knots, then the sooner they slowed down the engines to the number of revolutions that should give eight knots the better for the engines, and they would get over the same distance in twenty-four hours.

Mr. W. HOUFE (Member) observed that the practice of injecting oil or tallow into the stern tube had long been practised in Norwegian steamers, and he gave an instance within his own experience in which a nickel steel shaft had suffered much less than a shaft made of iron. It had occurred to him that one reason why the shafts of tramp steamers suffered more than those in passenger steamers was due to the construction of the propeller. In passenger ships the propeller was generally better designed and constructed, while in cargo boats it was often roughly made and the pitching of the blades was irregular.

The CHAIRMAN showed a drawing of a shaft with a liner fitted the whole length, and said that after this shaft had been running for three years and five months it was drawn and carefully examined, and, being found quite good and sound, was put back again. The length of the liner on this shaft was 8 ft. 9 in., and the diameter of the shaft, which was of wrought iron, was $14\frac{3}{4}$ in. The liner was carried right into a recess in the boss and fitted with an indiarubber ring, and there was no sign of nicking or fracture at the end of the liner. This shaft—having been put back—would no doubt run for another three or four years, unless something happened to it. Besides fitting the liner the whole length of the shaft the lignum vitæ was fitted the whole length of the bearing, and fitted in squares, not in parallel lengths. In this particular case there was certainly no difficulty in drawing the shaft.

Mr. J. T. SMITH (Member of Council) said that Mr. Nicholl, in discussing the causes of shaft failures, said, "I am aware that many engineers are inclined to put the failure down to chemical action between the brass liners on the shaft and the steel or iron, but this has always appeared to me to be at least very doubtful." His (Mr. Smith's) view was that there was no doubt about it at all, and that this corrosion was a very real and a very serious thing. Unless some special precautions were taken to guard against it he believed it would soon cause trouble in a shaft. There were many ways of trying to stop it, and one method was by means of paint, but to get a good coating of paint between the liners it would have to be done very carefully, and it was not easy to get it done in dry dock when they were usually working against time. But with the metal thoroughly well cleaned he believed that three or four coats of good paint properly applied would stop the corrosion between the liners. With regard to the corrosion at the end of the liners, the author would have added greatly to the value of his paper if he had told them what precautions had been taken in the shafts that had come under his notice to stop that grooving or pitting which went on and which doubtless accounted for some of the breakages. The question had been asked whether the present shafts were large enough. The fact that they broke showed that they were not strong enough. Probably they were large enough if they were made of good material, but they were not all made of good material, and considering that the present method of forging was likely to go on for some years to come they had better have the shafts a little bit larger and give the ships a chance. A question was raised at the last meeting about an outer bearing, but his view was that they were well rid of the outer bearing, because while it was well able to support the shaft in a vertical direction it was worse than useless as a support to the shaft at the sides, and every time the rudder was put hard over either way the rudderpost was bound to go in the opposite direction. If they had an outer bearing that would not give sufficient support sideways it only added to the risks of breakage.

The CHAIRMAN said it was quite evident to everybody that the outer bearing as it was applied at one time would not do, and the idea now was for some sort of arrangement to be designed which would furnish an outer bearing independent of the rudder. They all knew that the rudderpost was the last place in which to put a bearing, especially since the introduction of steam steering gear. Mr. Nicholl advocated increasing the size of the shafts, but Mr. Austin, Lloyd's surveyor at Glasgow, wrote: "A fact which should not be overlooked, and which is obtained from statistics, is this, that a large number of shafts whose strength is from 30 per cent. to 40 per cent. above the rules of the Board of Trade and Lloyd's Register, have failed within two years of the time they were fitted." This being so, what was the increase in the size of the shafts to be—how far was it to go? One gentleman at Cardiff suggested an increase of 100 per cent. Of course they could go on increasing sizes, but if for some vessels an increase of 30 or 40 per cent. was not enough, while other vessels with an increase of only 8 or 10 per cent. could run satisfactorily, it seemed to be quite evident that there was something wrong with the vessels in which the 30 or 40 per cent. increase proved inadequate—something wrong in the material of the shafts or in the vessels themselves.

Mr. ATKINSON (Member) believed that the explanation of so many shafts breaking was to be found not in the shafts themselves, but in the ships. When the propeller shaft was fitted in a ship it was placed properly in line, but after that ship had been loaded with, say, an ore cargo, she probably sagged 4 or 5 in. in the middle. He had measured a loaded ship that was 4 in. lower amidships than before she commenced to load. Supposing there was a distance of 150 ft. between the crank shaft and the propeller, where was that 4 in. to go to? Something must be out of line.

The CHAIRMAN said there could be no doubt that the condition of a ship had a great deal to do with the running of a shaft. Mr. Adamson had spoken about a propeller shaft bearing that was over 1 in. down. He (the Chairman) had had experience with a bearing that was $1\frac{7}{8}$ in. high, due to the vessel having stranded, and this particular bearing was the one next to the crank shaft. They, however, did the best they could with it, and with the shaft in this condition the ship came home with the engines working at full speed from Portland (Maine) to

Liverpool. The fact that they were able to do this said something for the quality of the shaft.

Mr. J. T. Smith: And it says something for the holding down bolts.

The Chairman: I know we had some trouble to get them out. We had to resort to the Yankee plan of blowing them out.

Mr. J. Sturrock (Visitor) said it must not be supposed that the racing of engines was limited to tramp steamers. He had seen a P. & O. steamer racing quite as badly as the vessel in which he was engaged, which was a cargo steamer with water ballast tanks.

The discussion was then adjourned until the second Monday in November.

DISCUSSION CONTINUED.

58 Romford Road, Stratford, E.

MONDAY, NOVEMBER 12th, 1900.

Chairman:

Mr. S. C. SAGE (Member of Council).

The Chairman: We have met this evening to continue the discussion on Propeller Shafts. It is a subject well worthy of the deepest thought and attention of all societies and persons connected with those who go down to the sea in ships, or with steam shipping, and it will be very gratifying to us all if, as the result of our various discussions, we are able to indicate some remedies for the defects, latent and otherwise, to which the authors of the papers have directed our attention. The contention that the frequent failure of propeller shafts is largely due to the underloading of ships, or sending them to sea in too light trim, is a theory that has been advanced in a good many directions. On this point Mr. Nicholl, in the course of his paper, quotes Mr. Austin, Lloyd's Surveyor at Glasgow, who says:

"It is known that in regular lines of steamers which are always well loaded the number of tail shafts which break at sea is comparatively small, and in many instances such failures are due to the propeller striking some object such as wreckage. On the other hand, it is among tramp steamers and liners which run a large portion of their voyages in water ballast that the large proportion of failures take place."

There is one of the nautical journals that has made a quarterly notification of all the failures of propeller shafts in the mercantile marine, and this journal makes it a very strong point that these failures are mainly on account of the vessels being in ballast so that their propellers are only partly immersed. There certainly appear some good reasons for the theory put forward, and I agree with the theory, that the lightness of the ships is the great cause. The failures occur chiefly in tramp steamers, often in smooth water and in the finest weather, and there is no doubt that the comparative immunity enjoyed by liners is due to the fact that the necessities of their employment cause them to be loaded on both outward and homeward passages. In my opinion, it is more a question of money than anything else. If in the first instance owners would procure the best shafting that money can buy, and then spend the money necessary for its proper maintenance and examination, we should not have nearly so many failures. But as I have already said once in the course of this discussion, there is really no inducement for any ordinary steamship owner to pay heavily, or anything extra, for having the best quality of material. By his contract with the underwriters he is indemnified against practically everything that may occur, and the owner of an ordinary tramp steamer has a very strong objection to paying extra for anything that is not really necessary. The ordinary shipbuilder is induced by the stress of competition to cut down the cost of every part that is put into a ship, and therefore it all comes back to a question of pounds, shillings and pence. The forging is made of common scrap, and it is not possible at the price to eliminate all mixture so as to get a shaft of one material only. Scrap iron and scrap steel of various qualities are compounded together to make the forging, and the forgings are made by the men at so much per ton. Indeed, the price paid to the workmen has been cut down until it is now at the irreducible minimum, and from that time onward every operation that the shaft undergoes is a question of the lowest possible cost. The stress of competition is so great that for ordinary cargo steamers the cheapest article is used in nine cases out of ten. I feel sure that the engineering and shipbuilding talent of this country could produce the best article in the world, but it must be remunerative.

Mr. W. LAWRIE (Member of Council): There is just one point in connection with this rather wide and comprehensive subject upon which I should like to say a word, and that is the treatment to which shafts are subjected after they have been fitted in steamers. I quite agree with what has been said as to the importance of getting the best material and the best workmanship—that of course is absolutely necessary—but it is equally important that the shaft shall afterwards be very carefully treated. It has been stated here during the discussion that in some cargo steamers the shaft has been allowed to wear down half an inch before the bearing has been lined up. If the propeller shaft and the bearings were of moderately good material my experience would lead me to believe that a shaft would not wear down to that extent until after it had been running for some years, but the failures dealt with in the papers—at any rate, those dealt with in Mr. Nicholl's paper—occurred for the most part within a very short time after the shafts had been fitted in the vessels, so that if these shafts had worn down in this short time to any such extent as that suggested—three-eights or half an inch—there must have been something radically wrong. I cannot believe that the material was very good. At a previous meeting Mr. Hulme spoke of overdriving engines in heavy seas, owing to the request sometimes received from the bridge to "give her a little more." Of course if an engineer is guided entirely by the wishes of the bridge, well, the chances are that he will soon run himself into trouble. I suggested at a former meeting, easing the vessel down in heavy weather to something like a proportionate speed—that is, having regard to the force of the wind and sea, but at our last meeting one of our members, referring to a voyage which he had made somewhere up the Persian Gulf, said that if he had this kind of thing he would never have got to the end of his journey. I do not care, however, what material you put in a vessel, if an engineer's first consideration is the arrival of his ship in port at a certain time. Without considering what his machinery will reasonably bear in the varying conditions of sea and weather, he is very likely to have a failure of his propeller shaft. We all know that if a vessel is to pay it must make a certain number of voyages in the year, which is a great incentive to drive her in rough weather, but then on the other hand it has been said that with the present system of marine insurance it is an easy matter for a shipowner to replace a fractured shaft. I hardly think, however, that that is a fact, because underwriters will soon find out those vessels which break their shafts very frequently and increase the premiums in respect of them. Nothing tells more quickly than that which touches a man's pocket.

The CHAIRMAN said that Mr. Lawrie had spoken of the treatment of shafts on board ship as though the ship's engineers had the whole care of a shaft, but no engineer on board ship was allowed to say, for instance, when a shaft should be drawn and examined, or when a bush was to be re-wooded. With regard to what had been said about a bearing being half an inch down, it was well known that a classification society would not pass a shaft that was down to that extent. He had had through his hands recently the particulars of a steamer that went into dry dock at New York, and her bush was found to be seven-eighths of an inch down. It was not suprising that when the shaft was drawn it was found to be circumferentially fractured and was condemned. Mr. Lawrie had also spoken about insurance premiums. Possibly it was not known to Mr. Lawrie and the majority of engineers that steamers of the cargo or tramp class were insured at very much higher rates of premium than those charged on steamers of the liner class. If it were not so underwriters could not make any profit at all. In many cases they did not make much now. Insurance premiums were, he thought, commensurate with the risks, and they had been increasing with the risks, but what they wanted to ascertain as the result of this discussion was what did they think, as practical men, was the cause of so many shaft failures in a certain class of ships? Of course, the liners did not experience entire immunity from failures, but practically they did, owing to the superior and more costly work and material used upon them, and owing also to the better supervision.

Mr. W. Lawrie: When I spoke about the treatment of shafts after being fitted on board ship, it was not in my mind that a ship's engineer has any say as to when a shaft shall be drawn. What I had in my mind was what had been said by Mr. Hulme about a message coming from the bridge: "Can't you give her a little more?"

The Hon. Secretary (Mr. James Adamson) said that in the course of his opening observations reference was made by the Chairman to one of the nautical journals which made a quarterly notification of all the failures of propeller shafts in the mercantile marine. The journal in question was possibly the *Syren and Shipping*, and he laid on the table a copy of the issue for October 10, 1900, which contained a list of shaft failures during July, August, and September. The same number also contained a leading article on the subject, and there were some parts of it which he thought were worth reading in connection with the present discussion. He had from other sources counted up the shaft failures reported, and found these to average from two to three per week.

"The cause of these disasters is as regrettable as their frequency. It is patent that the propelling machinery of many steamers is by no means of sufficient strength to withstand the strains to which it is subjected. In making this statement we have no desire to reflect on shipbuilders or those who are responsible for the supply of marine engines. There is another factor which is relevant to the case besides excellence of material and reliability of workmanship. The manner in which a steamer is used has much to do with the case, and again we must iterate that the practice of sending vessels to sea in very light trim is largely accountable for these mishaps to shaftings and propellers. Yet shipowners maintain, and not without some show of reason, that the economics of modern shipowning necessitate that steamships shall make long ocean voyages with no cargo on board. Unfortunately the vast majority of these cargo-less vessels have not a sufficiency of ballast. There is a certain provision in the cellular double-bottom and, say, in fore and after peak tanks for water ballast, but the deadweight carried is not adequate to immerse the ship to a safe point. The result is that, in bad weather, the shafting is subjected to strains which were certainly not provided for by the engine makers, and not reckoned with by the classification societies. The marvel is, considering how the propellers of these metal balloons are, in heavy weather, revolving in air and water alternately, that shaft failures are not inseparable adjuncts to a winter voyage in light trim. Now, if these disasters are inevitable under present conditions, it follows that they can only be prevented by a modification of existing practices. In other

Extract from the "Syren and Shipping," *October* 10, 1900.

THIRD QUARTER'S SHAFT FAILURES IN 1900.

JULY.

Steamer's Name	Gross Tonnage	Owners	When built	Class	Cargo	Voyage, etc.	Damage
Grecian	2,827	USA	1900	R.	Ballast	Philadelphia to Boston ..	Propeller lost
Addington ..	1,613	Br	1883	Lloyd's	Ballast	Towed into Grimsby.. ..	Crank shaft broken
Kingsley ..	679	Br	1881	Lloyd's	—	Arrived at Cape Hawke ..	Shaft broken
Border Knight..	3,730	Br	1899	Lloyd's	General	Port Natal to New York ..	Propeller lost
Medjerda ..	1,983	Fr	1898	V.	General	Oran to Marseilles	Shaft broken
Winnie	1,898	Br	1889	Lloyd's	—	Manchester to Pugwash ..	Eccentric shaft broken
Ville de Marseille	1,285	Fr	1869	—	General	Dunkirk to Oran	Shaft broken
Geneva	739	Br	1878	Lloyd's	General	Hull to Leith	Tail shaft broken
Dauphine ..	1,033	Fr	1866	—	General	Oran to Marseilles	Intermediate shaft broken
Herman Winter	2,626	USA	1886	R.S.	—	At New York	Shaft broken
Vine Branch ..	3,442	Br	1896	C.V.	—	Table Bay to Coronel.. ..	Propeller lost, shaft broken
Grand Lake ..	896	Br	1892	—	—	Towed into Frances Harbour	Tail shaft broken
Clan Monroe ..	4,853	Br	1897	C.	General	Calcutta to London	Thrust shaft broken
Too Nan ..	1,537	Chnse	1881	—	—	Towed into Moji	Propeller lost
Taff	871	Br	1890	Lloyd's	—	At Baltimore	Tail shaft broken

AUGUST.

Steamer's Name	Gross Tonnage	Owners	When built	Class	Cargo	Voyage, etc.	Damage
American ..	3,526	Dtch	1892	Lloyd's	General	New York to Amsterdam ..	Shaft fractured
Rhea	1,130	Rus	1883	Lloyd's	General	Hamburg to Helsingfors ..	Shaft broken
Syracuse ..	1,918	USA	1884	—	—	At Buffalo	Shaft broken
Salinas	1,185	Brazil	1871	—	—	Towed into Para	Propeller lost
City of London..	999	Br	1871	Lloyd's	—	Brussels to London	Shaft broken
Kong Olof ..	547	Nor	1883	—	—	Arrived at Bergen	Shaft broken
Athena	3,427	Br	1899	Lloyd's	Ballast	Algoa to Bahia Blanca ..	Tail shaft broken

AUGUST—*continued.*

Steamer's Name	Gross Tonnage	Owners	When built	Class	Cargo	Voyage, etc.	Damage
Conseil	2,087	Fr	1882	Lloyd's	Wheat	Oran to Rouen	Shaft broken
Viatka	884	Br	1867	—	General	St. Petersburg to London ..	Crank shaft broken
Angela	1,493	Ital	1882	Lloyd's	Wheat	Towed into Constantinople..	Propeller lost
Leonidas ..	1,578	Grk	1877	—	Wheat	Kertch to Palermo	Tail shaft broken
Tim	2,578	Br	1890	Lloyd's	—	At Adelaide	Tail shaft broken
Georgios Contzis	885	Grk	1890	Lloyd's	Wheat	Taganrog to Piræus	Tail shaft broken
Alfred Dumois..	728	Nor	1890	N.	—	Porto Plata to Boston ..	Shaft broken
Welhaven ..	683	Nor	1884	N.	Ballast	Manchester to Cardiff ..	Shaft broken

SEPTEMBER.

Steamer's Name	Gross Tonnage	Owners	When built	Class	Cargo	Voyage, etc.	Damage
Manchuria ..	5,710	Rus	1900	Lloyd's	—	Towed to Singapore	Main shaft broken
Holnis	987	Ger	1891	G.	Ballast	Hamburg to England ..	Propeller lost
Balmuir ..	1,381	Br	1879	Lloyd's	—	Carthagena to Palamos ..	Propeller lost
Apollo	1,710	Aust	1866	—	General	Trieste to Constantinople ..	Shaft broken
Yangtsze ..	6,457	Br	1899	Lloyd's	Coals	Barry to Shanghai	Tail shaft broken
Aquitaine ..	3,399	Fr	1891	V.	—	Haiphong—at Perim ..	Thrust shaft broken
Orinon	2,565	Sp	1896	Lloyd's	—	Rouen to Newport	Propeller lost
Robert Adamson	2,992	Br	1895	Lloyd's	—	At San Francisco	Crank and tail shaft damaged
Thomas Leigh ..	791	Ger	1899	—	Sleepers	Windau to Newcastle ..	Propeller lost
Chas. Tiberghein	4,200	Fr	1900	Lloyd's	Coals	Barry to Buenos Ayres ..	Shaft broken, propeller lost

Steamers under 500 tons not listed.

C. = Vessel classed in British Corporation. D. = Vessel classed in Nederlandsche Vereeniging. D.N. = Vessel classed in Nederlandsche Vereeniging and the Norske Veritas. D.V. = Vessel classed in Nederlandsche Vereeniging and Bureau Veritas. G.R. = Vessel classed in the Germanischer Lloyd and American Record. R. = Vessel classed in American Record. S. = Vessel classed in the United States Standard Register of Shipping. V. = Vessel classed in Bureau Veritas.

words, shipowners must cease to send their ships to sea light, or propelling machinery must be provided of such strength that it will not give way under the treatment to which it is subjected. Already there are signs that betterment is in progress. The new rules provide for stronger shafting, while greater attention is being paid to the material of which it is composed. These are steps in the right direction. But it is certainly strange that the alternative course is not more generally adopted. We cannot find that, as a rule, steamers of recent construction are provided with better facilities for the carriage of water ballast than their predecessors of, say, six or seven years ago. Nor do twin-screws seem much more popular. It is true that for big passenger boats two propellers are more frequently supplied than hitherto. This is largely due to the good sense of the voyaging public. They know that a boat with twin-screws is practically assured against a complete breakdown of her propelling machinery, and hence regarding this type of steamer as safer, they look upon the single-screw vessel with a certain amount of disfavour. This discounting of single-screw boats has spurred shipowners not a little towards building twin-screw vessels. The cargo boat, however, is in general a single screw. She is more economical than her sister provided with two propellers, and economy is the order of the day. When all is said and done, however, it is a very false economy which sends a vessel to sea in such a state that the risks of her prosecuting her voyage to a safe conclusion are materially enhanced. Much of the work of the Admiralty Court consists, as we have pointed out before, in adjudicating upon salvage services rendered to vessels which have been brought to a state of utter helplessness by shaft breakage or loss of propeller. For these disasters and delays the underwriters of course pay, but as they reimburse themselves for their losses by increased premiums, it follows that the economic waste due to shaft failures is a tax on our shipping industry in general. At this stage of the discussion of this important subject it is unnecessary to do more than state that the light ship evil is the cause of the bulk of breakdowns whether happening to light or loaded ships. Thus the practice of sending underladen vessels to sea may bear disastrous fruit when least expected. These breakdowns jeopardise property and also life, and in the interests of the safety of life at sea it is advisable that legislative action should be taken to check a practice which grows more common each year."

The CHAIRMAN said that reference had been made to the importance of taking care of shafts after they were fitted on board ship. The most extraordinary thing, in this connection, that he ever heard in his life was told him by the superintendent engineer of a line of passenger steamers making short voyages. This gentleman told him that when he succeeded the previous superintendent he found that in one steamer all the tunnel bearings had gone down to such an extent that they were about an inch too low. They had worn right through the metal and the flange of the tunnel blocks, so that they had to renew the whole of the blocks in the tunnel. Running under these conditions had apparently had no effect on the tail shaft, but according to the engineer of the ship the bearings took a little more oil. On the question of the risk of running steamers insufficiently loaded, the Chairman referred to the case of a steamer that would carry 5,500 tons deadweight engaged in the Atlantic trade. This vessel made frequent voyages with only 700 tons of water ballast and bunker coal, and in this trim her propeller boss was just awash. There was no trouble with any of her bearings, and no warning or signs of coming trouble, but on one of her voyages the propeller shaft broke clean off at the after end of the after liner. The diameter of the shaft was $13\frac{1}{2}$ in. and a similar set of engines in another ship had worked a shaft $12\frac{1}{4}$ in. in diameter. It appeared from this case that increasing the diameter and strength of the shaft was not an adequate protection when a vessel was persistently driven across the ocean insufficiently loaded.

Mr. J. B. JOHNSTON (Member) suggested that the increase in the number of accidents to propeller shafts was due in a large measure to the great increase in the number of steamers. The larger number made it more noticeable, but was the proportion of accidents so much larger?

Mr. T. F. AUKLAND (Companion) said it seemed to him there could be no doubt that the real question in this matter was one of pounds, shillings and pence. It was a question whether the shipowner, in the first instance, would pay for the best material, and secondly, whether he had a shore superintendent engineer who was sufficiently particular about the men whom he employed. In the olden times, when one of the old sailing ships came home practically everything was taken out of her. Everything was thoroughly overhauled, and everything required in the way of renewals or repairs was carried out before the vessel again went to sea, the result being that they very seldom heard of an accident happening to a vessel of this class. Now steamers had to a great extent taken the place of sailing ships, and he knew several lines of steamers, which had very good superintendent engineers, which ran comparatively free from accident. In the case of one fleet of steamers he was asked if he knew what percentage of those ships the owners placed aside as an insurance fund, and he was very much surprised indeed when he was told "only 2 per cent." With this provision for insurance the owners had not only saved money but they had actually built a number of steamers out of the profits of the 2 per cent. The freedom of a steamer from accident depended in a great measure upon the money that was expended in the first instance, upon her being properly looked after, and upon her not being worked too hard. With regard to premiums of insurance there could be no doubt that well found and well kept ships, such as he had been referring to, were insured for 2 or 3 per cent. as against 8, 10, or 12 per cent. for vessels of the other class, so that underwriters did take the increased risk into consideration. They had a private book which gave them the history of every steamer belonging to every line. Before they insured any steamer they referred to this book, and in assessing the premium to be charged for such insurance they were guided by the previous history of the vessel. There could be no doubt, however, that a very serious question in this matter was the number of vessels that went to sea in ballast trim, when of necessity their engines were more likely to race than if they were more deeply loaded, and they had to find a good deal of fault in this respect with vessels crossing the Atlantic. He also strongly deprecated the modern system of omitting to furnish steamers with spars and sails, and if it was necessary that steamers should only have pole masts, he really did think that they should be provided with all the requisite fastenings for spars, and that spars and sails should be carried on board so that they might be used if required. It was his conviction that some steamers had foundered after breaking their shafts simply because they had not the power to help themselves. He knew one case of a steamer which broke her shaft, where the captain, by utilising boat coverings and every scrap of canvas to be found on board, improvised sails by means of which—in addition to the schooner rig which he already had—he sailed his ship some 1,800 miles and brought her safely into port. He thought steamers should be compelled to carry some spars which could be used in an emergency, and, referring to a new steamer recently in one of the Thames docks, he quoted the strong recommendation of an experienced shipmaster that she should be barque rigged. Another point was the disadvantages of the flat bottom with which steamers were now built, as compared with the old keel bottoms. There was no doubt that a steamer with a keel bottom was much better off in a seaway. She certainly steered much better, and was much more manageable, having far greater grip of the water.

Mr. W. McLaren (Member of Council) said it had been very truly stated by more than one speaker in the course of this discussion that it was largely a question of pounds, shillings and pence, and he thought that shipowners were themselves the greatest victims of their own niggardliness in the building, upkeep and equipment of their vessels. With regard to propeller shafts he was in favour of liners being dispensed with altogether, and the bearings lubricated. If good material was used, and the shafts, after being fitted, were taken care of, it would not be necessary to make them of increased dimensions.

The Chairman, replying to a question by Mr. J. T. Smith, stated that the Norwegians had fitted nearly all their modern ships with linerless shafts running in a lubricated stern tube, and the Danes followed the same practice. Some of these steamers were running with white metal bushes and some with cast iron bushes, and they had a stuffing-box outside to keep the oil in. Some Scandinavian vessels fitted in this way had been running for ten years without any fracture having occurred. He was himself fitting a small steamer in the same way in order to see how it would work, but he was using solid oil because he had no stuffing-box on the outside. He had a compression box in the after part of the tunnel, which forced the grease through until it completely filled the tube. The engineer had told him that thus far this steamer had proved the quietest racing ship he had ever been in. His instructions to the engineer were to keep the tube full of oil until it commenced to exude at the end. He need scarcely add that he should watch very closely the performances of this little steamer, and when she was put in dry dock he would have very much pleasure in affording the members of this Institute an opportunity of inspecting her. Mr. Aisbitt, in a paper read before the Institute, in discussing the causes of slight fractures found in shafts that had not broken, was at first inclined to attribute them very much to chemical action, but apparently he had since abandoned that view and attributed the failures entirely to mechanical action. He (the Chairman) thought this latter view the correct one. He also thought that the Swedes were right, and that the linerless shaft was the proper thing.

Mr. SYMONDS: With reference to that little steamer which the Chairman spoke of, does he consider that the lubrication of the shaft would be any good unless there was a gland outside?

The CHAIRMAN: With a solid lubricant, yes. I should say that ordinary oil, without any attachment on the outside, would have a tendency to escape and float away. All the Norwegians have a box fitted for the lubricant.

Mr. JAMES ADAMSON (Hon. Secretary) said that one of the complaints made both here and at Cardiff was that light steamers ran with their propellers partly in air and partly in water, instead of being wholly in water. Apropos of this complaint, he was reminded of what was told him recently by one of their members who stated that a steamer was going down the coast very light, but owing to the condition of the weather, instead of making headway, she was making sternway and leeway. The captain and the chief engineer had a consultation, the result of which was that they agreed to flood the ship. They accordingly flooded the ship until they got her sufficiently immersed to give her headway, and they were then enabled to bring the ship safely into port. But for the flooding of the vessel in this way she would probably have been lost with all hands. There seemed therefore ground for complaint that ships were sent to sea too lightly laden. Another point raised was that partly laden steamers were sent to sea, and that on getting into a heavy seaway the engines raced so abnormally that something was bound to go. The shafts were weakened by the persistent hammering and thrashing, and strains were set up in the shafts which led to their ultimate breakage. But there was another cause which seemed to contribute to shaft failures. He had heard of steamers running on the coast some years ago in which the mortality among the shafts was noticeable. An order was issued that the captains were to be more careful in the orders that were given to the engine-room—that orders for sudden reversals from "full speed ahead" to "full speed astern" should be as few as possible, and since that order was issued the mortality among the shafts had been much less. At the recent annual dinner Mr. Dunlop referred to the flexibility of ships, and there was no doubt that the flexibility of our steamers did add to the breakage of propeller shafts. The Chairman had referred to the case of a ship where the bearings wore down abnormally, and he (Mr. Adamson) had in mind a case where, on the first voyage of a steamer, the bearings wore down almost as much. He attributed this circumstance to the fact that the shafting was put into the ship when she was on the stocks. When she was afterwards floated she probably altered her form or trim in some way so that the shaft became out of line, but since her first voyage, after the bearings were overhauled and re-adjusted, she had given no further trouble. Then there was a complaint of the want of inspection or supervision in allowing shafts to run too long without examination. Years ago it was quite common to see shafts down three-fourths or seven-eighths of an inch without being drawn, but now the rule was "three-eighths down or three years." If a shaft was three-eighths down it was examined, and if it had not worn down to that extent it was examined every three years. He had found this rule to work very well in practice, inasmuch as he had never in the company he served had a propeller shaft break at sea. With regard to the life of a shaft, the longest time that he had seen a shaft running in his experience was sixteen years, although he had heard of a shaft running for twenty-six years. Another point was the bad scrap iron, or the mixture of steel and iron, that was used in the manufacture of shafts. He thought they were pretty well agreed that where proper care was taken in making up the scrap, an iron shaft built up from good scrap would do very well. In some cases forgemen occupied too short a time in manufacturing a shaft, and if there was such hurry in the making it could not get that supervision which it would otherwise obtain.

The following points might be noted in connection with the mortality of shafts, as affecting causes:

I. Light steamers running with the propeller partly in air and partly in water.

II. Partly laden steamers running in a seaway with engines racing.

III. Steamers running on routes where the engines are subjected to frequent and sudden reversals.

IV. Steamers running with varying loads, especially where the scantlings are light, this giving flexibility to the structure and bending strains to the shafting.

V. Steamers running too long between the examination and lining up of the shafting, or with too small a margin of strength.

VI. Steamers running with shafting out of line.

VII. Steamers running with shafting inherently weak by reason of faulty material, workmanship, or local corrosion.

The CHAIRMAN then declared the discussion closed, and announced that at the next meeting, to be held on November 24, the subject for discussion would be the paper read before the North-East Coast Institution of Shipbuilders and Engineers on "The British Naval Engineer."

A vote of thanks to the Chairman, proposed by Mr. Aukland, concluded the meeting.

CORRESPONDENCE.

Mr. W. F. PINKERTON (Member) writes : How to prevent propeller shafts from breaking is a difficult problem to solve, and one requiring the essence of the collective experiences of every engineer who has ever had anything to do with them. From the papers and the discussion already published, it seems to me that nearly everything that is worth saying has already been said by experienced members of the Institute. I am in favour of heavier propeller shafts to the extent of 50 per cent. A linerless shaft is ideal provided the corrosion can be prevented. From the evidence of some of the members in discussion, this seems to be quite feasible. If the Norwegian steamers can run their shafts in oil, then we should also be able to do so.

Mr. Lawrie, at the meeting when I was present before sailing, passed round a sketch of a shaft with one long liner ; the idea is good, and if we could be sure of sound workmanship, with the liner carried inside the boss (provided the shaft has a big factor of safety) no trouble should be experienced either from chemical action in the stern tube or outside of it. No doubt the mortality is greatest in steamers of the tramp class, and unless we have either heavier shafts or a Board of Trade minimum load line the mortality is bound to go on.

Could not some of our eminent engineering chemists compound a substance that would defy the chemical action which seems to take place ?

There is little need to go over the questions that have already been thrashed out in discussion, unless it be to add weight to the great need of revolution in the diameter of shafts. Mr. Nicholl's formula of "submerge the propeller" is perhaps the best way out of the difficulty, but this cannot be easily attained by shipowners at all times.

As already suggested by one member, I think a number of questions drawn up in the form of a voting paper should be passed round the members of the Institute, and the results published, so that we might have the united voice of our own members throughout the world on the subject with a view to obtain a majority opinion on the causes contributing to the breakages and the remedies suggested. I was well pleased to be able to attend one of the meetings; it is so seldom that I have had the opportunity of attending. I make up for this by reading up the *Transactions*.

Mr. JOHN R. RUTHVEN (Member of Council) writes: To save the screw shaft to some extent and to add an extra propelling power I propose that abaft the thrust block a centrifugal pump should be fitted on the shaft. This pump to draw water from the sea or bilge, and discharge overboard in such a way as to get the full effect in propulsion. This pump would be most valuable in preventing racing. In the case of a breakdown of the propeller or shaft the water jet would then take up all the power of the engines, and the ship could proceed on her voyage without the great delay and danger due to total helplessness. As a bilge pump the power of the centrifugal pump would be of great service in case of a serious leak. Suitably arranged a leak that might sink the ship in an hour or less could be kept under and the ship propelled at the same time. By the addition of a centrifugal pump on the main screw shaft, a single screw ship would practically have a second means of propulsion, and so in effect would be superior to a twin-screw, for when one set of engines of a twin-screw break down, there is only about half power left to propel the ship, while with suitable arrangements the whole power of the ship could be used on the centrifugal pump when the screw was out of use, and so the full effect of the power of the engines would be used by the water jet. The efficiency of the water jet would entirely depend on its method of application, but at any rate, it would be quite equal to the screw propeller in bad weather, and the worse the weather the better the jet compares with the screw.

The following are reports of three notable instances of broken propeller shafts which have been repaired at sea, and it has been considered desirable to include these records in the *Transactions* of the Institute, as illustrating the expedients which were adopted to overcome the difficulties in the way of making good the propelling power in the steamers referred to after the shafts broke, thus saving the owners and underwriters from serious claims :

SS. "ATHENA."

ABOUT mid-way between St. Helena and Tristan d'Acunha, in the month of July, the *Athena* (Captain W. Jones) broke her propeller shaft when bound for Bahia Banca from Algoa Bay, and before the repairs were effected she had drifted north, and on making for port arrived at Bahia, San Salvador, considerably out of their course.

The shaft broke just as darkness was setting in on July 9th, and on examination it was found that the fracture had occurred in the stern tube, breaking it also, and exposing the damaged shaft in the last frame of the after peak, so that it seemed almost hopeless to repair it.

The ship was provisioned for five months on starting the voyage. Of these three months had expired, and it was decided to reduce the rations to one-third allowance, while the engineers engaged themselves to try and bind the broken portions of the shaft together; and during the time—thirty-five days—thus occupied, not a sail was sighted.

The chief engineer, Mr. Shepherd, on considering the best way and means to set to work to repair the damage, found that, owing to the contracted space, only one man could work at a time, while the donkey engine would have to be kept going to pump the water coming through the stern bush. However, the work was agreed upon and at once commenced and carried out successfully in the following manner. Stanchions were taken from the holds, forged and dressed, to form keys and bands; bolts were taken out here and there from the feet of the engine columns to secure the bands, and a sleeve of quarter steel plate was made to fit closely to the shaft, every detail of the work being thoroughly done. Meantime the two ends of the broken shaft were examined, keyways were cut into them ready to receive the keys which were being forged to bind the broken portions together, and the stern tube being at the same time cleared away to give sufficient room for the binding sleeve and bands to turn.

When all the keys were fitted the open fracture was wedged with $\frac{1}{2}$-in. and $\frac{5}{8}$-in. iron and made solid, and over all and through was run patent metal. The shaft was then sheathed with the sleeve and bound firm.

After weeks of anxiety and aimless drifting thirty-five miles aft daily, the work was tested and the engines run about half-speed, the ship reaching port after about 900 miles steaming, and was safely moored in harbour.

SS. "BORDER KNIGHT."

THE *Border Knight*, a British steamer of 2,392 tons, sailed from Port Natal on June 9th in water ballast bound for New York, under command of Captain Splatt. A splendid run was experienced until July 2nd, when, in Lat. 9° N., Long. 53°·48′ W., it was discovered at 2.30 p.m. that the ship had lost her propeller; the shaft was also found to be broken outside the liner. All hands were turned out at once and steam reduced. The second engineer (Mr. Campbell) with the aid of three of the crew started to disconnect the one coupling, while the third engineer (Mr. Findley) with three men dealt with the other. Meanwhile the fourth engineer was put to work cutting and bolting a piece of angle iron across the tunnel, underneath the forward end of the intermediate shaft, and cutting away the channel irons which the wheel chains run in, to bolt across the after end of the shaft.

The after tanks were then pumped out and the fore peak filled with water, but there being such a heavy swell on at the time, it was deemed imprudent to draw the tail shaft. It was afterwards decided to fill the fore hold with at least six feet of water, so as to bring down the head of the ship and elevate the stern. The whole staff of engineers worked until 8 p.m. and on their watches up to 6 a.m. the next day. The shaft weighed quite four tons, and as there was only one 2-ton and one 1-ton tackle on board, they were somewhat handicapped. However, this difficulty was overcome. The stock of the Kedge anchor was brought into use, being carried into the tunnel and used as a ram. Holes were bored in the tunnel top, tackles hung up, and the bulkhead gland removed at the after peak bulkhead. On the second day the intermediate shaft was lowered, one end resting on the tunnel floor and the other resting on the angle iron. All the tackles were then shifted so as to make ready for drawing in the tail shaft.

When that was finished—9 p.m.—all hands were rested until daylight on the third day; the ship was kept head on to the sea by the aid of a sea anchor, but the vessel dipped too much to permit of any outside work being done on that day.

A plug was then made of a wooden fender, which the chief engineer took down over the vessel's stern and inserted it into the sleeve, while the second engineer with the crew drew in the shaft. It was drawn in past the channel iron. The channel iron was put up again and the shaft balanced, one end being lowered on the tunnel floor and the other end hove up. The channel iron was then taken down and the shaft lowered; the spare shaft was now got up in like manner and subsequently pushed into the tube against the plug. All hands on watches worked all night getting coupling bolts, etc., ready for use on the morning of the fourth day. The shaft was pushed through, plenty of spun yarn being used, bound round the screw to prevent it from getting damaged. At 9 a.m. the spare propeller was lifted off the deck, put over the port side, and at 11 a.m. was placed in the aperture and the shaft pushed out.

After some trouble the key was inserted, and by 6 p.m. the nut run on two threads. The engineers worked in the tunnel all that night coupling up, etc. At daylight the chief engineer was lowered over the stern to the propeller, and succeeded in screwing up the nut with the aid of a wire purchase from the after winch. At 11 a.m. he had the nut in its place and the pin through the shaft, after which the sea anchor was hove up and the vessel proceeded to St. Lucia, being stopped only four days, three and a half hours. The work was accomplished without the slightest accident. Great praise is due to the engine-room staff for their promptitude and energy, and to Captain Splatt, the chief officer (Mr. Mathie), and the deck department for their support and assistance. The work of setting the propeller was attended with great difficulty, the chief engineer being submerged and jolted around by the lifting of the ship, causing the blood to flow from his ears and nostrils. Chief Officer Mathie, who was also over the stern assisting in the work, was swept away, and his rescue was attended with much difficulty. While at the work they were annoyed by the sharks, and it was only when four had been caught, killed, cut in pieces, and thrown overboard that the voracity of the others was appeased, and they were able to proceed with the work. Should a similar case arise, it is advised that the aid of a sea anchor be dispensed with. The chief engineer stated that he preferred to allow the ship to roll instead of to dip, as work could be prosecuted more promptly and with less danger.

SS. "FAZILKA."

On February 6th, between Mauritius and Colombo, the engines of the *Fazilka* raced away so suddenly it was evident to the engineer on watch that one of the shafts had broken. On examination it was found that the propeller shaft had given way in the stern tube, and the outer end had run out until brought up by the rudder post. After clearing away the broken pieces of the stern tube, the shaft was seen to be broken in two places between the liners. The ship was tipped, and the plating and framework cut away as necessary; the measurements then showed that it was impossible to make use of the Thomson patent coupling which was on board. It was determined, after the situation was discussed by the engineers, to secure the broken ends of the shaft by using the high pressure and the spare crank-pin bushes; these were therefore fitted and bound together by ½-in. steel plates, the shaft being pushed out from the tunnel to bring the two ends together. This part of the repair being effected, the next point was to make up the space left in the tunnel shafting due to the piece broken out of the propeller shaft, which measured 2 ft. 6½ in. This space was left between the coupling on the propeller shaft and the adjoining tunnel shaft coupling, and in order to fill this up a spar was cut and fitted in, the standards were removed from the Weir pumps and bedded into the wood and through the coupling bolt holes; a stanchion was also cut from the hold for the same purpose, and three stretching screws; the whole was then bound together by chains. This occupied the time from February 6th to 23rd, when the engines were tried under steam and the work tested; the coupling, however, slipped and was made more secure by the addition of two pins at each coupling, a further trial resulting in the coupling again slipping. It was now decided to cut the short length of tunnel shafting and draw the couplings together by removing the piece of the spar and binding stays and

chains. From February 26th to March 7th, all hands were occupied in cutting the short length of shaft, shifting the tunnel block bearing further aft, securing it, and fixing the Thomson patent coupling on the short length to bridge over the gap left. When this work was completed, another trial of the engines under steam was made, but the patent coupling slipped on the shaft, and in the tightening up the nuts the flange gave way; this was ultimately made secure by means of four pins entered into the body of the shaft through the coupling. At length their efforts were crowned with success, and the chief engineer, Mr. L. Brown, and his staff had the satisfaction of seeing the engines under way on March 9th, but on the 11th after steaming 200 miles, the strain sheared the pins—probably caused by the propeller boss gland catching on the outer stern tube flange, and as the shaft was drawn out, breaking the stern gland. This damage being cleared away, the broken pins were renewed and the engines again started on the 16th, when the coupling nuts started back. These being tightened up, next day they again slackened back, causing the plates to give way. These were renewed, and the space inside the patent coupling filled up with white metal and on the afternoon of the 19th the ship was again underway, and after steaming 380 miles arrived at Colombo on March 28th.

The ship was under the command of Captain Goss. The chief engineer, Mr. L. Brown, is a member of the Institute of Marine Engineers.

Mr. A. E. SHARP (Member): I wish to make a few remarks on the diagrams of turning moments in Mr. Mason's paper, and while sympathising with him, knowing the amount of time they take to prepare, the results obtained do not agree with the powers given in the paper. On casually looking at the diagrams I could not help noting that what purported to be the maximum and minimum turning moments in the two cases quoted, came out quite contrary to what I had usually seen, viz., the two cylinder engines giving a more uniform turning moment than the three cylinder engines.

I have measured each of the diagrams with the planimeter, and find their mean heights to be 88·9 for the red and 75·65 tons for the black diagram, and these figures should be the mean twisting moments, which they are not. The author has omitted one of the dimensions from his scale of units; undoubtedly it should be of two dimensions, as for instance, inch-pounds, foot-pounds, inch-tons, foot-tons, etc., etc. The indicator cards from which the diagrams are worked were taken when running ordinary speed as stated in the second paragraph of p. 24, so that the lesser powers and revolutions are assumed to be those from which the turning moment diagrams have been compiled, namely, 1772 and 1136 at 60 revs.

Where the indicated horse-power is known, the mean twisting moment is obtained from the following formula:

$$\text{T.M. in inch-pounds} = \frac{\text{I.H.P.} \times 33000 \times \text{C in in.}}{\text{Revs.} \times 3{\cdot}1416 \times 2\ \text{C in ft.}} = \frac{\text{I.H.P.} \times 63024}{\text{Revs.}}$$

the C in the formula being the length of the crank. Inserting the figures for the I.H.P. and revs. we have

$$\frac{1772 \times 63024}{60 \times 12 \times 2240} = 69{\cdot}4 \text{ feet-tons for the red and}$$

$$\frac{1136 \times 63024}{60 \times 12 \times 2240} = 44{\cdot}6 \text{ feet-tons for the black}$$

diagram, so that the mean heights of 88·9 and 75·65 tons do not correspond with what is obtained from the powers given.

Again, from the transactions of several of the engineering societies I find the maximum twisting moment of triple engines on three cranks is 1·2, and for two cylinders on two cranks is 1·48 times the mean twisting moment, so that the maximum figures for the two types of engines here given will be something like 83·3 and 66 feet-tons, and not 119·2 and 85·9 tons respectively.

To those interested in, or requiring information on twisting moment diagrams, I would refer them to the admirable paper by Mr. Sinclair in the first volume of the North-East Coast Institution of Engineers' and Shipbuilders' *Transactions*.

In conclusion, the writers of both these papers seem to think the panacea for the most of the breakages is to substantially increase the size of the shaft. In this I do not agree with them, our ships are handicapped enough already, and it takes us all our time to hold our own with foreign competition; what we want is the shaft material like the boiler material subjected to a test, not tensile but bending and torsional tests, and frame our sizes according to these results.

Mr. GEO. F. MASON replies to the discussion as follows: I much regret having been unable to attend the meetings held for the discussion of these two papers, especially as so much interest has been shown on the subject. I am glad to see that most of the members who have spoken agree with my deductions, and I am more than pleased to note that, since the papers have been read, Lloyd's Committee have fallen in with one of the suggestions made in them and increased the size of the propeller shafting, an alteration of their rules that I am sure will produce beneficial results.

I am glad to see Mr. Manuel is quite of my opinion that the majority of the breakdowns in question can be prevented, and I also agree with him when he refers to the difficulty of getting honestly expressed opinions accepted on account of trade or other interests.

Mr. Lawrie does not see why lubrication for shafts should be done from the upper deck. This may be a matter of fancy, but it is convenient, easily got-at-able, continually working, cannot go wrong, and cheap. He is also of the opinion that the cost of extra ballast might prove practically prohibitive, but I can assure him that the extra cost is a very small item, and would be saved in two or three ballast trips.

Mr. Lawrie also thinks it impossible for a shaft to become a mass of reeds. Perhaps he is taking my words too literally, although all fibrous shafts must consist of a mass of reeds; but at any rate, I have counted as many as forty in the circumference of one shaft. As regards his remark "that no sensible marine engineer would allow his engines to race in a head sea with throttle valve full open," he is quite correct. No one would if he could help it, but I have yet to learn how this can always be prevented. Of course, in the instances I have quoted in my paper, the engines were allowed to race for a purpose, otherwise I could not have procured the data I required for the purpose of contrasting the workings of triple and compound engines. My usual practice is to reduce the boiler pressure when the vessels are in light trim and heavy weather to ease the strain on the shafting.

I am quite with Mr. Sage when he blames the constant vibration and concussions for deteriorating the material in the shafting, and I have endeavoured to show how this has been increased of late years by the advent of multi-cranks and smaller shafts for given powers.

I believe with Mr. Newall that the proper place for the thrust-block is next the propeller shaft.

Mr. Ruthven has evidently not gone into the size of pump required to be of any use in propelling the vessels of the present day, and I would advise him to read the results of the experiments on H.M.S. *Waterwitch*.

Mr. Sharp's criticism is very interesting, and I at once had my figures checked over, fearing I had made a mistake, but I find them perfectly correct.

I noticed, however, that my original diagrams had been reduced for convenience in printing, and this may have led Mr. Sharp astray, as the scale has been left in the same. Still, I think on second thoughts he will find his arguments are fallacious, as his premises being wrong, his deductions must naturally be incorrect. Mr. Sharp first of all assumes a mean pressure and multiplies this by a constant—gathered from some other engineering transactions—to find a maximum and minimum twisting effort, an argument manifestly absurd, as I might point out that, although the mean pressure worked out to be 69·4 and 44·6 against 88·9 and 75·6, as he states, the maximum and minimum twisting moments might be 119·2 — 54·35 and 85·9 — 44·8, as I give them. I would again remind him that the figures given are taken from actual working cards, and can be corroborated by a dozen other examples. Again, even supposing his figures to be correct, my conclusions are still right, as he would only alter them in degree. I know it is almost accepted as a truism that multi-crank engines give more equal turning moments than do the old-fashioned compound, and this has been one of my reasons for bringing this paper before you.

Mr. Sinclair's paper is very interesting, but I fail to find anything in it that upsets my facts. Mr. Sharp need have no fear that an increase of 20 per cent. in the size of a propeller shaft will handicap our builders with foreign competition. Other builders would have to work up to the same rules, and he must not forget that anything that reduces the chance of breakdowns tends to reduce the rate of insurance—probably one of the largest items an owner has to face.

As regards linerless shafts, I may state I have just had an instance of one—a new vessel which had only made one loaded and one light trip—where the cast iron bush was worn right through and the shaft so badly cut as to have to be condemned, although this shaft had been run in oil fed as suggested by Mr. Lawrie.

In conclusion, I must thank the members who have taken part in this discussion, and trust the results arising from the reading of the paper may be of some benefit to the subject and Institute generally.