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President—A. J. DURSTON, Esq., R.N.

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FIFTY-SIXTH PAPER

(OF TRANSACTIONS)

The Structural Weakness of Steamers, And its Influence on the Propelling Machinery

BY

Mr. JOHN McCALLUM

(MEMBER).

READ AT

THE UNIVERSITY COLLEGE, CARDIFF,
WEDNESDAY, FEBRUARY 20TH, 1895,

THE INSTITUTE PREMISES, 58, ROMFORD ROAD, STRATFORD
MONDAY, MARCH 25TH, 1895.

THE ARTS' SOCIETY HALL, SOUTHAMPTON,
WEDNESDAY, APRIL 10TH, 1895.

PREFACE.

58, ROMFORD ROAD,

STRATFORD ESSEX,

March 25th, 1895.

A meeting of the Institute of Marine Engineers was held here this evening, presided over by Mr. J. F. FLANNERY, J.P., when a paper on "The Structural Weakness of Steamers, and its Influence on the Propelling Machinery," by Mr. JOHN McCALLUM (Member) was read and discussed.

The further discussion was adjourned till Monday, April 8th.

The paper was read before the members of the Bristol Channel Centre on February 20th, and the discussion was adjourned till February 27th, while arrangements are also made for it being read before the members of the Southampton Centre on Wednesday, 10th April.

JAS. ADAMSON,

Honorary Secretary.

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"THE STRUCTURAL WEAKNESS OF STEAMERS, AND ITS INFLUENCE ON THE PROPELLING MACHINERY."

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MR. JOHN McCALLUM

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WEDNESDAY, APRIL 10TH.

The Structural Weakness of Vessels, and the study of the stresses and strains set up in a sea-way, and under different conditions of loading, is a subject which has lately been receiving the serious attention of Naval Architects.

Opinions are conflicting, and, in a measure, it is beneficial that they are so, and that a certain amount of misbelief exists, as it has led to the reading of some interesting papers on the subject, and has elicited the opinions and criticisms of gentlemen of experience who hold definite positions, in these matters

Whatever differences of opinion may exist, one thing is certain, viz. :—That it is most desirable and to our interest, as engineers, to gain the necessary knowledge for our future guidance; and, anticipating that the criticism and discussion which will probably follow as likely to lead to this end, the writer has endeavoured in this paper to bring together some of the most essential points connected with structural weakness from an engineer's point of view, and to this end, is especially desirous to learn the views of those who are competent to speak on the subject, as he is not aware that it has been discussed at any of the learned societies' meetings from this aspect.

That vessels deflect when loading has long been a debatable point, but it has lately been clearly demonstrated, despite the opinions to the contrary, *that the forms of vessels do alter*, and in the port of Cardiff, which offers special advantages in observing vessels which are constantly trading to and from the port, we have the evidence of those persons responsible for the loading, and who have ample opportunities of verifying their statements, that under different conditions of loading, different weights are carried, water ballast and coal remaining in bunkers being allowed for. If we are to believe these statements, is it surprising to hear of detention and subsequent prosecution for overloading? In many cases doubtless there are evasions of the law, but in others I submit that the submersion of the disc is not entirely due to weight carried, but to the manner in which it was put in the vessel, and there is reason to doubt that the vessel has an excess of cargo over her usual complement.

It would be difficult to define even approximately the extent of this evil at sea, as with all our experience, and our advance in design and workmanship of both hull and machinery, we are often made painfully aware of defects in our modern screw steamers, and these failures have given the shipowner good cause for criticising a state of things he could not control or account for, and for which neither he nor his engineering representative were in any way responsible.

The theories advanced in the past by men of standing in the profession have attributed the failures of marine engines and shafts to bad material, bad workmanship, and faulty design; but the structural strength of the steamer, its deflection and working in a sea-way, is, I contend, one of the main points of weakness which it is absolutely necessary to study and allow for.

Is it not a fact that some steamers are veritable white elephants to the companies to which they belong, and despite all the care and attention given to them, and innumerable over-haulings at endless expense, they are continually in trouble:—coupling bolts and shafts breaking, bed plates and columns cracking, and are these mishaps to be traced to bad workmanship and design? In some cases certainly, but in others the majority of the accidents can only be attributed to structural weakness and subsequent working and straining.

To those who do not believe this statement, how can we reconcile ourselves and account for the ruptures, the open butts and loose rivets which, up till recently, have developed in the sheer strakes of some of our merchant vessels; in some instances the 'tween decks have been so contorted that the feet of hold stanchions are broken adrift, and 'tween deck hatch coamings so twisted that the hatches would not fit.

It may be argued that the prejudicial stowing of the cargo was the source of the evil; if such was the case, is it not a singular feature that almost all the defects are to be located in one hold, either fore or aft, and not uniformly over the whole vessel, and if we observe such a state of affairs in the hull, have we not good reason to suppose that the rigidity and smooth working of the engines is affected also?

Even in dock, loading, whilst repairs are in progress, it is a common experience, which no doubt some of our members can corroborate, that in the lining up of a tunnel shafting in some steamers, considerable difficulty is met with, owing to the varying form of the vessel, so much so that it is a matter of speculation whether at the finish the line of shafting has been improved by the operation.

Judging from this, are we not led to believe that this movement will be more aggravated in a sea way? Common sense tells us so, despite any assertions to the contrary, and practical facts are more reliable then speculative data, and if additional confirmation is required it is borne out by the fact that it is not an uncommon experience with marine engineers to observe that the smooth working of an engine is oft-times considerably affected by a change of cargo.

What we aim and look for in the marine engine is to get a rigid and smooth working machine, but what is the value of it, if, after careful construction at the works, we have good grounds for supposing that such a state of affairs as has been referred to exists on shipboard; and exist it does, for although it has been asserted in theory that the effect of the movement is only felt to an infinitesimal extent in the engine room, I maintain that however small it is, if the smooth working of the engines is affected by a change of cargo, or the lining of a shaft in the dock through the alteration of the vessel's form when loading, these give you sufficient reasons to doubt its accuracy. It proves conclusively that the structural strength of a steamer plays a very important part in the good, safe and efficient working of the machinery.

I am indebted to the courtesy of a gentlemen of known position in the engineering profession who has kindly furnished me with particulars of a series of observations taken on board of a large steel steamer, which had made herself notorious through her shafts breaking. The vessel was about 3,000 tons net register, and was engaged in the Eastern trade, carrying coal and general cargo, and the observations were taken on a voyage out and home.

She was well built and of a superior class, engines triple and well balanced, both hull and machinery being constructed by first-class builders. On the second voyage one shaft broke, and within two years four lengths of shafting were either broken or condemned, the material in every case showing itself solid at the fractures and of the best quality.

The shafts were made of the best selected iron and 20°/ₒ in excess of Board of Trade requirements.

Observations in the first instance were taken in the tunnel by the engineer of the steamer, by means of a steel wire, 19 B.W.G., running parallel with and directly above the centre line of shafting, one end of which was secured to the engine room bulkhead and the other conveyed over a small pulley, 6in. diameter, acting in a suitable bracket, which was bolted to the after bulkhead in the tunnel (see fig. 1.) and the wire was kept taut by a weight of 46lbs. suspended at the end.

The distance from bulkhead to bulkhead was about 112 feet, and midway between, a square graduated rod with jaw end, in which a pulley acted, was brought into contact with the shaft and kept in the vertical position by means of two projecting brackets of light design, fastened to the tunnel sides, one above the other, and through which the graduated rod operated vertically. See figs. 1 & 2.

The wire crossed the face of the graduated rod, and any difference in the indications was easily noted.

It may be urged that this method of determining the vessel's movement was crude and unreliable, and that the actual amount could not be estimated with sufficient precision, but at the same time it seems clear that if there was no movement in the hull the indications would remain unaltered.

The difficulties which have to be overcome in taking observations in a tunnel are doubtless the principal reasons why we have no record of any, and when we consider the unfavourable conditions in a dark and confined space in which a shaft is revolving, the method adopted by the engineer with the means he had at his disposal recommends itself as ingenious. The result of the observations was :—with ship loaded, draft 24 feet, with a heavy confused sea on starboard beam and quarter, engines racing occasionally, and vessel lurching and pitching about 18 to 20 feet, a maximum movement of $1\frac{1}{4}$in. vertically, was observed. This was the greatest deflection seen, happening invariably when the steamer's stern was high and the seas passing between Nos. two, four and five hatches.

The ordinary amount observed when the vessel was pitching in a head sea about 10 feet forward, was from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch.

No change took place when in port, for as a rule the holds were discharged together and loaded together.

With engines stopped at sea, the wire resumed its normal position exactly as in port, and on re-starting and getting under weigh the graduated rod indicated a deflection of $\frac{3}{8}$ of an inch in smooth water, the vessel's stern showing a downward tendency which was attributed to the movement of the propeller.

Very similar results were obtained on repeating the observations on deck by means of sights which were fixed in the most approved manner, and taking into account the deckhouses and the various deck fittings, they were fixed as near as possible to the centre line of vessel. The forward one being fixed on forecastle head at a distance of 43 feet 6 inches from stem, the centre one on bridge deck, and the after one 12 feet 2 inches from the rudderhead. See fig. 3.

The distance of line of sight from bridge deck was 4 feet $10\frac{1}{4}$ inches, when sighted in Graving Dock and sitting on blocks which had been previously prepared and sighted, midship tanks full (300 tons), holds empty, and 70 tons of coal in bunkers.

Alongside quay, with no alteration in holds, tanks or bunkers, 4 feet $10\frac{1}{8}$ inches.

When loaded, with holds and bunkers full, and tanks empty, 4 feet $10\frac{3}{8}$ inches.

The day previous to arrival at Port Said, cross bunkers empty, holds full and tanks empty, 4 feet $9\frac{3}{8}$ inches.

Ten days later, cross bunkers empty, No. 3 lower hold, which was used as a spare bunker, half empty, and midship tank full, 4 feet $9\frac{3}{8}$ inches. When sighted on this occasion the vessel was pitching about 17 feet forward into head sea, and about 12 feet aft, and by the sights the hull was moving $\frac{5}{8}$ of an inch, 4 feet $9\frac{3}{8}$ inches being the mean of the movement. Sighted on arrival at Bombay before hatches were opened, 4 feet $8\frac{7}{8}$ inches, but failed in taking observations on departing, owing to heavy rain. On arrival at Port Said, homeward bound, 4 feet $8\frac{5}{8}$ inches, holds full, tanks empty, and about 50 tons of coal in bunkers.

At sea a maximum difference of 2 inches was noted according to load and effect of the wave force; in a stiff head wind and sea, a maximum movement of $1\frac{1}{2}$ inch vertically, and $1\frac{3}{4}$ inch laterally, was observed.

Then with after ballast tank full (80 tons), midship tank (300 tons), and side bunkers (400 tons) empty, and holds full, a downward deflection of $\frac{3}{4}$ inch was noted at the stern of the steamer.

Working under these conditions of hull movement, a squeaking noise was heard in the tunnel, this was located in the after couplings, and on this noise increasing, the engines were stopped for examination, when it was found that the coupling bolts were loosened, and the nuts could be tightened up one and a half panes more or less.

On former occasions it was noted that the bolts had behaved in a similar manner, and for closer observation the nuts had been marked accurately on the bolts, and the bolts were alike marked on the shaft, so it was clearly evident that the bolts had elongated due to the strains set up through the vessel's movement.

After the bolts had been carefully refitted the trouble would cease for about three months. This steamer's hull was afterwards strengthened, and up to the present there has been no further complaint.

There are certain facts about which there can be no dispute and were anything wanting, to prove how difficult it is to get a perfectly rigid structure, consistent with an economical working vessel, we have only to instance the behaviour of wrought iron or steel land structures, which have the advantage of solid foundations and of stresses carefully calculated.

When such structures deflect when subjected to load, however well strutted, is it possible (without penalizing the cargo) that we shall ever attain to that perfection with a structure which has not, in its elementary stage, the advantage of any method whereby we can calculate the stresses, to meet the varying conditions of the wave forces, or of weights unevenly distributed throughout the hull ?

Probably more errors arise owing to the tendency to rely upon theoretical assumptions to the exclusion of practical facts, but were anything wanting to show how unreliable this is, as applied to this subject, we have the testimony of our most notable experts in marine architecture, who unanimously agree that it is impossible to determine with any accuracy the conditions affecting a vessel in a turbulent sea, and the results obtained from carefully conducted observations and experiments do not afford sufficient reliable data as a basis for future calculations.

So far the engineer has not interested himself in trying to obviate this evil, but has rather taken the position of an inactive spectator at the praiseworthy efforts of the architect. Doubtless we are all sound enough in the desire to see a better state of things, and it is as much a problem for the engineer as for the designer of the structure, for not on him chiefly as the expected solver of it, will the failure of a solution to the difficulty entirely fall. The most modern developments in marine architecture in the direction of structural strength are the results of past experience, and in the absence of any reliable method of calculating the unknown forces which act on a vessel at sea, great credit is due to the architect in considerably reducing a weakness, the existence of which has long been placed beyond a doubt. But the engineer has only grappled with the difficulty in a half-hearted and blind manner, adopting methods which are in direct contradiction to an acknowledged estimate of his inventive and resourceful faculties. Irrespective of his calculations, his margins of safety, his excess over requirements, he has not the courage of his convictions, but must needs remedy the evil by substituting (in many cases) the broken parts with others of increased weight and strength, oft-times leading to the development of the evil in some other quarter.

The writer has a distinct recollection of an experience he met with which fully illustrates this fact, and which he believes is not peculiar to this vessel alone. The failures covered a period of two years, and occurred in a steamer of the tramp class, which had some structural additions made on deck, and the evil originated in the couplings of the tunnel shafting, which gave continual trouble through coupling bolts breaking.

These were repeatedly replaced with good fitting bolts of increased sectional area, necessitated by the re-riming of the holes, and the trouble continuing, mild steel ones were fitted, resulting in the failure of three shafts, one after the other, viz:—one length of tunnel shafting, one thrust and one crank shaft, and in the order named; on every occasion of a renewal, the shafting was of a larger section and the whole was carefully lined up. The vessel was subsequently sold to foreign owners, and her behaviour afterwards not noted.

Although no observations were taken at the time, it was generally believed that the frequency of the mishaps could only be attributed to structural weakness.

The question of dealing with such an important subject in a manner creditable to both engineer and architect, is a task, the difficulty of which is universally recognised, but it is necessary that every phase of it should be carefully studied, and it comes within the province of the engineer to tackle it, and give proof of his resourcefulness and ingenuity by the introduction of intermediary appliances which will minimise the stresses and strains set up by the varying conditions of the hull. Flexible couplings or the fitting of stiff springs underneath the tunnel blocks have been suggested as an arrangement which would effect this purpose and would enable the shafting to harmonise with the hull's movement. Both fittings have been tried and their value as auxiliaries have been tested, and have given satisfaction.

The objection to the more general adoption of the coupling is that it is both cumbersome and complex, and the general opinion is that it is not applicable in its present form to that portion of the marine engine which is not immediately under the engineer's eye, and which he therefore desires as much as possible to keep free from any complicated fittings. In the present state of our knowledge it is not safe to prophesy whether this fitting will ever be sufficiently perfected as to justify its adoption.

But there is no obstacle to the more extensive application of the spring arrangement underneath tunnel blocks. It has been found a most simple and efficient fitting in steel steamers which were troubled with their shafting, and the balance in its favour, as compared with the flexible coupling, should recommend it to our first consideration.

By earnest application it is possible to surmount this difficulty. The progressive spirit which animated the breasts of workers in the past is as keen in the present age, and we feel sanguine that sooner or later an appliance will be evolved which, despite the vessel's movement, will conform to it and afford us almost immunity from accident and therefore greater security.

DISCUSSION

HELD AT

58, ROMFORD ROAD, STRATFORD,

MONDAY, MARCH 25TH, 1895.

CHAIRMAN:

MR. J. F. FLANNERY, J.P.

The CHAIRMAN: I do not quite know the exact custom of these meetings, because I am not so regular an attendant here as I should like to be; but if it be not out of place, perhaps while some of the other members are collecting their thoughts, I may say a few words upon the subject of the paper. It seems to me to be a very thoughtful paper, dealing with a matter which frequently troubles us in steamship practice, while it affords us the widest possible field for scientific research. The title of the paper is "The Structural Weakness of Steamers," but I think that the author might also have entitled it "The Elasticity of Steamers," because we know perfectly well that it is impossible to build a steamship which, longitudinally, should be perfectly rigid; nor would it be desirable, or in any way practical or good, if you could attain to such a vessel. The elasticity of the structure of the ship, particularly when it is fastened by rivetted joints, must necessarily exist. I remember being engaged some years ago in an arbitration case, which turned upon a point that the author has mentioned in his paper, viz., the fact that, although the disc on the side of the vessel amidships may be submerged, it does not necessarily follow that the vessel had more cargo in her than had been expected. This case was that of a vessel engaged in carrying iron ore between Bilbao and Cardiff. She was a steel vessel, built in the early days of steel. The owners said that the vessel, which was guaranteed to carry a certain weight, was not up to the guarantee, and the builders replied, "Perhaps not, but the reason is that you put all your weight amidships. You cause the vessel to sag, the bow and the stern turn up, and when the disc amidships is submerged your draft marks are representing something considerably less than the draft amidships, and in that way we lose an inch and a half, which is about equal to the weight of cargo you say you are short of." Well, we took sights in much the same way as the author of the paper has described, and instead of the vessel, under the most trying circumstances, in still water, sagging an inch and a half, we found that she sagged but five-eighths of an inch. That showed, to my mind, that in still water the elasticity of a vessel like this is certainly capable of observation, and that it does exist, and perhaps to the advantage of the vessel. I think that every one of us, in our practical experience, will remember some instances of injury, though I do not suppose that many of us have been quite so unfortunate in this respect as the author of the paper and his friends, whose experiences he records. The author speaks of broken coupling bolts and shafts, cracked bed plates and columns, open butts and loose rivets, 'tween decks contorted so that the feet of hold stanchions were broken adrift, and 'tween decks hatch coamings so twisted that the hatches would not fit. That is a very severe category, and I do hope that there are not many ships which combine so many defects. I remember that a learned professor at the Victoria University at Manchester once proposed, in all seriousness, that the tunnel shafting should be carried in a sort of carriage suspended from girders, which were to extend the full length of the tunnel. These girders were to be hung at each end, and they were to be fixed rigid, and to be quite independent of any movement of the vessel longitudinally, and at the same time carry the bearings in a true line. Well, we all know that that would never do, and we also know that the flexible couplings which the author speaks of would never do either. There is one small point in my experience which is worth mentioning, just to illustrate the amount of elasticity in a tunnel shaft of considerable length. According to Lloyds rules, when the stern bush is down $\frac{5}{16}$ or $\frac{3}{8}$ of an inch, it is required to be lined up, yet we have found that in ships like large oil steamers, where the engines are right aft, and which, of course, have a much less length of shafting than when the machinery is about amidships, we could not safely run them with more wear on the stern bush than about $\frac{3}{16}$ in. That illustrates the fact of the elasticity of the long shafting, and also that a long length of shafting does yield a great deal. There is always a tendency on the part of every steamer when afloat to hog, because the midship section of the vessel has necessarily a greater displacement than its own weight, and the two ends of the vessel have necessarily less displacement than their own weight. If you could cut a ship into ten or twelve sections, leaving each section to float as it would, you would find that the midship section would rise to a higher level than its ordinary water line, while the two ends would sink to a lower level, and somewhere between the midship section and each end would be found the part of the ship that would float at the ordinary level. The effect of that consideration is that all vessels necessarily have a tendency to hog, and recent improvements in the structure of vessels, particularly steel vessels, have been mainly in the direction of giving increased rigidity fore and aft. With regard to a large number of vessels that I have been acquainted with, it has been necessary when repeating them to add to their longitudinal strength; but I have never yet found an instance of transverse strength in an ordinary commercial vessel being lacking. There was one vessel in the Port of London which showed a travel of fully $\frac{3}{16}$ of an inch at the engine room bulkhead when loaded, as compared with her condition when light. Her engine room bulkhead happened to coincide with a break of some 4 feet 6 inches. She was a large single decked vessel, of a type which was begun to be built on the North-East Coast some eight or nine years ago. But now we have found out how to strengthen such vessels, and so prevent any such strainings in the way of the breaks fore and aft. I would just say, with reference to the remarks in the paper about this question of lining-up shafting, that it is the custom now in a great many good yards not to put in the tunnel shafting, or, at any rate, not to line it up until after the vessel is launched. That is a practical recognition of the fact that a vessel changes in form to some extent when she gets afloat; and, personally, I prefer that the lining-up should not take place until after the vessel is launched. I should also like to say a word or two in recognition of the very careful manner in which the experiments at sea, referred to by the author, appear to have been carried out. It seems to me that those experiments teach us a good deal, and they are quite consistent with my own observations, so far as they have gone, although I have never had quite the same opportunities in this respect as the author of this paper has had. But so far as my observations of vessels in still water have gone, I quite recognise that these figures are probably entirely correct, and they certainly yield us good lessons. I think this paper is worthy of very close scrutiny at our hands. It is a thoroughly practical paper, and it opens up, as I have said, the widest field for scientific observation and discussion. I, therefore, hope that we shall have a very full discussion among the members present. As I see no one is inclined to begin, I will call upon our Secretary, Mr. Adamson, to open the discussion.

Mr. JAMES ADAMSON (Hon Secretary) : I think we shall all agree with the chairman as to the care that Mr. McCallum has taken in the preparation of this paper, and our thanks are due to him for the way in which he has brought the subject before us. It is very much to his regret and disappointment that he has been prevented by illness from being present with us. The paper itself will require to be read over paragraph by paragraph to get the full value of it under discussion, and possibly at our next meeting the discussion will be more free and full than it can be to-night. On page 7 the author refers to the shipowners, and states that the shipowner has no control whatever over the state of matters which is complained of. Now, I think that the shipowner has the matter very largely in his own hands. The craze for cheap steamers, and for large carrying steamers of the utmost lightness, has reached such a pitch that each shipbuilder is doing his utmost to outvie his brother shipbuilders in cutting down weight, so as to give greater space and carrying capacity per registered ton, and that, I am afraid, is one of the causes of the troubles which Mr. McCallum mentions. Personally, I cannot say that I have had much experience of the evils referred to, but it is well known among us that most ships differ in the bearings according to the way in which they are loaded. On one voyage it is found that No. 1 tunnel block requires special attention; on the next voyage, with a different distribution of cargo, No. 1 block may probably give no trouble whatever, special attention being required by No. 2 or No. 3. There is no doubt that vessels do vary according to the stowage of the cargo, but not, in my experience, to the extent represented by Mr. McCallum. I know of one steamer which gave some trouble on her first voyage with the tunnel shafting, from the thrust to the propeller shaft. It was most difficult, however, to say wherein the trouble originated. I have been inclined to think that the shafting had not been properly lined up in the first instance, due, possibly, to the ship altering her shape after launching. The experience on the first voyage was that the engineers spent more time in the tunnel than in the engine room, and the oil cans and the hose were very freely used. At the end of the voyage the white metal had gone from the lower blocks, and the shafting had ground into the cast iron. The collar on the tunnel end of the propeller shaft, when the ship left on the voyage, was close up to the block, but at the end of the voyage it was about $\frac{7}{8}$ of an inch open, showing something like a shortening of the shafting or a lengthening of the ship. At the end of the first voyage the tunnel blocks were refiled with white metal and the shafting re-adjusted. On the second voyage no trouble whatever was experienced, and all has gone well and without trouble since—covering a period of seven years. Had the troubles experienced on the first voyage been due to structural weakness in the ship, the difficulty would not have been obviated by the readjustment of the shafting and change of oil for lubricating the bearings, although this no doubt helped. The matter at the time excited a good deal of discussion, but it was extremely difficult to locate the exact cause of the trouble. That is simply a case showing that a vessel may give trouble in her shafting, which might have been set down to structural weakness in the ship, whereas no alteration was made in the vessel in the way of strengthening or otherwise, yet no trouble has been experienced with her since. I might cite another steamer, in which, when loaded with a general cargo of evenly distributed weight, no trouble whatever is experienced with the shafting. In the event of the ship being loaded in certain parts with heavy material, trouble is experienced on account of two or three bearings running warm and requiring extra attention, nothing more, and the trouble has not been very great. In another case, I have seen the upper part of the structure of the ship alter. Sights were taken very carefully, and these seemed to show that the ship was hogged on the upper deck. The sights were taken along the casing, and showed a deflection of $\frac{3}{8}$ of an inch, yet the ship or her machinery had never given any trouble, and she is still running. With reference to the breaking of shafting, one of our members has had the intention of writing a paper on this subject, and possibly the interest in it will be intensified after this paper by Mr. McCallum. In looking up the records of shafts broken at sea, I was astonished at the number. I will not anticipate what will be brought forward, no doubt, in due course, but close at present in the hope that the discussion will be continued heartily on the subject-matter of the present paper.

The CHAIRMAN: With regard to the case of the first steamer referred to by Mr. Adamson, does he not think that the trouble may have been due to the vessel having altered her set permanently, so that the shafting had to be altered to follow it, rather than that the shafting was not lined up true in the first instance?

Mr. ADAMSON: Something had evidently altered between the first and second voyages, or possibly after the vessel left the ways. I cannot say whether or not the shafting was put in before or after launching.

The CHAIRMAN: I mean that it may have been, not that the shafting was necessarily out of line on the first voyage, but that the vessel may have altered her set.

Mr. ADAMSON: I wished merely to illustrate this, that if the trouble on the first voyage was due to structural weakness the difficulty would have continued on succeeding voyages, and this has not been the case.

Mr. T. F. AUKLAND (Hon. Member): I am afraid that I cannot speak professionally on this subject, but I think that the author of this paper really deserves our very warmest thanks for having taken so much trouble in compiling the paper. There is very little doubt, I think, that Mr. Adamson has hit the right nail on the head in saying that a great deal of this trouble is probably due to ships the owners of which require to have the lightest structures carrying the largest amount of cargo. That is, unfortunately, a great fault at the present day. People find that the old ships built years ago do not pay now. I remember a sailing ship being in dry dock when one-third of the strengthening was said to have been taken out of her, and even then she was left with more strength than Lloyd's require now. That shows the kind of ship built years ago, and I doubt very much if these troubles were experienced then. It is necessary, at the present day, to give the largest amount of carrying power for a given weight, and in order to do that, shipbuilders put into vessels the least amount of material they possibly can, the consequence being, especially with steel so largely employed, that there is this liability for shafts and other parts to alter their relative positions and give trouble. There is no doubt that iron is much more rigid than steel, and in steel ships you must add something to give the required rigidity. It will not do to have steel entirely. You may have steel plates with iron frames in order to ensure greater rigidity, but if ships are properly designed and thoroughly well built I do not think that many of these difficulties will arise. Of course, I am speaking rather against the profession in what I have said, because the tendency at the present time undoubtedly is to have the largest carrying power possible for a given weight.

Mr. F. W. SHOREY (Member of Council): I have not given this subject any attention, but I may say I have certainly been at sea when I have had coupling bolts break. Yet it was the last of my thoughts to attribute it to weakness in the construction of the ship. I think the author has rather overdrawn the case, when he attributes broken shafts, and all these other troubles, almost solely to structural weakness in the ship. The great fault that we find, as engineers, is that engine builders are cut down very fine in price. Engines are almost thrown into the vessel, and we get trouble with a new pair of engines because they are out of line, or there is bad material. Many things may account for the breaking of shafts or coupling bolts. I remember one vessel in which the coupling bolts were frequently breaking. When we came to make an examination we found that the shaft was down, and when it was properly lined up we experienced no further difficulty. On page 9 the author, speaking of a vessel, says: "She was well built and of a superior class, engines triple and well balanced, both hull and machinery being constructed by first-class builders. On the second voyage one shaft broke, and within two years four lengths of shafting were either broken or condemned, the material in every case showing itself solid at the fractures and of the best quality." Now, I think that that clause is the strongest proof which the author gives us, in support of his view, throughout the paper. Doubtless in that case it was through the weakness of the vessel. I always understood that if you wanted a vessel to travel well you had to build her light, and that a vessel lightly constructed would travel much better than if constructed rigidly. We are going in now for speed as well as carrying power, and in designing for strength are you not defeating one purpose for the sake of the other? Is it not a fact that we can have a vessel too rigid? We should be burning more coal, the cost of the machinery would be greater, and the question would be how all that would compare with the cost of a broken shaft now and again. If a vessel is properly constructed —and we have now naval architects who have had great experience—should it not be possible for them to build a vessel strong enough so that we should not have these breakages, and at the same time provide a vessel which would travel through the water in the way we should expect—a vessel not too light or too heavy? I cannot think that all these cases of breakdown mentioned in the paper can be attributed solely to the weakness of the vessels. As I said, I have not given this subject my attention, but I do not think that springs underneath the tunnel bearings would ever do, because we want something that we can depend upon—

a good pair of engines and a good ship. I think that most of these instances of engines breaking down are through the fault of the engine builder in the first place. The engines are thrown into the ship; they are out of line, and made as cheaply as possible.

Mr. J. MILNE (Member): I will just make an observation as to the difference between the ships being built now and those built twenty years ago. I have seen a ship which is little more than a large tank, and very different to the old fashioned ships, which had plenty of material in them, being structurally strong, while the tank one is structurally very weak. The plates are light and the scantlings are light, and, of course, allow a larger amount of room in the ship. I think it will lead eventually to the breaking of the shafts, which, I think, generally arises from the structural weakness and the working of the vessels. I have known of a case where a line, with a weight attached, and marked with the distance from the upper deck, has been found to show a working of quite half-an-inch. Though the shafting had not broken, the working of that vessel would probably develop defects somewhere, because the machinery happens to be stronger than the ship and you have a flexible ship; you have machinery that ought to be rigid, and every departure from that rigidity must show an effect upon the working of the machinery. I think it would be very much better, and give the engines a much better chance, if ships were made more rigid than they are at the present time. Of course, a ship must pay, but if a shaft breaks the shipowner has to pay in the long run.

The CHAIRMAN: I am afraid it is the underwriter who pays for broken shafts.

The CHAIRMAN: I fancy that this discussion will initiate something that we shall be very glad to listen to. With regard to some of the observations that have been made in the course of the discussion, I would just like to say that the lightness of construction which has been referred to as a sort of evil on the part of the greedy shipbuilder is not necessarily a reproach. If skilfully attained it is rather an element of praise, because it is our duty as engineers to produce the best possible ship with the least possible amount of material. It is our duty to carry out that principle in the hull of the ship, in the engines, and in the boilers—to use the least amount of material that will do the work. But, then, the question comes in, if we use too little material to do the work effectively we are carrying our attempted improvement too far, and from the experience given during this meeting I think there is no doubt that in the early stages of the transition to steel ships we did carry that improvement a little further than was justified at the time. We have since gained experience, and the net result is that we can now build ships considerably lighter in proportion to the dead weight carried than we could ever build them before, and I believe that discussions such as this are of the greatest advantage in giving instances of practical experience which others are benefited by. There was one vessel that I had to do with which showed a good deal of working on the upper deck. We just put in, fore and aft, intercostal girders between the deck beams, held in by angle irons. I suppose about ten tons in weight was added altogether in a ship carrying a total of 4,000 tons. This ten tons of weight, just placed in the position where it was required, in the upper deck amidships, was quite sufficient to stop that straining and working; and although the vessel is now six years old we have never had the least trouble with her since. That is an illustration of how important it is to know just the weak spot, and to put your strengthening just at the place where it is required. We now adjourn this discussion until this night fortnight, and if all your discussions are as practical and as useful as that of to-night I am sure that this Institute will go on and prosper to the fullest possible extent.

Mr. ELMSLIE proposed a vote of thanks to Mr. McCallum, the author of the paper.

Mr. MILNE seconded the motion, which was carried unanimously.

Mr. AUKLAND: Before we part, I think we should also accord our chairman a vote of thanks for coming here to-night. I am sure we have all listened to him with very great pleasure indeed. From his great practical experience as a naval architect, and from the fact that he has built so many steamers, all that he says is very valuable, and I propose that our best thanks be tendered to Mr. Flannery for presiding over this meeting.

Mr. JAMES ADAMSON: I have much pleasure in seconding that vote of thanks, and, with regard to the adjourned discussion a fortnight hence, I hope that we shall have Mr. Flannery occupying the same position then as he has occupied to-night. I also hope that our friend Mr. McCallum will be able to come up from Cardiff on the next occasion to take part in the discussion. As it is owing to illness that he is unable to be with us to-night, I am quite certain that we all join in wishing him speedy and complete recovery.

ADJOURNED DISCUSSION

HELD AT

58 ROMFORD ROAD, STRATFORD,

ON MONDAY, APRIL 8TH, 1895.

CHAIRMAN:

MR. J. FORTESCUE FLANNERY, J.P.

The CHAIRMAN: Gentlemen,—I do not think I can open this meeting better than by announcing to you that our Past President, Dr. White, is going on exceedingly well after the operation that has been performed upon him. Sir William White is so beloved by his brethren, both in the Royal Navy and in the mercantile marine, that I am sure that announcement will give pleasure to every one. There is naturally some little anxiety still remaining after such a severe operation as he has undergone; but there is every reason to hope that he will very shortly be restored to us all, and he will nowhere receive a more hearty welcome on his return to work in renewed health than from the Institute of Marine Engineers. We are met to-night to continue the discussion upon the very excellent and thoughtful paper that was read at our last meeting. I have myself not many remarks to make, but such as I may be able to offer will perhaps come better by way of conclusion at the close of the discussion. I will therefore throw the discussion open to the meeting.

The HONORARY SECRETARY: The following letter dated April 7, 1895, I have received from Mr. T. F. Aukland (Hon. Member), bearing on the subject before us:—"I am very sorry that I cannot be with you to-morrow night as I am going away from town for a day or two. I hope you will have a good continuation of the discussion upon Mr. McCallum's good and interesting paper, though I am afraid that I still hold the opinion that if steamers were all constructed with due regard to the weight they were intended to carry such difficulties would very seldom if ever arise. But the great craze for producing a money-earning machine in these desperately competitive days, in which freights are driven down to the very lowest ebb conceivable, induces builders and owners to combine together in trying experiments how they can construct the vessel which will earn a maximum of freight coupled with a minimum of cost, both in original construction and atter maintenance. The underwriters have to pay the piper when casualties arise which originally they never undertook to run the risk of, simply because they were in blissful ignorance of the experiments which were being tried. Of course, there is abundant truth in the chairman's remark that the lighter structure may possibly be made capable of doing a good amount of serviceable work, provided that very special attention is paid to strengthening the most vital points where strains are most likely to be set up, and no doubt experience does tend to information in this direction. But when you have done all this, you have still in all probability only got a boat which is just equal to the requirements under fair conditions, and with no surplus of power for emergencies in meeting with very bad weather. Then again these modern tramps with their slight construction are not built for one kind of work only, but they have to accommodate themselves to cargoes of all kinds and to all seas. We know that a steamer with a reasonable cargo might travel fairly well eastward, while with ore, grain or phosphate across the Atlantic, especially in the winter, she might tell a very different tale."

Mr. J. H. Thomson (Chairman of Council): I was unable to attend the last meeting when this paper was read, but while reading it the idea of flexible couplings occurred to me; however, I find on page 14 that Mr. McCallum refers to this way of getting over the difficulty. I can easily understand that in the old days, when ships were only about the length of the present screw shafting, the change in the shape of vessels was not noticed so much, so that the necessity for a flexible coupling is more recognised now than it was formerly. In thinking over this coupling, I bethought me that a friend of mine connected with the Darlington Forge had devoted considerable attention to a similar kind of thing. I therefore wrote to him, and he has sent some circulars, one of which I have placed on the table; there is also a model of the arrangement which may be examined, however, the diagram gives a very good idea of the coupling.

The idea of springs underneath the tunnel blocks has also been suggested, and this is the first time that I have heard of them. There may be gentlemen present who have heard of them before, but they are new to me. I am afraid they will hardly give universal satisfaction.

I think the only thing I have got to say about the matter is this—I only bring this coupling before you, and perhaps some one here may be able to improve upon it. With reference to the universal coupling, I may say that I was on the Tyne, I think, in 1875, when I saw a little vessel called the *Camel*, built, I believe, by Messrs. Harland and Wolff of Belfast, to bring machinery from the Clyde to Belfast, and, when I saw it, was being employed by the contractors to take machinery from the Tyne to be put on board ships at Chatham. This little steamer was fitted with one of those lowering screws and universal coupling—the same as the *Britannic*. At that time it had been at work for three or four years, and the wear upon the coupling was scarcely perceptible. The wear and tear was so little during the four years that there was no necessity to readjust the bearings at all. The drawback to these flexible couplings is the amount of space they occupy. They are so cumbersome.

Mr. ELMSLIE (Member) : Judging by the experiences that have been given by the various speakers, and the reference made by the Honorary Secretary the other night as to the large number of shafts that had broken in twelve months, I think we may come to the conclusion that there must be a want of stiffness or longitudinal strength to account for this. I am inclined, therefore, to agree to a considerable extent with the writer whose letter has just been read by the Honorary Secretary. I think the difficulty is caused by endeavouring to get too large a dead-weight carrying capacity on given dimensions. I think this is shown by the fact that the block co-efficient has in some cases been stated to be as high as ·82. For the sake of sea-going qualities I consider ·7 high enough, certainly not more than ·75. It has been stated by one or two of the speakers that they had found it desirable to bore out the stern tube after the ship was launched. If the ship is built on a perfectly solid foundation, and proper care is taken to keep her form of sufficient strength and correct during building, I do not think there should be any trouble with boring out the stern tube. If, on the other hand, the foundation is not solid, and the ground of the yard generally soft, if care is not taken, a constant change of form will go on during the building, and a certain amount of change will take place after the ship is afloat. As an illustration that some foundations are yielding, I may mention that a few years back, when two cruisers were built for the Admiralty by one of the largest shipbuilding firms on the Clyde, it was pointed out to the overseers that in laying the blocks it was necessary to provide for the yielding nature of the ground, more particularly at the lower end of the ship. To do this, having taken a straight line for the top of the blocks, at the stern post they raised the top of the after block half an inch above this line, and tapered this off to nothing at 40 feet from the back of the stern post. It was found during the building that the after end was gradually dropping. The ship was also found to come down slightly in the middle, and when completed it was found that the fore foot of the ship practically remained in its original position, and that the stern post had not only come down the half inch originally given to it, but half an inch in addition, and that the keel was perfectly straight from heel of stern post to fore foot of stem. There can be little doubt as to the correctness of this, as it was mentioned two or three years ago at the Institution of Naval Architects by one of the Admiralty overseers who had charge of these ships while building. From this it is easy to understand that if the ground is not sound, and care is not taken, a great deal of alteration in form may take place during the building, particularly with the class of ships under discussion. I am inclined to think that if the longitudinal system of building, recommended by Mr. Scott Russell many years ago, were followed, a considerable gain in longitudinal strength and stiffness would result. It has, so far as the ship is concerned, everything to recommend it, for there can be no doubt of its great structural advantages, but it requires more care and skill in the building, and there may therefore be the objection of increased expense. Probably the bottom of the ships referred to are strong enough, and such want of strength as there is, may be at the top.

Mr. McEachran (Member): I think the whole thing lays in the construction of the ship and the strength put into it. If a shipowner wants a good strong ship to stand all sorts of work, the strength must be put into the plates, and there will be no deflection then. There is one great mistake which I think shipbuilders make in the building of ships, although perhaps they are obliged to do it owing to the rules of the Board of Trade. I consider that they put the strength of the ship in the wrong place. I know a firm of shipbuilders in this country who tried to make an alteration in this matter but were not allowed. I also know that in order to build a ship on the principles they advocated they went to another country, and I know further that that ship has been very successful. A ship sitting in the water may be regarded as a beam, and, unfortunately perhaps for the ship, her machinery is nearly all in the centre. If she is a powerful ship she requires a large amount of space for bunkers, and when the bunkers are getting empty that part of the ship is inclined to rise. The whole of the cargo is in the extreme ends of the beam, and if the upper part of the beam is not sufficiently strong to carry that weight it must give out. That is where I think our shipbuilders fail to a great extent. One of the speakers said something about the ships being too deep or too narrow, but I do not think that that has anything to do with it if you give the ship sufficient strength. The upper row of plates is where the strength is required, and until such times as shipowners determine to strengthen the upper parts of ships we shall have to suffer these troubles. It always has occurred and it will occur probably. This is a matter that has come under my own notice in the course of my experience. I consider that the upper plates in all ships ought to be a great deal heavier than they are, and the shipowner would then obtain a very much stronger vessel. It would not be necessary to interfere with the construction of any other part of the ship. Take the case of a vessel supported on a wave, if that ship is going to give way at all it must give way at the upper part of the beam first, and if the upper part of the beam is made of sufficient strength you will have no trouble.

Mr. H. C. WILSON (Member): I am rather at a disadvantage to-night, not having read the paper, and not having been at the last meeting I do not know what has been said on the subject. But according to what I have been able to gather, it appears to me that the author is asking for some ideas to overcome these troubles which are known to exist, and he asks the question whether it is a fact that ships do work in a sea way. I think there can be very little doubt about that, and any one who has been at sea for a few months must very soon have found that out. I have been at sea in ships that worked a good deal. No doubt the great fault is that ships are improperly laid in the first place, and in the second place they are not altogether strong enough for the work they have to do owing to the competition in the price of building. At the same time I do not think that it is possible to construct a ship which will not work more or less in a sea way. Naval architects endeavour to construct a fabric that shall be perfectly rigid, and the engineer constructs machinery that requires rigidity for its proper working. But so long as ships are built with engines and boilers amidships, or nearly so, and consequently requiring a considerable length of tunnel shafting, there will always be trouble or breakdowns of this shafting owing to the unavoidable working of the hull. The only direction open to engineers to overcome, or at all events to mitigate, this defect is, to effect a compromise between the rigidity of the shafting and the want of it in the hull. One method may be the introduction of flexible couplings such as that now before us, but a great disadvantage is, that there is an additional amount of gear to be overhauled and looked after, and further than that, these things might work a little too much occasionally. I agree with Mr. McCallum that the use of flexible couplings is not desirable, at all events for large powers. The use of suitable springs as suggested certainly seems a step in the right direction although only as a compromise. A good way out of the difficulty would be to eliminate the long tunnel shafting altogether, and place the engines and boilers right aft in the run of the ship. The prevailing arrangement of having engines amidships, outside the reasons for facility of trimming ship and making her movements easier in a seaway, is necessitated by the amount of space required for engines, boilers, and bunkers. But the engines can be greatly reduced in size, the boilers made far smaller and more powerful, and the bunkers entirely done away with, if liquid fuel is used. Let tanks be constructed along the bottom of the ship to do the duty of bunkers, and when each tank becomes empty it can be run up with water to preserve the sea trim of the ship. The injurious strains set up in a ship having her engines aft, say, when pitching, have, I think, been exaggerated, and the advantages to be gained not sufficiently recognised.

The CHAIRMAN: In inviting further discussion, I may say I am sure there is no engineer present but who can tell us something that is useful, and however short he may be in telling it, I am certain it will be appreciated by every one in the room.

Mr. H. C. WILSON: There is a sentence here, which I certainly do not think is quite in accordance with facts. On page 13, Mr. McCallum says: "So far, the engineer has not interested himself in trying to obviate this evil, but has rather taken the part of an inactive spectator at the praiseworthy efforts of the architect." I do not think that Mr. McCallum is correct in that statement, because there is scarcely a sea-going engineer who has any regard for the good working of his engines, who does not do something to get over the difficulties which arise in connection with the working of the machinery. I think that by far the majority of sea-going engineers, those who at any rate are worthy of their name, do something with their engines under different conditions of loading, to get over the difficulties which present themselves. For instance, I was in one ship in which, under certain conditions, we used to slacken everything, and under other conditions we had to tighten up. In my opinion that sentence which I have read is not quite right.

Mr. J. MURPHY (Member): I am not prepared to say anything of moment, and may not succeed in enlightening anyone, but I can furnish a few extracts from past experience which may have some bearing on this important subject. It was recommended by one of the speakers that steamers generally should have stouter upper strake plates, and I am in favour of this, especially in long vessels of small proportional beam. These upper strake plates should be at least as wide as at present, but stouter according to the ship's dimensions and the work likely to be expected from her. Another speaker was of opinion that strengthening might be indulged in to such an extent that at last it would be next to impossible to move such a vessel without a proportional increase of power applied; and with this I quite agree. I have had experience in some of the lightest and heaviest of vessels, and it has often occurred to me, that just as there is such diversity of opinion about the structure of steamers and the effect that any change of shape in a vessel might be expected to exercise on the working of the propelling machinery, so I think there is plenty of room for the improvement in the classing of merchant steamers, according to their dimensions, design and the sort of work intended for them when first built, apart from the question of cost price. For how can anyone reconcile these facts: I may belong to one ship of a certain size or dimensions, class, &c., and she is considered in every way perfect, but, on some future occasion I am appointed by another firm to a similar vessel, having exactly the same sort of work to do in the same trade, the only difference being in cabin fittings, &c., and I find this one a better sea boat than the other, through being much lighter, but as leaky as a sieve in anything like ordinary rough weather at sea.

One cannot, of course, always expect the same lines in two similar ships by different builders, but we ought to get the same seaworthiness and reliability, and then there would be no room for one member to recommend stouter or more substantial shear-strakes, or for me to suggest them in all cases where a vessel was inclined to spring or yield about the waist, or between the engine-room bulkheads, and so, perhaps, influence the centre line of shafting detrimentally. I would not only be in favour of stouter upper strake plates for about $\frac{2}{3}$rds. or $\frac{3}{4}$ths. of such ship's length, but also of more substantial waterways throughout, and in the event of there being only a wooden deck or decks fitted, there might be an iron or steel deck run across from waterway to waterway, and extending in a fore and aft line at least the distance between the engine room bulkheads. This iron deck should be well riveted to the deck beams under the wooden deck and across the bulkheads. This arrangement, I consider, would tie a vessel well across, and in a fore and aft direction in this important part of a steamer's length and width. It would also obviate the necessity of fitting awkward and cumbersome girder beams, as at present, across the engine and boiler rooms, very often in the worst possible places, whether of use or not, so long as they conform with somebody's conflicting rules. Certainly a great deal could be said about the structural weakness of some steamers now afloat, and reasons given why this is so. But that necessarily would require elaborate and extensive treatment, especially when considering and laying bare the influences such weak vessels have on the propelling machinery. Now, as far as my experience goes, extending back for about thirty years, I consider that the rigidity of shafting is desirable in every way, with the object of maintaining the centre line throughout, under all circumstances. To help this, at least in the tunnel shafting, instead of having the stools pitched off about 20 ft. apart as at present, I would do away with these stools and introduce one long box work, substantially built in off the ship's flooring below the tunnel, and longitudinally between the bulkheads.

This would not only be something better for the shafting generally, by resisting local strains and stresses that are apt to arise in bad weather, but it would also help to stiffen the centre line at this important part of the vessel. Instead of reducing the number of bearing blocks, I would reduce the lengths of shafting, have one bearing in the centre between the couplings, and as these shorter lengths with more frequent supports would have less sagg or spring in them than as at present, so with the assistance of the longitudinal box work or kelson, I am sure there would be more reliability throughout. Of course, if flexibility of shafting were desirable, then we might as well have some sort of indiarubber support at once.

Mr. J. R. RUTHVEN (Member of Council): The only thing that strikes me in regard to this paper is that it is not so much a question of the ship altering in shape as it is a question of the limits within which the engines will run safely. Mr. McCallum gives an instance where in a length of 112 feet of shafting there was a maximum variation of two inches. I think it would be a good thing if some of our members would test for themselves whether that is an excessive variation. I think that it is, and that most shafts will not vary more than half an inch in 100 feet. If that is the case, Mr. McCallum has been rather unfortunate in picking up a bad one. It has also occurred to me that there is no reference here to any coupling of the nature of the old paddle wheel coupling. There was an arrangement there to allow for a considerable variation, but I fancy this is quite an excessive movement. Yet there is no doubt that there is a movement in every ship, and I think it would be very interesting if we could have correct data as to the exact amount of it. It is a point on which every one who has the opportunity should make observations and record them, because it is only by that means that we can arrive at any definite way of curing the evil.

Mr. F. W. SHOREY (Member of Council): I must agree with the author when he states that a ship works to a certain extent, and tail-end shafts and also coupling bolts may, I admit, be broken by the working of the ship. But there is one part of the paper where he speaks of crank shafts being broken in this way, and when we come to consider the bed plates as rigid as they can possibly be made, then the columns, and the cylinders bolted on top, to what extent, I would ask, would a ship have to work so as to break a crank shaft? I confess I cannot understand a crank shaft breaking from this cause. Again, the author says on page 8, "What we aim and look for in the marine engine is to get a rigid and smooth working machine," but on page 15 he advocates an arrangement of springs underneath the tunnel bearings; to my mind, he simply contradicts himself, because you cannot have a thing rigid and springing at the same time. The only idea the author puts forward in this paper to correct the trouble is with regard to these springs underneath the tunnel blocks. I do not think there are many of us here who would venture to say that a vessel does not deflect more or less when loading, some more than others, but I think we must leave the remedy to the art of the naval architect. We look after the boilers and engines, and have pretty well enough to do. We now have ships filled with machinery—more powerful engines, electric lighting machinery, refrigerating machinery—and we are getting more to look after every day. I do not therefore think that many marine engineers, who are going to sea, have given this particular question very much attention, or care to go into this matter about the structural weakness of ships as discussed in the paper. Doubtless it is a good thing to be acquainted with such things, so as to be able to suggest some means of overcoming the evils pointed out, but it appears to me that Mr. Wilson's remarks are more to the point—his arguments for putting the engines aft. You then have less shafting to spring, for the longer the shafting the more it feels the movement of the vessel, the more bearings to get hot and the more couplings to break. I did not, however, come here to-night prepared to put forward any idea on the subject, but only to listen.

MR. R. T. THORNTON (Member): With regard to the longitudinal weakness of steamers, a case in point came under my notice in a steamer that I was in about fifteen months ago. We were loading a cargo of iron ore in the Greek Islands when the ship sagged 2½ inches in the centre; that is to say, she was down to her Plimsoll mark midship when she really required another 2½ inches to be down to her mean loading depth, according to the figures on the stem and stern. This ship was the usual short well type of modern steamer, lifting about 3,500 tons, and about 386 feet long. On the occcasion I refer to the ship was loaded in Nos. 2 and 3 holds and trimmed by Nos. 1 and 4 holds. But on the next occasion the ship was partly loaded in Nos. 2 and 3 holds, then Nos. 1 and 4, and trimmed with Nos. 2 and 3; on that occasion the difference was 2 inches. Under different conditions of loading I found that sometimes one bearing and sometimes another would give us trouble by warming, and sometimes we had to slacken them back. The deck plates in the bridge deck would buckle quite an inch in some places, especially just before the bridge. In a seaway you could see the plates buckle and straighten again, and quite a report followed when the plates rose. One that had a ventilator on it was very noticeable, and this was the first to attract my attention on account of the noise it made. The deck beams in the bridge were 4 feet apart where buckled, but in the lower deck only 2 feet apart. I may also mention that, on the first occasion I referred to, the holds were loaded, as nearly as I remember, as follows: No. 2 hold, 1,200 tons; No. 3, 1,000; No. 1, 500; and No. 4, 600. These figures may not be quite accurate, but they are near enough for the purpose. I got them from the captain at the time, as we were discussing the matter. On the next occasion he loaded about 800 tons in No. 2 hold, and 800 tons in No. 3; proceeding to No. 1 hold he put in about 500 tons, then to No. 4 about 600 tons were stowed, and ultimately trimmed with Nos. 2 and 3 holds. This, I consider, is a better way of loading than putting in the full quantity into Nos. 2 and 3 holds at first.

Mr. JOHNSTON (Member): With reference to the observations of Mr. Wilson, I would like to disabuse the minds of any present who might entertain the idea that placing the engines aft is the best thing. I do not speak from personal experience, but from information which I can depend upon. In the large oil steamers which have their engines aft there is nothing but the skin of the ship between the engines and the water outside, and the vibration I have been told is considerable. It is not so long ago that a well-equipped ship was lost through this vibration. The water came in, but they could not find out where the leak was, and she simply went down. The name of this ship was the *Bear Creek.* The engineers of these oil steamers say that the vibration is very great. I think this vibration ought to be avoided, and that the centre of the ship is the best place for the machinery.

Mr. JAMES ADAMSON (Hon. Sec.): Reference was made to-night at the beginning of the discussion to a case which I cited at our last meeting, and I am sorry that I cannot give exactly the conditions under which the shafting of that steamer was lined up. It was suggested by one of the speakers that shafting sometimes gives trouble because it is lined up before the vessel is launched, and the ship changes its form after entering the water. I think that possibly the trouble in the case I referred to was due to an alteration in the form of the ship after the shafting was lined up, whether the shafting was lined up before or after she was launched I am unable to say. There are many steamers that are launched with engines all complete and steam up, and in cases like that it would be very interesting to know how the machinery behaves afterwards, and to trace the history of the steamers that are so launched. Mr. McCallum refers to deflection while loading, and Mr. Elmslie has called attention to deflection while a ship is building. Mr. Thornton's illustration shows us that deflection does take place according to the nature of the cargo and the way it is stowed, and in your remarks at the last meeting, Mr. Chairman, you referred to a similar case which was the subject of an arbitration. Then there is deflection at sea. Mr. McCallum gives us a very remarkable case where the shafting had deflected two inches. At our last meeting I held that the shipowner has more control over the matter than Mr. McCallum lays down, inasmuch as the craze for light ships has been going on until it has got to such a pitch that we are getting lighter ships with lighter scantlings every year. That is a matter which is to a certain extent in the shipowner's control, although desirable enough within limits. Mr. Shorey at our last meeting referred to the way in which engines and machinery are put into steamers, say, by piece work, and possibly a good many of the breakages of shafting are due to this cause and not to structural defects in the ship itself. I hope, as I said at the last meeting, that on a future occasion we shall have a paper on broken shaftings. I hoped that the member who is preparing that paper would have been here to-night so as to indicate in what direction he is working. I think that Mr. Wilson has rather misapprehended Mr. McCallum's meaning when he says in the paper that the engineer has not interested himself in trying to obviate the evil referred to. What Mr. McCallum means, I think, is that the engine builder has not represented in strong enough terms the imperative necessity of having the structure of the ship designed and stiffened with due regard to the machinery. Mr. McCallum then refers to the lining up of shafting in port. I do not know whether any members present have had any experience in that matter—whether they have observed that the shafting does alter after it has been lined up due to an alteration in the form of the ship in the process of loading. Reference was also made at the last meeting to different tunnel blocks heating according to the character of the cargo and the manner in which it is stowed. Experiences were given showing that ships which presumably are structurally strong do alter, and alter sufficiently, at any rate, to heat up some of the tunnel bearings, although giving no further trouble than to require a little more attention during the voyage, this, however, I apprehend is not of material moment. I think that Mr. Johnston's remarks are very apropos of what was said by Mr. Wilson. I can quite understand the vibration being very great owing to the engines being so far aft.

Mr. H. C. WILSON : I must admit the truth of Mr. Adamson's reading of this paragraph to which I called attention on page 13. I think that my misapprehension is owing to a great extent to the fact that I had not read the paper through When I read it through carefully I shall see more clearly what he means. With regard to the remarks of Mr. Johnston about the vibration of ships having their engines aft, I must say that I cannot agree with him. My experience is that there is much less vibration in such ships, both in hull and machinery, than when the engines are placed amidships. I do not refer to tank steamers, as I do not consider that one has been yet built which is worthy of the name, inasmuch as they are all, or nearly all compromises, and I can quite understand them vibrating But I have found general cargo boats with engines aft to be far smoother running in heavy weather, and there is no trouble with tunnel bearings, because, as a rule, there are none. This position of the machinery may not be the best when tested by the laws of dynamics, but there are many ships of this type at work which never broke a tunnel shaft. I will admit that in a heavy seaway, ships with the engines aft are very lively, but we never had any trouble with the tunnel bearings for the very good and sufficient reason that we had none.

Mr. A. W. ANDERSON (Member): I have not read the paper, but I have listened to a few of Mr. Adamson's remarks, and I can corroborate what he says. Twenty years ago I was in a ship that used to bring the stern collar up against the bearing at sea, and the chief engineer wanted to get it altered in port. The assistant superintendent went down and found it clear $\frac{1}{8}$ of an inch, so he said he could not see why the chief engineer wanted it altered. There was a difference between them, and as they could not agree I was referred to, and told them they were both right. It was bearing up against the collar at sea, and $\frac{1}{8}$ of an inch clear in port. That showed that the ship worked at sea. I know that in many steamers they used to break a great number of shafts. There was nothing to account for it but light ships, and they were the best ships with sails that ever crossed the Atlantic. When they broke a shaft they used to sail ten or eleven knots, but they were light and they were always breaking shafts. In my opinion a great deal of the blame for broken shafts is attributable to weak ships.

Mr. SIMPSON (Member): I have never noticed a great deal of deflection in a vertical direction, but I have found considerable deflection at right angles to the longitudinal section of the ships. I think that there is a considerable amount of working transversely.

The CHAIRMAN: That is the first experience of the kind that has been mentioned throughout this discussion. We have had a great many instances related of vertical deflection, but we have never until now had any instance mentioned of lateral or thwartship movement, and it is very interesting to hear it.

Mr. SIMPSON: I have never known deck rivets to be slackened by the working of the ship, which would be the case if there was vertical deflection.

The CHAIRMAN: You are quite clear that the apparent lateral motion did not arise from the falling away of the plummer blocks from the shaft?

Mr. SIMPSON: Yes, quite clear.

Mr. ELMSLIE: One of the speakers said that he does not see that increased beam has anything to do with the matter. I think it has, for if you increase the beam and keep the length, draught, and dead-weight capacity the same, you reduce the block co-efficient, and thus get a better sea boat, a boat that will be far easier in a seaway, and therefore will not get the same amount of straining as a ship that makes bad weather, and, you increase the scantlings. A boat of ·82 block co-efficient is a near approach to a log, which is hardly an ideal model. Some speakers have mentioned a thwartship movement of the vessel. This I think unlikely, as the steel decks would, I should say, prevent this, but I do not think that the steel deck gives the longitudinal strength which is required. A cellular deck would give all that is wanted, and probably make a stronger arrangement than any other plan, but I doubt if any want of longitudinal strength has been found sufficient to warrant the expense. As the principal stress comes on the gunwale, probably the best plan would be to have some arrangement of box waterways. A great deal has been said about the working of these ships, but probably vibration is what is referred to. As to placing the engines at the ends of the ships, as recommended by Mr. Wilson, I am clearly of opinion that the middle of the ship is the proper place for them. The engine beams (or bearers) cannot, I think, be too strong, but they should be carried well beyond the engine and boiler spaces, and be so worked as to form the kelsons forward and aft of the engine and boiler spaces to avoid discontinuity of strength. Having mentioned the longitudinal system of building, I may add that, with the same weight of material, Mr. Scott Russell estimated the gain of longitudinal strength over the transverse system in the ratio of 5 to 4.

Mr. A. W. ANDERSON: I know a case of a steamer, engaged in the Atlantic trade, which was put in dry dock when all the tunnel shafting was taken out of her. The bearings, on being sighted, were found to be much out of line, the forward bearing no less than 4 inches low. We were so much surprised that it was thought possible the ship had changed her form upon the blocks. She was re-floated, and the bearings again sighted, but the ship did not alter her shape, as the same bearing was still 4 inches low.

Mr. McEachran: After all it is possible to make a set of engines too rigid in a ship. If you take into consideration the flexibility of the ships of the present day I think it would be unreasonable to try and make the engines and shafting too rigid. If the ships are flexible and give, I think we ought to have the engines give to a certain extent also. In many ships I believe there are too many tunnel shafting bearings—too many of them and far too little surface in each bearing. I consider that if the bearings were kept much further apart and each bearing made longer there would be a better tendency to give with the yield of the ship. Tunnel shafting will bend like anything else. A length of tunnel shafting of 100 feet and more, if you allow it room, will bend considerably, but if you support it every 20 feet it cannot "give," and you set up these strains. But if you increase the distance between those pedestals and increase the length of each bearing then there would not be the tendency to prevent the shafting from giving a little with the give of the ship. Make the same amount of bearing surface as at present but fewer blocks. I also agree that perhaps shafting suffers more from lateral motion than from fore and aft motion. As for universal joints and couplings of one sort or another I am a little doubtful about them. A big ship in a heavy seaway if she has these loose parts about her, will soon shake them looser. I do not believe in any universal joints for heavy shafting, as it is only a matter of time for them to cause you trouble. There is another thing that may tend to break shafting. If the shafting is a little bit out of line in the neighbourhood of the crank shaft and you follow it down to the first bearing too sharp. I have seen bearings get very hot and cause a lot of trouble because, in my opinion, the shaft was followed down too sharp with the upper brass. But as I have said, if you have a flexible ship and the ship gives, you ought to have your engines so that they will give with the ship to a certain extent, and that would allow the bearings to follow each other.

The Chairman: If there are no other remarks I will say a few words upon some of the points—all of them interesting—that have been brought out during the discussion. First of all, as to the letter of my good friend Mr. Auckland. Evidently Mr. Auckland is smarting under the sense of some recent average claim which he thinks ought not to have come out of the pockets of underwriters, but out of the pockets of some of the shipowners concerned. I would like to point out, however, that it is quite easy to blame shipbuilders and others connected with them for building ships too light, but if those of us who are concerned in designing ships and machinery simply went on in the beaten track, never attempting to make improvements, never seeking to make the same amount of material go further, we should have no advancement at all. At the present time we can point proudly to the fact that we, as marine engineers, have made more progress during the last half century than any other class of engineers who are concerned in making structures. I do not care whether you look among locomotive engineers, civil engineers, or engineers of any other kind, you find nowhere a greater amount of progress in construction and design than you find among marine engines and the ships that carry them. Why is that? It is because every time we build a ship or design an engine we are going on trying to do better than we have ever done before, and I for one should feel very sorry if the time should ever come when marine engineers would cease their efforts to improve as they go from ship to ship. It is only by improvements, and by continued attempts to improve that we can arrive at the perfection we have already attained, and the still greater perfection which I am sure lies before us; and I say that even these comparative evils and difficulties which have shown themselves in the construction of some ships are a necessary accompaniment of experiment and improvement. Now, as regards the question of the position of the machinery referred to by Mr. Wilson, and the experience that has been given of fitting the engines aft in tank steamers. I have myself had some experience of a special kind in that matter, and I quite concur with what several speakers have said that the placing of such enormous weight as large engines and boilers right aft in a vessel has the effect of increasing the vibration, and also the effect of causing very serious local straining in the structure of the hull in the after part of the vessel. When one of these steamers with the machinery aft pitches, the after part of the ship necessarily rises through a greater distance vertically than the centre of the vessel. This is, of course, the reason why the saloons of passenger steamers are now placed amidships, and the dynamic result of this heavy weight passing through such a large vertical height with the increased speed that necessarily arises from the extra distance travelled within the same limit of time, is to produce a shaking and an effect upon the whole structure of the ship very similar to the effect of a piece of lead tied to the end of a stick. And we have found that many vessels with their engines aft which have had the same amount of stringers and the same amount of fore and aft strength as other vessels, have shown serious straining, and even leakage at the after part. We have therefore been obliged to strengthen these vessels right aft. This has been the case with a considerable number of the tank steamers that have been built, and we have always attributed the necessity for this strengthening to the action that I have referred to. Some little difference of opinion has arisen among the members as to whether or not it is wise to place the engines aft, and so get rid of the tunnel bearings and the attention which has to be given to them. The great objection to placing the engines aft is the question of trim. You know that the engines are placed aft in tank steamers mainly for reasons of safety, so that the fires may be entirely removed from the neighbourhood of the petroleum carried. But it is perfectly well known that you can never trim such vessels with anything like the facility that you can trim vessels with the engines amidships. When you have the engines amidships the coal bunkers are as nearly as possible above the centre of buoyancy of the ship, and as the coal is burnt the vessel rises bodily without causing any large difference in the trim. But with the engines aft, as you burn the coal the vessel is lifted aft, and in the course of a voyage across the Atlantic the lifting amounts to two feet, and frequently to three feet from this cause, even when corrected by ballast. In order to correct that lifting, one has to provide very large water ballast tanks in the after part of the vessel, and as the bunkers are emptied these tanks have to be filled. Now that really means a reduction in cargo carried on any limit of arrival draught, corresponding to the weight of the water ballast that has to be put in during the latter part of the voyage. It is a means of correcting the evil of trim which is only effective to a limited extent, because many tank steamers do arrive very seriously by the stern. So that the great objection to having the engines aft, especially with engines which have to load and discharge parts of their cargoes at different ports, is the difficulty of trim. I remember 25 years ago it was a fashion to have the engines aft, but experience and practice have shown that for the practical purposes of seeking freight, and loading and discharging at different ports, the better and more convenient plan is to have the machinery amidships, notwithstanding the difficulties of construction that have been pointed out. Therefore, while we recognise the advantages arising from having the engines aft, I think we must also recognise that in practice the difficulties of trim, and so forth, would neutralise and quite overcome all those advantages. Just one word more upon the question of longitudinal strength. In the case of the tank steamers that have been referred to, the transverse bulkheads which are frequently seven and eight in number, are made to cut the ship transversely from skin to skin, and there is no perforation longitudinally through those bulkheads. The stringers come against each side of the bulkhead and are fastened by diagonals, and there are in the great majority of cases no stringers which continue through the bulkheads. The result has been that these vessels have been found lacking in the feature of longitudinal strength, and all the improvements that have been made of late have been in the direction of giving

I do not attribute all failures of shafting or machinery to structural weakness, as Mr. F. W. Shorey has remarked, but my contention is—that having a repetition of accidents, the cause of which is a mystery, the solution is rarely looked for in the elasticity of the structure, unless it be very pronounced; it is oftener attributed to bad material, workmanship and design, even when there is no evidence to prove it. And I contend that, when criticizing failures, it is as necessary to study and consider them from the one aspect as from the other.

The movement of hull is common to all classes of steamers, more or less; but it is understood that we are dealing more particularly with the tramp class, whose lighter structure and unfavourable conditions of loading render it more susceptible to this evil than the mail steamer.

Several members have accused the shipowner with having assisted in bringing about this condition of affairs in his demands for large cargo capacity, light draught, &c., but before criticizing his conduct, it would be as well for us to consider that he is not proficient in matters dealing with the design and construction of steamers, but delegates that duty to his engineering representative or naval architect, who is guided by the rules of the different registries—why, therefore, blame him more than they. Should not the classing of the vessel by a registry (often in excess of requirements) be a sufficient guarantee to him that he has a strong and capable vessel, and in cases of engine failures, has he not good cause (quoting from my paper) for criticizing a state of things he could not control, nor account for, and for which he was not in any way responsible? I am inclined to take the lenient view of the chairman, Mr. Flannery, in not blaming the shipowner, but would rather attribute it to a desire on the part of the naval architect to get the maximum amount of strength in his vessel with the minimum amount of weight.

Report has it, and our experieace has proved it, that the flexible structure gives the speediest and most sea-worthy vessel—consistent with good workmanship—and as Mr. F. W. Shorey has remarked: "We are going in for speed as well as carrying power, and in designing for strength are we not defeating one purpose for the sake of another."

Both Mr. Ruthven and Mr. Adamson are in error regarding the deflection of 2 inches; this does not represent the shaft's movement, but is the maximum amount of deflection noted through deck sights. The maximum amount of deflection of shaft observed in the tunnel is $1\frac{1}{4}$ inches and it does not follow that even this amount is constant, but only occurring at intervals.

The ordinary amount of deflection observed was from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch, and agrees very closely with theory, which, however, makes no allowance for bad weather strains.

The 2 inch deflectiou appears excessive, but all sights taken on deck probably indicate more than what is really occurring, and, therefore, must be accepted with reserve. The lateral movement tends to prove this unreliability and to indicate a bellows-like movement in the hulls and decks when hogging, and the deck structures present difficulties which prevent reliable observations being taken by means of standards resting on the keelson.

I have more faith in our engine builders than those who assert that in these days of keen competition engines are "thrown together." It is not reasonable to suppose, that any firm with a reputation will risk losing it by scamping this work, even to supply the accommodating engine and flexible shaft which Mr. McEachran advocates, and his suggestions that the tunnel blocks be spaced further apart to get the desired flexibility is a state of affairs to be avoided.

What we desire, is to retain the centre line of shafting true throughout, and, without sufficient supports, the weight of shaft and its centrifugal force would cause a deflection even in a rigid structure—an evil we are seeking to obviate and in contradiction to the suggestion; I have experience of an instance where the fitting of extra tunnel bearings stopped the shaft breaking, and if Mr. McEachran has any case to record in support of his argument it would tend to prove that what works well in one vessel will not do so in another.

The style of coupling mentioned by Mr. Ruthven, in an improved form, is fitted in several of the up-to-date paddle passenger steamers, and is indeed a very primitive one; and dates its origin back to a period anterior to the introduction of iron and steel in ship-building, when engines were fitted in wooden hulls of pronounced elasticity. This fitting, in screw steamers, was applied to the coupling connecting the crank and tunnel shafting, the diameter of coupling being in excess of the others to admit of the arrangement.

In one flange the coupling pins or coupling bolts were either screwed or tightly fitted, and, in the other flange, the holes corresponding to the bolts or pins were left large enough to ensure plenty of play.

The playfulness of this coupling was remarkable; now separating, now closing; open at the top to a marked extent and close at the bottom, and anon *vice versa* the lateral movement also being carried on with the same independence as the vertical one, and its heated ardour could only be cooled through the medium of a hose and a liberal allowance of tallow and oil.

It seems incredible in these days to think that such a fitting was deemed a necessary one in all Her Majesty's steam vessels.

In its modified and improved form it has proved an efficient fitting in paddle passenger steamers of recent build where it can be examined daily.

The faces of the coupling adjacent to the crank shaft are slightly convex, and have a stiff rubber ring inserted between them, and the coupling bolts are a tight fit in one flange and easy in the other, the nuts of the bolts being tightened up on spring washers. This fitting requires no lubrication, and answers admirably the purpose for which it was designed; but the engineer of the present day would hesitate to adopt it as an intermediary appliance in the long length of shafting found in screw steamers, where he is accustomed to look upon a loose coupling bolt as a precursor of evil.

I am fortunate in having seen the flexible coupling of the s.s. *Camel* mentioned by Mr. Thomson, which was the one I had in my mind when I referred to that style of fitting. It is still in the *Camel*, and after 25 years' service does good work, and it has been reported to me that the cost of upkeep has not been such as to occasion comment.

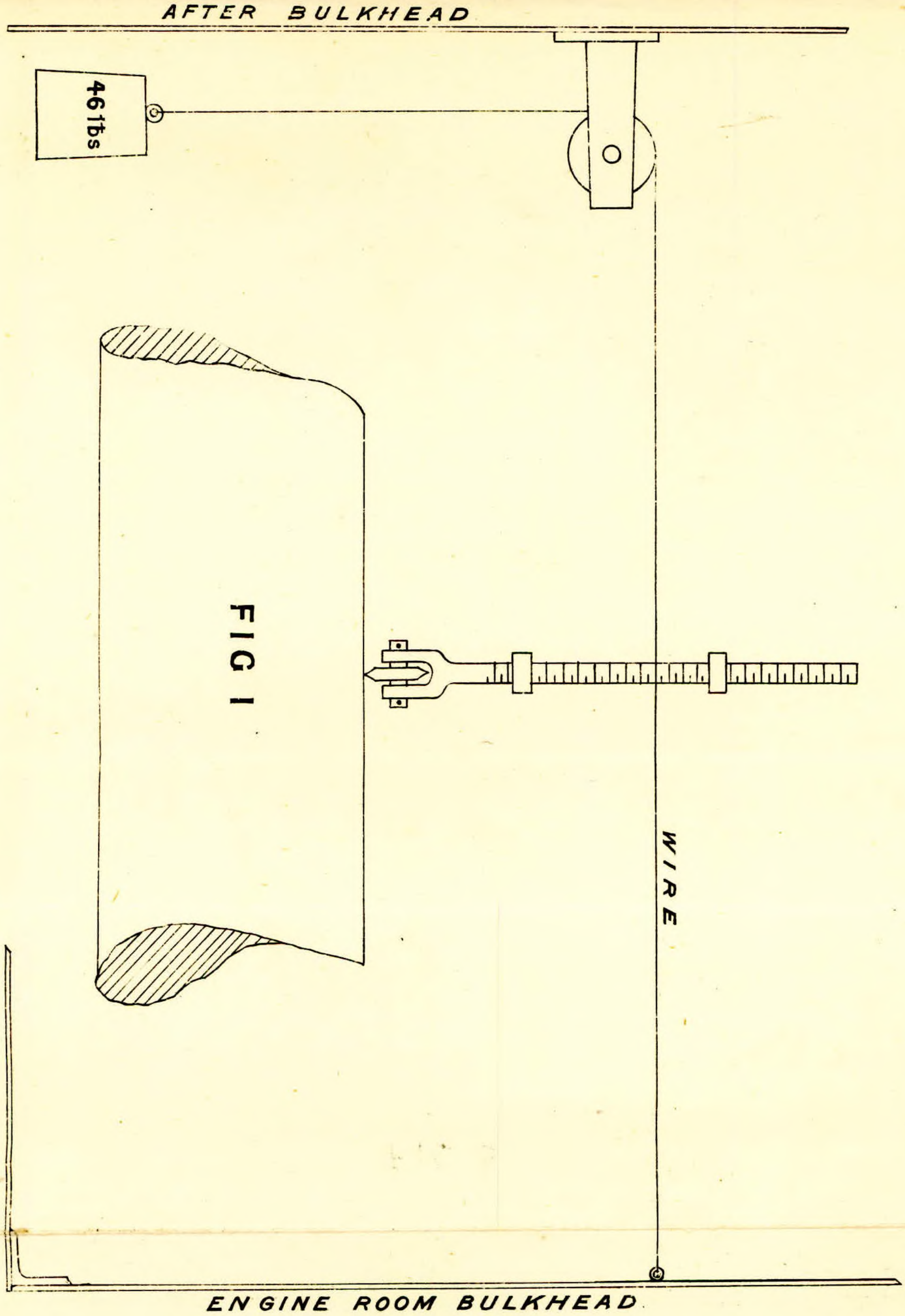
It forms part of an arrangement whereby the propeller can be lowered at sea and raised when in shallow waters, and was fitted as an experiment, prior to introducing it on the White Star liner *Britannic.*

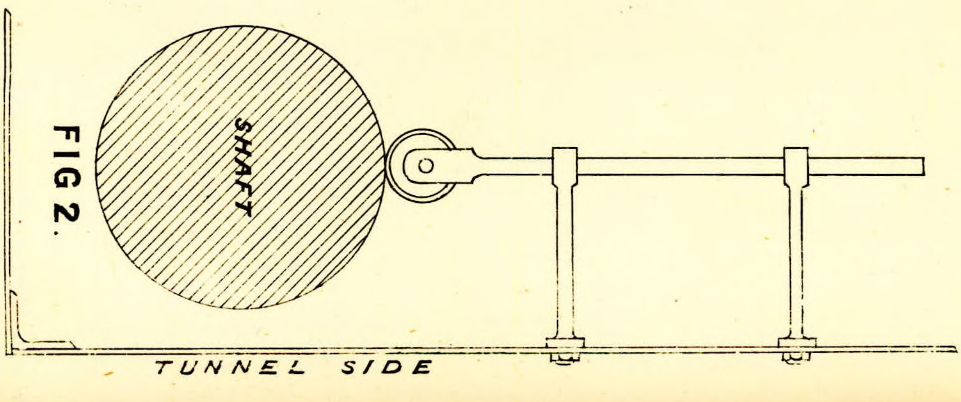
Although the arrangement was not a success on the *Britannic*, and had to be removed, the fact of its failure should not decide the fate of the coupling, as it was not solely on account of it that the arrangement was condemned, but rather on account of other complicated attachments; and again, its work in connection with this system of propeller lowering gear, would be much more severe than what it would undergo as an intermediary appliance, such as I have referred to, and I still am inclined to think that engineers have not interested themselves in studying and perfecting this fitting, which to my knowledge has never been applied in an improved form since its rejection on the *Britannic.*

Those gentlemen are at fault who credit me with suggesting the flexible coupling and the spring fitting underneath tunnel blocks. Both fittings, as I have stated in my paper, have been tried, the latter one most successfully, and, in referring to them, I only desired to indicate the direction I wished the discussion to take, and suggestions as to how best to strengthen the vessel was not what I looked for.

To judge whether the structure is weak, and to ascertain at what point it is so, is all guess work, before the vessel is at sea and encounters heavy weathers. And again, I have no knowledge of weakness in a vessel ever being detected before damage was done—a state of affairs we desire to anticipate and provide against.

No steamer is rigid, and it is impossible for the naval architect to make it so; but the engineer requires rigidity for the safe and efficient working of his engine. The engine base, owing to its contracted area, is not affected to the same extent as the long line of shafting, and any intermediary appliance or fitting which can be designed to minimise the danger of broken shafting, or which will assist in preserving the centre line of shafting true from after bearing to stern gland, in spite of the vessel's movement, deserves our serious consideration, and, in view of possible contingencies, such a fitting should be as necessary an adjunct to the marine engine as the shaft itself.


AFTER BULKHEAD
46 lbs
WIRE
ENGINE ROOM BULKHEAD
FIG I


SHAFT
TUNNEL SIDE
FIG 2.

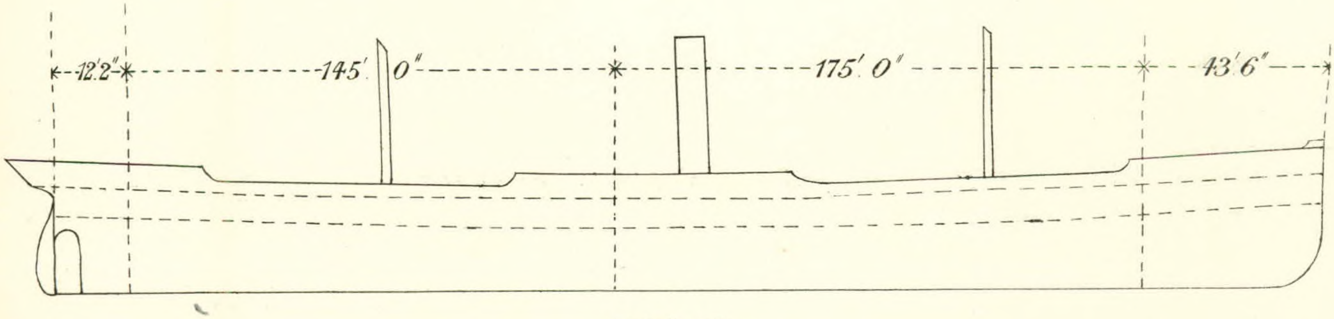


FIG 3.