INSTITUTE OF MARINE ENGINEERS
INCORPORATED.

Patron: HIS MAJESTY THE KING.

SESSION 1928.

President: SIR ALAN G. ANDERSON, K.B.E.

VOLUME XL.

The Effect of Type and Disposition of Machinery on the Strength of Ships.

BY T. R. THOMAS, B.SC., M.I.N.A.,

READ ON

Tuesday, January 10, *at* 6.30 *p.m.*

CHAIRMAN: A. E. LASLETT (Vice-President).

The CHAIRMAN: I wish to state first how very pleased I am to have this opportunity to come here to-night, and I thank you for asking me. In introducing Mr. Thomas I do not know whether he is as well known to you as he is to me. He has not been in London very long, but I feel that it is a great privilege to have a paper from one who has made his name at such an early age as Mr. Thomas has done. (I am sure he will forgive me for mentioning that fact). He has been appointed as Chief Surveyor of the British Corporation in London, and I am sure he will do honour to the position. I will not say anything on the paper at present, but will call upon Mr. Thomas directly to read his paper.

BEFORE considering the aspects of the subject which are outlined in the title of this brief paper it may be of interest to members of the Institute if some consideration is given to the general subject of the longitudinal strength of ships. The academic interest of calculations of both the longitudinal and transverse strength of ships is so great that naval architects often lose sight of the facts of practice, but the methods of estimating the bending moments to which a ship may be subjected when among waves have been a necessity ever since the days of the *Great Eastern*, when such advance was made in the length of sea-going vessels.

The attainment of economy in weight of structure can only be met by an efficient distribution of the material in the ship girder, and this efficient distribution in turn depends upon the correctness of our estimates of the stresses to which the structure of a ship would be subject in ordinary service. The calculations at present involved in an estimate of the bending moments likely to be met with among waves are very laborious, and after all the results are only of comparative value between ship and ship. It is well to remember this as the constant repetition of the statement that a vessel of a certain size is normally subject to a certain stress tends to make people think that the stress figure is a " known " stress. The stresses which have to be met by the structure of a normal ship under normal conditions of service resolve themselves broadly into two classes. The first and more important one is that of stresses induced by longitudinal bending moments and the second those induced on the transverse section of a ship. To some extent the stresses induced in the longitudinal and transverse directions are interdependent, but we are not in a position to say to what extent this is the case. In any event investigations of transverse strength depend on methods of calculation which are unreliable when applied to such a complicated structure as a ship. The present methods of assessment of the stress due to longitudinal bending are simpler and provided due regard is paid to their limitations and that the results are regarded as comparative they may be of considerable practical value as a guide to strength.

It may be useful to restate the assumptions upon which such calculations are based. The ship is considered as a beam, the support of which is provided by the buoyancy distributed in accordance with the trochoidal wave form. The length of wave on which the ship is supported is assumed to be equal to the length of the ship and of a standard height, equal to 1/20th of its length. In one condition the ship is assumed to have the crest of a wave in the bow and stern and in the other to have the crest of a wave amidships. It will be readily appreciated that in the first condition the ship approximates to a beam supported at the end and that it tends to sag in the centre, while in the second condition it resembles a beam having a support at the centre and that there is a tendency for the ends to drop. The first of these conditions is usually described as "sagging" and the second as "hogging." The load upon this beam at any point in the length of the ship is measured by the excess of the weight of the ship and its contents over the buoyancy at that particular point. Consequently the disposition of the weight in the ship has a very important bearing on the stress to which the structure may be subject. For instance, when the ship is in the sagging condition, the presence of large machinery weights in the midship portion may suffice to give rise to serious bending moments.

Modern development has been in the direction of concentrating the machinery weights in a small portion of the length of the ship and the advent of deep tanks of large capacity has combined to bring about a condition of affairs to which the naval architect has to give his consideration.

Before considering Figures 1 and 2, which illustrate this particular point, I should explain that the longitudinal strength of most ships now approximates to, and in the case of British Corporation ships has always had a definite relationship to, standard bending moments, which are expressed by 75 per cent. of the length squared, multiplied by the breadth and draught and divided by 35 squared. The experience of many years has shown that this has been a satisfactory guide for general practice where the distribution of weight throughout the ship is fairly uniform. In cases where there are large concentrations of weight amidships or at the ends it is obvious that the basis condition may be transgressed and in the examples given in Figures 1 and 2 (which are cases of ships in service to-day) consideration of the curves of weights draws attention to the fact that in what look to be normal conditions, there may be abrupt changes in the loads on the "beam." The conditions which obtained in the vessel illustrated in Figure 1 made it inevitable that the ship would suffer severe sagging moments when in ballast condition and required more than the usual standard of strength in the upper structure in order to avoid a condition of weakness, which is a constant source of irritation and expense to the owner.

The second example is of a ship which was loaded in such a manner as to cause damage to the structure. Excessive compression in the decks caused buckling of the deck plating, etc., and this is only one of several similar cases which suggest that those responsible for the handling of ships should know or be provided with knowledge of the limits which stress imposes

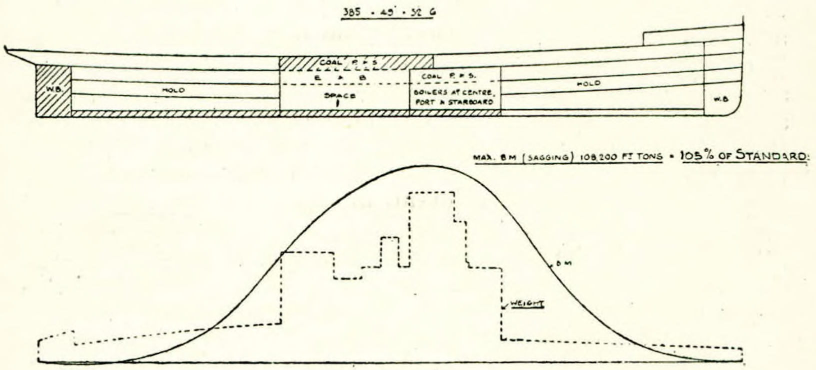

FIG 1.

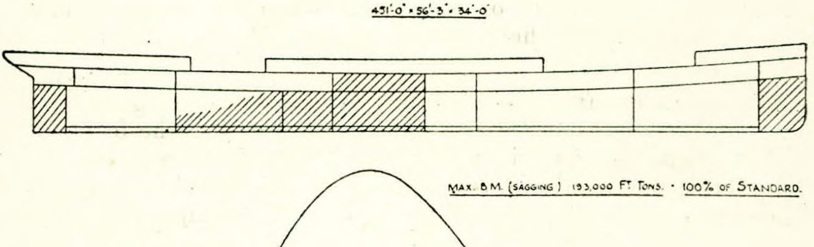

FIG 2.

upon permissible disposition of weights in the ship. In the ships illustrated in Figures 1 and 2 the condition which gives rise to the most serious stress is that of sagging. It may be well to draw attention here to the importance of the sagging condition in which the deck is subject to compressive and the bottom to tensile stress. The double bottom of the ordinary ship is well fitted to take compressive stress, because the tank top and shell plating are combined by the floors and intercostals into an effective pillar. The deck plating, however, while quite effective in tension, has a value in compression which is governed by its thickness in relation to the beam spacing. That is why the practical superintendent likes the ship with thick deck plating, and this factor in design is becoming more and more important because the average ship is passing and in many cases has passed from the long standing condition where hogging or tension stresses in the decks were much more important than compressive stresses.

While in the majority of cases, the machinery of a ship is placed amidships, there is an important class of ship in which it is placed at the after end, namely, in bulk oil carriers and, from the point of view of longitudinal strength, this type provides an interesting field for investigation.*

In the case of a bulk oil carrier or indeed any ship having the machinery aft, if in the ballast condition the weight of the machinery is balanced by water ballast carried in the fore part of the ship, the conditions of Figures 1 and 2 are reversed and the structure would be subjected to particularly severe hogging moments when the crest of the wave is amidships. In practice, however, experience has caused the operators of large bulk oil carriers to arrange distribution of the water ballast so as to avoid excessive hogging moments in ballast trim. There is, however, the less obvious fact that excessive weight of midship cargo often gives rise to serious sagging moments in loaded condition. To illustrate this, a reference to Figures 3 and 4 indicates the bending moments which may occur in the sagging condition.

Figure 3 is the bending moment diagram for a bulk oil carrier fully loaded, where the disposition of the weights is such as to avoid excessive bending moments in normal conditions of loading and the ships have proved very satisfactory in service. In Figure 4, the effect of greater concentration of the cargo amid-

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*The Longitudinal Strength of Bulk Oil Carrying Vessels, by T. R. Thomas and J. Turnbull, Trans. I.E.S., 1922-3.

ALL CARGO, FUEL & STORES ABOARD.

S.S. 425' × 56'-8" × 33'

FULL LOAD CONDITION.

MAX. B.M. (SAGGING)	140,200 F^{T} TONS
MAX S.F. (FOR^{D})	1260 TONS
DISPL^{MT}	14,180 TONS
DRAUGHT (MEAN.)	26'-1½" M^{LD}.

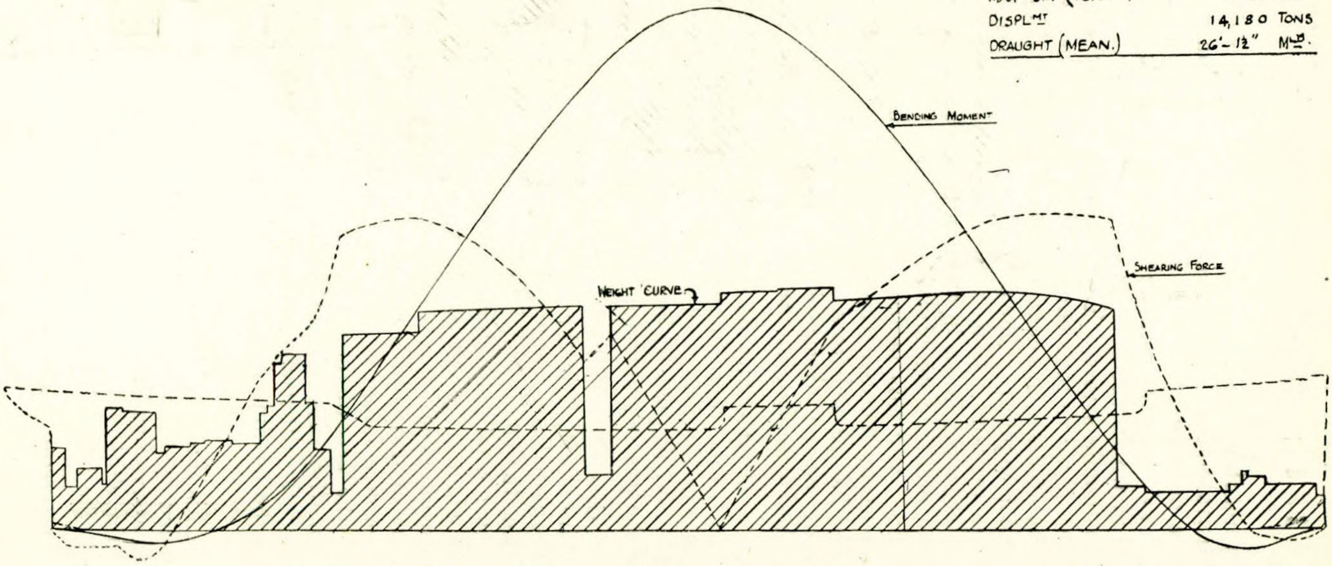


FIG 3.

S.S. 425' × 56'-8" × 33'-0."

MEAN HEIGHT OF CARGO RAISED 8 FT.

MAX. B.M. (SAGGING)	181,100 F^T TONS.
MAX. S.F. (FOR^D.)	1,830 F^T TONS.
DISPL^{MT}.	14,180 F^T TONS.
DRAUGHT (MEAN)	26'-1½". M^{LD}

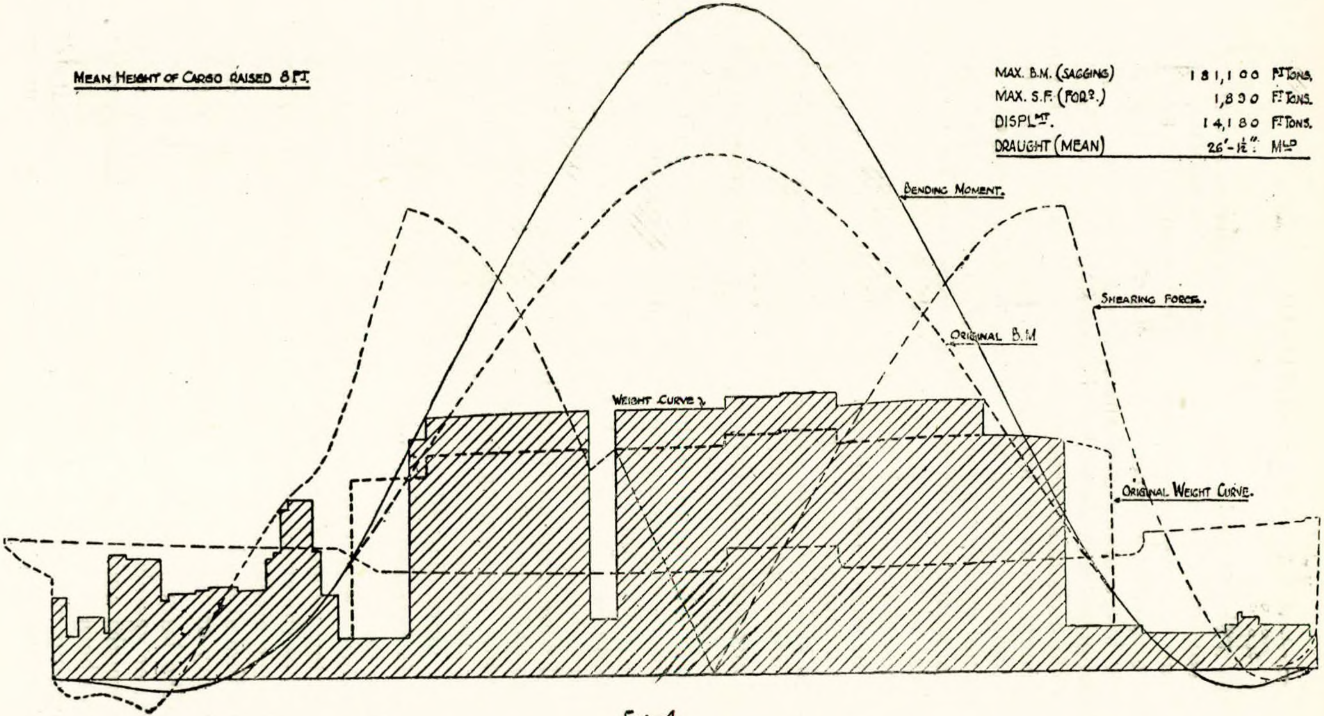


FIG 4.

ships is shown and certain cases which have occurred show that the condition illustrated is moderate in relation to what can be and is sometimes done. Danger usually arises from the desire to carry cargoes of high specific gravity and the consequent lengthening of the empty space forward. The consequent stresses often show themselves by means of local failures and the tensile stresses on the bottom may cause trouble with the connections of longitudinal material. This stress may become great enough to fracture the bottom plating so that it need not cause surprise if it be held accountable for the failure which sometimes occur in the connections of bottom longitudinal stiffeners. As it is obviously desirable for many reasons to place machinery at the after end of a ship, it follows that in such cases the cargo weight should be spread over as great a proportion of the length as possible where the weight of cargo amidships can so easily be made to outweigh the corresponding displacement.

A measure of the distribution of cargo over the length of the vessel can be obtained by considering the ratio of the mean depth of the cargo to the mean draught. This is a simple method of expressing the results of calculations and Figure 5 shows a diagram which has been prepared from which a rapid estimate may be made of the effect of different ratios of depth of cargo to draft. The calculations upon which this diagram is based were made on the assumption that the oil which fills the tanks had a specific gravity which corresponds to 40 cubic feet per ton. As sagging moments are the most important in such cases a reasonable standard for the value of C should be something more than 40.

It is interesting to note that placing the machinery amidships in the vessel referred to in Figures 3 and 4, reduces the sagging moment to about 40% of the above standard while the hogging moment becomes the maximum bending moment and reaches the standard value given at the beginning of the paper. Placing machinery amidships may not be so good as choosing a position at about the quarter length, but all may be made satisfactory or unsatisfactory by disposition of cargo weight.

The large machinery weights of modern high powered passenger vessels give rise to similar conditions of concentration of weight amidships, and it has been found that modern ships have become liable to sagging moments in excess of their major hogging moments. As such ships have a multiplicity of light superstructure they are peculiarly liable to suffer under com-

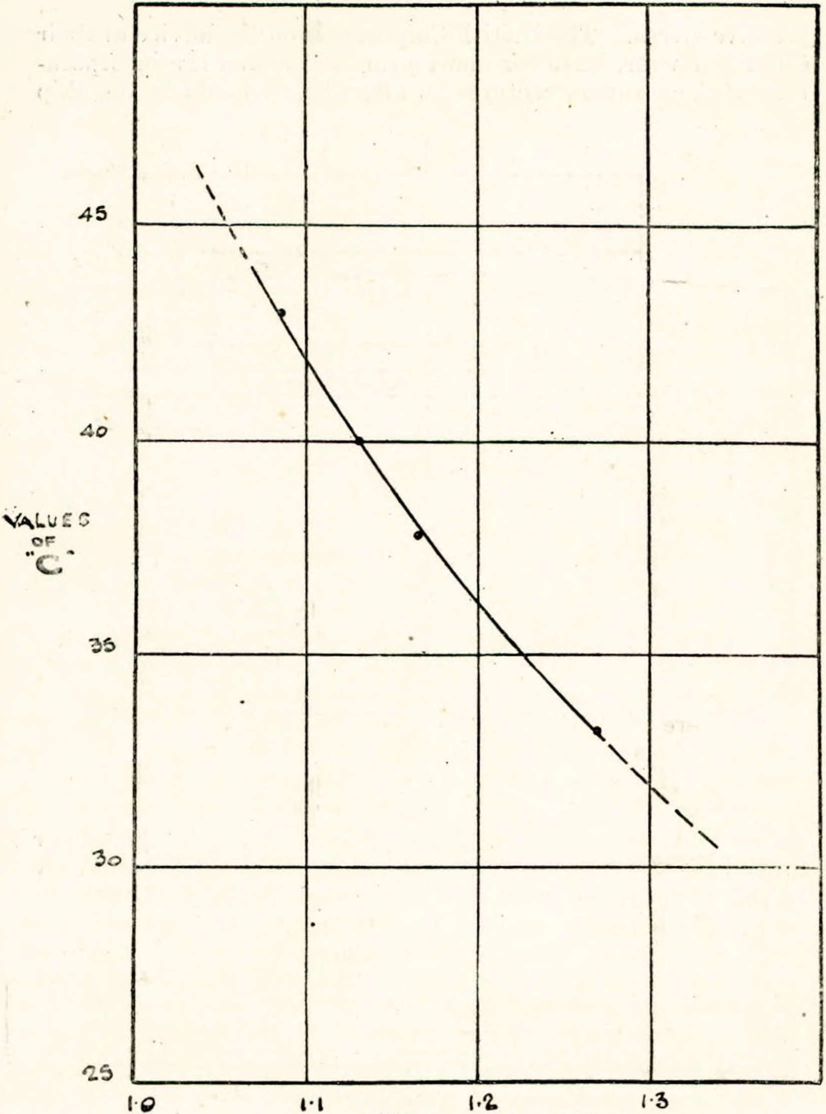

45
40
VALUES OF "C"
35
30
25
1·0
1·1
1·2
1·3
MEAN DEPTH OF CARGO
MEAN DRAUGHT

FIG 5.

pressive stress. The British Corporation on the advice of their Chief Surveyor, have for many years advocated the incorporation of such superstructures as effective elements in the ship girder. By thus increasing the effective depth of the girder high stress and consequent damage in light superstructures may be practically eliminated.

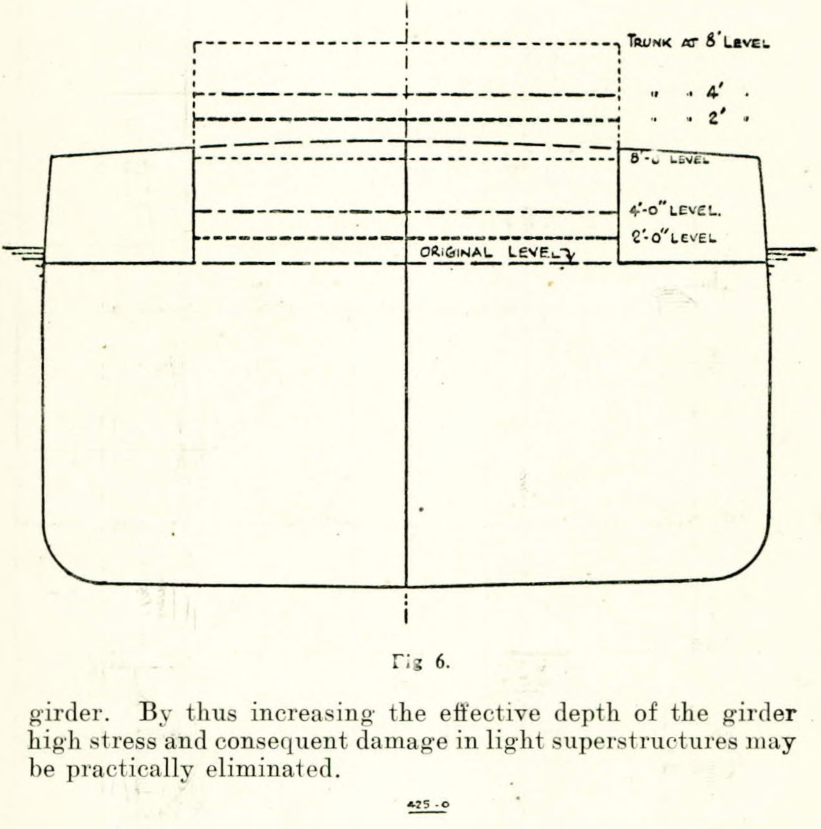


Fig 6.

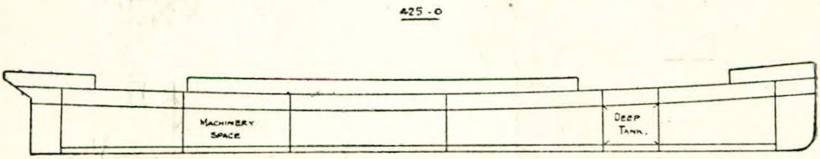


FIG. 7.

Figure 6 shows the outline profile of a ship which has been built to the order of a large firm of owners, in which the question of stresses induced by longitudinal bending can hardly arise. Here the machinery is placed at the quarter length aft and is balanced by a deep tank at about the corresponding position forward. I have not investigated the bending moments

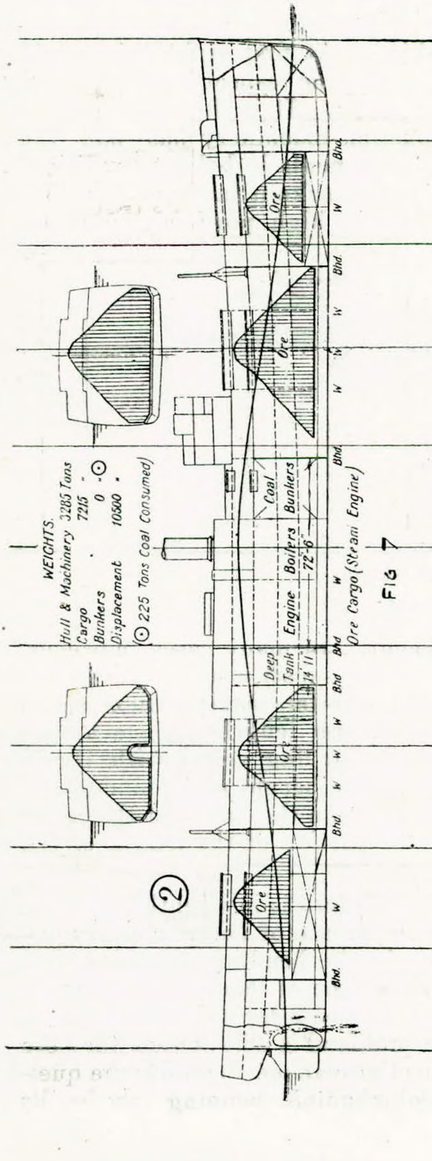
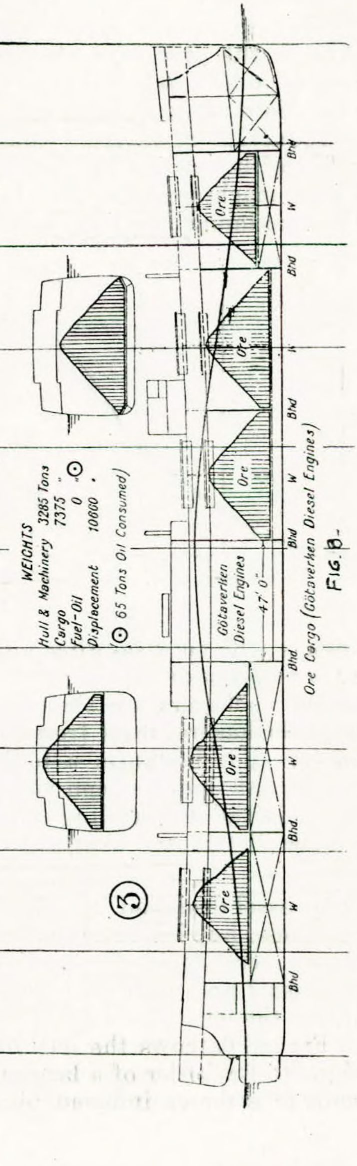


FIG 7

Ore Cargo (Steam Engine)

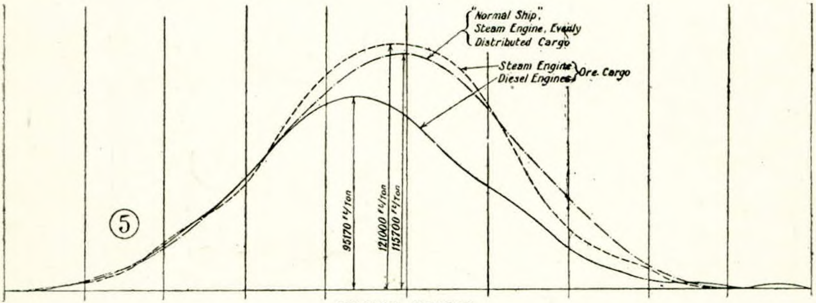


Ore Cargo (Götaverken Diesel Engines)

FIG. 8.

this ship is likely to meet when amongst waves, but they will obviously be small.

Passing to the introduction of Diesel machinery in place of steam machinery we are faced with the concentration of machinery weights in a smaller proportion of the length of the ship than is the case in a steamship. At first sight this would appear to be a disadvantage and in some respects similar to the conditions shown in Figures 1 and 2. It is the case that the introduction of internal combustion machinery has had the effect of increasing the bending moments in ballast condition. Diesel machinery has also tended to make it fairly certain that the maximum bending moments in high powered passenger vessels will be a sagging moment. In many cases, however, an investigation of the effect of the substitution of Diesel for steam machinery has shown that a better distribution of cargo weights has resulted from the shorter length of machinery space. For instance, a bulk oil carrying vessel with Diesel engines at the after end will reap the benefit of a reduction in the longitudinal bending moment, from the fact that the cargo can be distributed over a greater portion of the length of the ship.



BENDINC MOMENT

FIG 9

A vessel designed to carry ore cargoes is in slightly different category, but in particular cases the use of Diesel engines has shown very decided reductions in the bending moments, and Figures 7 and 8 illustrate a comparison of this sort. Figure 9 shows the comparative bending moments for the load arrangements indicated in Figures 7 and 8, and it will be seen that the ship fitted with steam engines is likely to meet conditions represented by bending moments of about 5 per cent. above the

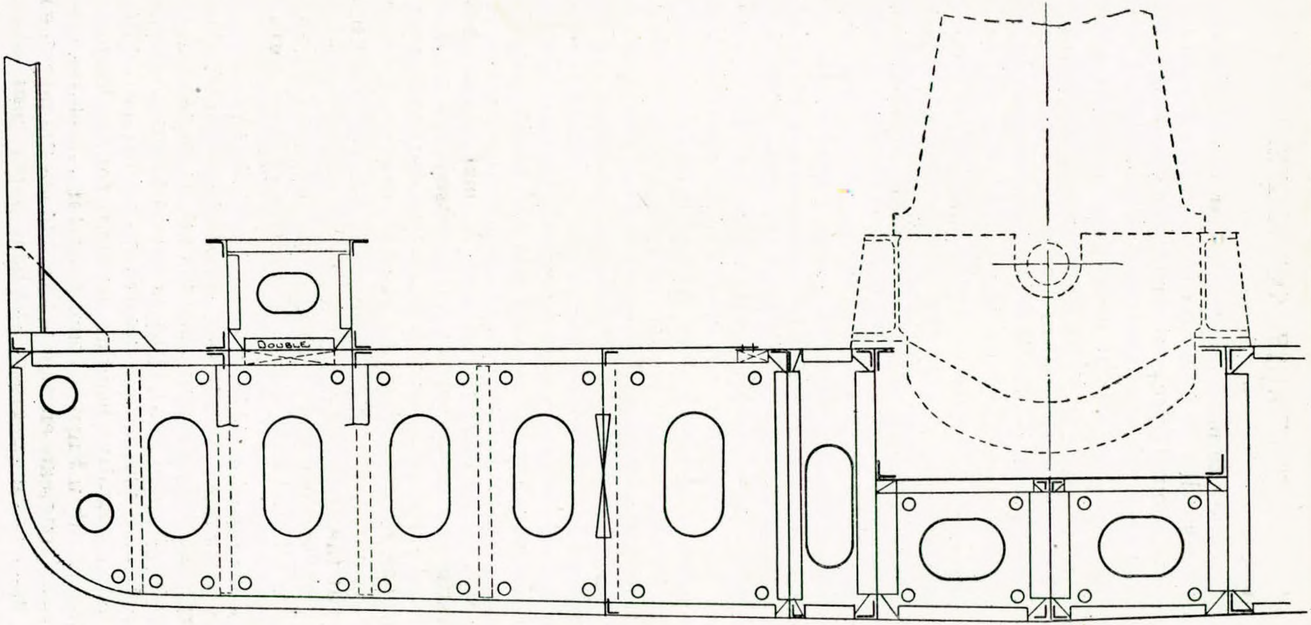


FIG. 10

standard, while the arrangement of the ore in the case of a Diesel engine ship is such that the comparative bending moment is reduced to about 17 per cent. below the standard. Although this is a particular case it illustrates the desirability of investigating the effects of weight disposition upon any ship where that disposition is not fairly uniform. In the foregoing remarks I have endeavoured to draw your attention to various classes of ships in which the bending moments may be expected to exceed the normal, because the weight dispositions are not normal, but it will be obvious that knowledge of the effects of the abnormal disposition upon each ship is necessary if bending moments are to be kept within the limits for which strength provision has been made. The advent of the Diesel engine has incidentally drawn attention to the necessity for providing sufficient local strength and stiffness under the engine, not only to resist the stresses induced by concentration of weight, but by the vibration set up by this type of engine. The outstanding difference between the Diesel engine and the steam engine from the structural point of view is found in the fact that for similar powers the width of the Diesel bed plate is much less, while the height of the engine is much greater. It is often erected on girder stools with a consequent magnification of faults which developed in the seatings of steam engines of a past generation. However, the matter of provision of a satisfactory seating for this type of machinery becomes simple when these essential faults are realised and past marine experience is applied. Figure 10 gives an indication of the manner in which this particular problem has recently been approached, and is based upon the probability that the simplest and most satisfactory way of dealing with a seating for Diesel machinery is to incorporate it in the hull structure.

The foregoing is a brief outline of one or two of the many problems which the naval architect has to face and which I hope will be of interest to those who are concerned with the handling of ships in service. It is impossible to make useful strength calculations for every ship, because in the first place the calculations are too long, and in the second place the calculator has no control over the actual disposition of weight in a cargo ship. He can never profess to calculate actual bending moments at sea, but it may become possible to devise some relationship between the strength of ships and their loading. This paper will have served its purpose if it awakens superintendents and others responsible for the loading of ships to the fact that much can be done to reduce stress and damage to the structure by careful adjustment of the disposition of weights carried in the ship.

DISCUSSION.

The Chairman: We have heard a very excellent paper dealing with a subject which is of vital importance to engineers, at least as much as to hull builders. Troubles with engine seatings are old troubles—we have had these always. Recently with the introduction of Diesel machinery we have had these troubles more pronouncedly. Some of those present may be able to discuss the matter from their practical experience.

Mr. W. E. McConnell: I rather think the silence which followed Mr. Thomas's remarks is due to his having taken us out of our depth. This is not a subject which we as engineers can discuss with any degree of confidence. In the first place I would like to say that the author has done one thing which badly wanted doing. He points out in the second paragraph that " the calculations at present involved in an estimate of the bending moments likely to be met with among waves are very laborious, and after all, the results are only of comparative value between ship and ship." I think we are all familiar with the papers published by academical people from time to time which present a jumble of figures showing a result as a definite, irrefutable mathematical conclusion. The author has pointed out that what we know of the structure of vessels is largely empirical. He points out that it is practical comparative data. We have progressed from small to large ships and we have to-day a large accumulation of data which is worth all the academical discussions that the world has seen.

Referring to the third paragraph, where the author has pointed out that a ship may be supported by waves at the end and in another condition by a wave at the centre, most of us who have been to sea know that that condition is frequently approximated to, especially in fast vessels. I can speak personally from experience in a Cunard ship, the *Umbria*, which was about 540ft. long—we saw that vessel's keel as far as her forward funnel. If you imagine a ship of that size and weight (about 12,500 tons) in which the whole of the fore part of the ship to the forward funnel is overhung, and when it strikes the water it does so at a velocity of 20 knots, it will be realised that the resulting stresses are enormous. The application of the comparative data which I have mentioned is of the very first importance. We have the experience of the unfortunate destroyers of the *Snake* class, which had not the strength to withstand the conditions.

The author refers to the ship which requires more than the usual standard of strength in the upper structure. I should be glad if he would expand that a little, as to the best method of applying that strength in the upper structure. Some people think it is better to have the addition to the side plating as a girder. Others think that the super-structure should be strengthened so as to act as a girder.

The author says that those responsible for the handling of ships should be provided with information as to the limits of stress which can be imposed on the strength of the ship. I think it is a notorious fact that the people who are primarily responsible for the handling of ships are the people who know least about it. I think this paper does a useful service in emphasising this point. By an extraordinary circumstance in this country it has got to the pitch that the people who are primarily responsible for the handling and loading of ships are the people who are utterly devoid of the knowledge about which the author speaks. I know of only a few companies who retain people who are qualified to supervise not only the loading but the building of their ships. The knowledge which is pointed out by the author as being necessary can only be acquired by a long course of systematic study and a large amount of practical experience. That is not found in the people who usually have the handling of ships.

Referring to the design of tankers and the distribution of material, the author says: "As it is obviously desirable for many reasons to place machinery at the after end of a ship, it follows that in such cases the cargo weight should be spread over as great a proportion of the length as possible where the weight of cargo amidships can so easily be made to outweigh the corresponding displacement." That statement requires to be read carefully because when you are spreading the weight in a bulk oil carrier, if you do not provide for the filling of the tanks you get the conditions of free surface which would make the ship unstable.

The author mentions the vibration in Diesel-engined ships and the desirability of incorporating the engine seating in the structure forming the hull of the vessel. My experience of this is not very great, but I have recently seen a very impressive example of Diesel engines which, not being properly installed in a ship, gave rise to almost untold trouble. The ship belonged to a prominent English firm and was being surveyed at Hamburg. The plates forming the bases of the crank pits were so made and welded that they could not be got out; the consequence was that the bed plates (which were built girder fashion) could not be got at, and when many of the rivets in the engine seating were shaken loose it was necessary to resort to the expedient of tapping out the holes to a larger size and fitting tapped bolts to tighten up the various members of the seating. So far I have not heard the result. Such troubles do not occur in engines of the balanced type like the Doxford engine, and I expect that ships fitted with engines of that type have been free from that trouble.

The whole lesson of the paper is that the primary factor in the design is the most efficient use of material to achieve the maximum of strength with the minimum of material. In the earliest ships that ideal was not approximated to at all. The builders put plenty of material in, in the hope that it would prove satisfactory. Those older than myself will remember the extraordinary margins of strength which the earlier ships possessed. They contained huge quantities of material; the builders took no chances. To-day we have, by a long experience found out where we can eliminate surplus material, and the result is, although we do not realise it, that the modern ship is practically a miracle of design. If we look at what has been achieved in a modern ship of 400-500ft. long which has to run at 20-25 knots, we cannot withhold our meed of admiration and respect for the designers.

Mr. E. G. **Warne**: With reference to the profile shown in Figure 6, the author says " the question of stresses induced by longitudinal bending can hardly arise. Here the machinery is placed at the quarter length aft and is balanced by a deep tank at about the corresponding position forward." I take it that the author means that the question of reduction of stresses induced by longitudinal bending occurs only when the ship is in loaded condition. The position is not very much better in this particular design when light than in the ordinary ship with machinery amidships.

With reference to the previous speaker's remarks concerning the ship considered as a beam and the difficulties which arise when compressive stresses occur in the deck, this has been taken care of in one instance which came to my knowledge (and only one) by the introduction of deck girders of heavy section running the whole length of the ship from forward to aft, which I presume were introduced to take care of those stresses. Perhaps the author can give us instances of this method being adopted elsewhere.

With reference to a proposed design, a few months ago the suggestion was advanced on behalf of a well-known firm of Diesel engine builders that they should build machinery of 100,000 h.p. for a ship of the size of the *Leviathan*, driven by four screws, with a centre auxiliary engine room. The *Leviathan* is roughly 950ft. in length. I have not been able to get figures for the length of the proposed engine room or for the weight of the engines, but making a hurried calculation I figured that in each main engine room there would be not less than 4,500 tons of machinery, and in the centre auxiliary engine room the weight might run to 3,000 tons or probably less. The question arises as to what proportion of the weight might be safely allocated to a centre auxiliary engine room which obviously must contain engines of less weight than those forward and aft. If the author has considered that point, possibly he would give us the benefit of his experience.

In conclusion I should like to thank him for what I consider a very useful paper on an important subject, which could scarcely have been dealt with in a shorter length or in a better manner.

Mr. A. F. Evans: In one respect I am slightly disappointed in the paper, inasmuch as it does not deal with the effect that bending, hogging and sagging, to say nothing of twisting, has on the machinery itself.

I am interested more in the smaller engine, and in this sphere we have experienced far more trouble from ship movement than perhaps you gentlemen have to put up with in the larger vessels.

This small machinery has often been thrown entirely out of gear, bearings seized, bearers fractured, etc., entirely through ship movement, and the question has often been raised as to whether it is better to endeavour to tie up the ship with the engine or to allow the structure to have movement independent of the machinery.

From our point of view the steam engine is a flexible structure that can be rigid with the vessel and therefore move with same, but the oil engine should be a rigid affair, a box structure in fact that must be kept in perfect alignment. I am aware that there are many instances of oil engines that are far removed from this; they consist of a long, shallow and narrow girder which is rigidly bolted to the ship bearers. This girder contains the crankshaft and supports four or six separate cylinders and in consequence any movement of this light girder is detrimental to the engine.

The rigid box idea has been adopted by the Lentz steam propelling engine, together with many other oil engine features, and we all know how excellent is the service rendered by the rigid box form of steam and oil engine when applied to electric lighting ashore, where the foundations do not move.

The whole point appears to be whether the unpreventable movement of the foundation that is supplied in a vessel is to be transmitted to the engine, or whether it shall be quite independent and I should like to cite an instance of engine mounting of which there are six or seven million examples, where the after part of the engine, which carries perhaps 60 per cent. of the weight, is supported on two brackets, while the fore part rests on a trunnion carried on a transverse bearer rigid with the main bearers.

I should be glad to have the author's opinion of this system —a short rigid box with two horn plates aft and a trunnion bearing amidships at the fore end.

Mention has been made of vibration that is sometimes felt from Diesel machinery, and very definite instances of this have come to my notice even with six-cylinder engines, where there should be no vibration. This has been caused by the flexing of the engine structure imparting vibrations to the vessel, and this is another reason for rigid engine construction.

Mr. G. R. Hutchinson: Mr. Thomas has given us a paper which, while primarily not on marine engineering, is on a subject which every marine engineer could and should study with profit. The paper condenses in an admirable way the essential aspects of the longitudinal strength of ships as it appeals to, and as it concerns the marine engineer. Perhaps the most interesting point brought out by the paper is that the adoption of heavy oil engines for ship propulsion has, in a great many cases, resulted in a reduction of longitudinal bending moments, notwithstanding the usually higher weight of this type of propelling machinery, and its concentration in a shorter length. This, the author tells us, is primarily due to a better distribution of cargo weights. Figs. 7, 8 and 9 relating to Diesel-engined ore-carrying vessels are most instructive, the reduction of 17 per cent. in the standard bending moment for the Diesel-engined ship as compared with the equivalent steamship being most surprising at first sight.

Although perhaps not relevant to the paper, the interesting suggestion put forward by Mr. Evans in his remarks on the paper recalls to mind an invention of a somewhat similar nature which was brought out some years ago. In this invention it was proposed to give a set of marine-geared turbines four-point suspension in the vessel, the turbines and gearing being arranged in a special sub-frame. Such an arrangement would undoubtedly be very beneficial from the point of view of the elimination of the transmission of structural vibration to the machinery and *vice versa.* It would seem with such an arrangement that a useful reduction of machinery weight would have been possible. Despite the undoubted promise of this invention, which, incidentally, was protected by a prominent firm of marine steam turbine builders, it was, to the best of my knowledge, never applied in an actual ship.

I was interested in what the author had to say with regard to Diesel engine seatings. There is no doubt that this part of the structure needs special design treatment, coupled with the best workmanship, when Diesel engines are fitted in a vessel. A considerable amount of trouble has been experienced in this direction in the past, and I am pleased to note that Mr. McConnell has referred to it in his remarks. I think the author is right when he suggests that the spread of the bedplate of a marine Diesel engine could be somewhat greater than it is at present. The type of seating he illustrates in Fig. 10 is undoubtedly an improvement upon that usually adopted in motorships having engines which do not employ the direct-seating, flat-bottomed, bedplate such as is used in certain marine oil engines. The type of seating put forward by Mr. Thomas is now being adopted by numerous owners and builders, and there is no doubt that for the type of bedplate illustrated in Fig. 10 it has everything to recommend it.

Some time ago I was in Italy witnessing the trials of the motor liner *Saturnia*, and when going over her sister ship the *Vulcania*, then completing, I was impressed by the very great care which the builders were taking in the construction of the engine seatings. Hydraulic riveting was being extensively employed, and, I understand, electric welding was also being introduced in the construction of the seating wherever possible. Another interesting detail in this connection which I noticed was the fact that no fuel oil or lubricating oil was carried in the double bottom tanks under the main and auxiliary machinery. There seems no doubt that not a little of the engine seating trouble which has been experienced in certain motorships has been due to the practice of carrying fuel and lubricating oils in the double bottom tanks under the machinery. Even if the workmanship is, in the first place, of the highest possible order, the heavy forces and vibrations which are usually transmitted through the structure of the engine seating will, in turn, cause loosening of the rivets. The percolation of the oil into the slackened rivet holes is then unavoidable, and the oil acts as an excellent lubricating medium which accelerates and accentuates the loosening of the rivets. As most practical engineers are aware, the restoration of such an engine seating to a condition of rigidity and tightness is an expensive and difficult job. There seems no doubt, I think, that the practice adopted on the *Saturnia* and her sister ship, namely, that of carrying water in the double bottom tanks beneath the engine rooms, is correct, particularly when such practice is associated with the best possible workmanship and, preferably, a longitudinal system of double bottom framing, such as, for example, the Vickers-Wingate system.

I would like to join the other speakers in congratulating Mr. Thomas on the production of an interesting and instructive paper, which possesses the additional recommendations of brevity and clarity.

Mr. A. F. Evans: May I ask the author his opinion of the tank top structure shown in Figure 10? It seems to me to be very excellent.

Mr. F. M. Timpson: I should like to follow other speakers in congratulating the author. This paper is certainly of great interest to engineers, and as Mr. McConnell has pointed out, it proves the need of the services of the naval architect in ship problems of to-day. As regards the troubles with Diesel engine seatings, these seem to occur and we have all heard of costly repair jobs due to this fault. The practice of welding parts of the structure has been adopted to prevent oil getting between the parts, as this feature tends to assist vibration.

In conversation with the representative of one of the largest Diesel engine makers in this country recently, he stated that they had realised that seatings required special consideration in design and construction. Others say that the solution of the difficulty lies largely with the engine designers and in the balancing.

The author has put his subject in a very simple form, and draws attention to a very important matter.

Mr. F. O. Beckett: Although this subject is rather beyond my experience, I have been particularly interested in the discussion which has taken place. One point was mentioned with regard to the loading of vessels and those who have not the requisite knowledge to supervise it properly. I remember an instance of a vessel which was being loaded at both ends simultaneously. The stern gland started giving trouble in the wet dock and I had the loading stopped. It nearly cost me my job because the ship did not carry the cargo which was anticipated. It goes to illustrate the practice of hogging the ship first and sagging it afterwards. The people at the South Wales ports are the worst offenders in this respect.

On another occasion the loading of a ship labouring in bad weather caused the cracking of a plate right down, outside my cabin. The crack was 19ft. long by 3/16th. inch wide, and the plate was $\frac{7}{8}$in. thick. On another occasion we had loaded in the midship bunker (not in the same ship) with silver ore from Marseilles, and we took in about 50 tons too much. We were down to the load line due to the bulk being of such weight concentrated amidships. The result was that we could not shut a door. On yet another occasion the mast came out when the keel sat on the blocks in dry dock. These instances show the importance of the author's remarks, which I have much appreciated.

The Chairman: The point which Mr. Thomas made as to the difficulty in calculating the stresses set up in a ship will be emphasised perhaps if I remind you of the behaviour of a ship, of which many of us have had unfortunate experience, in a seaway where she not only pitches, not only rides on the crest of a large wave, but simultaneously heels over to a large angle. When you consider the ship in that position and think of her as a beam, it is evident the value of her structure as a beam must vary very considerably from what it does in the upright position. The various members of the beam are at distances from the neutral axis differing from their original distances and have lower values, and it follows that an enormous factor of safety must be used in designing the ship. As

Mr. McConnell said, our forefathers were wise in their day, using plenty of material, but now the tendency is to keep down weights, and yet the naval architect must keep a large amount in reserve. Following that comes the proposal mentioned by Mr. Thomas to strengthen the main structure by strengthening and including the superstructure in the calculations. I do not know what your experience has been, but I have had to do with some of the largest ships in the world. These vessels had enormous superstructures. It was the practice to interpose in the uppermost deck what we call expansion joints. The behaviour of these expansion joints was very evident at sea; you would see the movement, which was very considerable indeed. One of the minor effects was that by creaking and squealing it caused a horrible noise which could be heard in all the accommodation. These joints did not fulfil their function, and did not prevent the upper structure receiving damage, and in my experience it was a common fault to find the vertical plates forming the sides of upper deck houses fracturing. The lower strake of these houses, though stronger than the upper strake, still cracked right down to the foundation angle. I should like to ask Mr. Thomas how it is proposed to bring these erections into the main structure of the ship, bearing in mind that the stress is going to be high for light structures. In the modern liner, owing to the need for comfortable running, the metacentric height is not usually very great, and it seems to me that building heavier superstructures is going to put the vessel in a peculiar position as regards stability when approaching the end of a voyage and when all her bottom weight is worked out. The secret is so distributing your material that it is used in its strongest way. You can dispose the material of a beam, say an H-section girder, so as to get very varying values.

It seems to me that Mr. Thomas has shown that the Diesel-engined ship has given another dig to the steam-engined ship in that the Diesel ship is in a better position as regards stresses caused by distribution of cargo. I am not surprised to find that, because we know that the weight of Diesel machinery, though very great indeed, is concentrated in a very short space. As you have a shortened engine-room you can distribute the whole of your weight of cargo over the whole of your length practically. The engine takes such a short amount of the length of the ship that you can distribute your weight very scientifically.

I should like to have an explanation (this was also asked for by Mr. McConnell) as to when tankers are going out light, how the ballast is distributed. Some of the oil tanks are used for ballast. Does it mean that No. 1 on the port, No. 3 on the starboard, No. 5 on the port, and so on are filled or partly filled? It does not seem to me a safe proposition. Mr. Thomas can perhaps explain.

Most of the points which occurred to me have been ably dealt with by the previous speakers, but I should like to ask Mr. Thomas to explain how the weakening of the deck abreast of hatchways is compensated for under compression, *i.e.*, when the vessel is sagging. Speaking from memory I cannot remember that it is the practice to strengthen the deck in the way of the hatches by increasing the thickness of the deck plating, except at the corners, but I do not think the deck plating itself is strengthened at that position.

Mr. Evans spoke about the rigidity of a steam engine. He, I think, asked the question—should a steam engine be allowed to work with the hull or be rigid? I did not quite understand the point, but what occurred to me was this, that it is supremely necessary in a steam engine to retain the relative position of engines and boilers. You are only asking for steam pipe trouble unless your boiler maintains its position with respect to the engine, and you cannot ensure that unless you have a very rigid structure underneath. In my experience I have had one or two very unfortunate cases of that kind; on a large twin-screw vessel the engine stop valve was broken right off where it joined the high pressure valve casing. We found that the movement of the engines with reference to the boilers was very great indeed. It is true they look greater than they are, but even a small movement of the engines with reference to the boilers is very serious, and the introduction of expansion glands does not meet the trouble, because these glands get screwed up hard and set fast and do not help; the best thing to do is to have your seating, and that means the structure of the ship itself, particularly at that point, very strong indeed.

As I said at first, I did not quite understand Mr. Evans remarks, but I do wish to point out the absolute necessity for rigidity of engines with respect to boilers. We are constantly getting trouble due to relative movements.

Mr. F. H. Alexander, M.Sc. (by Correspondence): The formula given in Mr. Thomas's fifth paragraph amounts to stating that the maximum bending moment may be assessed by taking one thirty-fifth of the product of the ship's weight and length; and that for convenience an average block coefficient of 0·75 may be assumed for all vessels in respect of displacement weight.

It has been my experience to come across cases where the application of this divisor factor 35 has led to serious error. In one extreme case a large vessel was designed on the basis of that factor, but calculations made when she was nearly completed, showed that she would be subject to a hogging stress of over 10 tons per square inch on parts of the deck if she should meet with wave conditions similar to those used in the calculations. Drastic measures were taken to strengthen the deck and neighbouring structure, but the vessel promptly proceeded to rupture these as soon as she met with heavy weather. The factor used at the design stage should have been 24.

The value of the divisor factor is not influenced solely by the distribution of the loading of the vessel, as one might perhaps be pardoned for assuming after reading Mr. Thomas's paper. A far more important influence is that of the ratio of draught to length of ship. Large vessels have relatively less draught than small ones owing to the limitations imposed by harbour depths; and as the size of vessels tends to increase as time goes on, a factor based on current practice at one period may need modification at a later one. To show the influence of decrease in draught ratio, it may be said that if 35 is correctly used where draught is one-fifteenth of length, then 28 should be used where draught is one -twentieth of length, otherwise the assessed bending moment will be too small, and will require an addition of 25 per cent. to give reasonable accuracy.

Mr. Thomas shows the effect of length and position of the space occupied by propelling machinery. The following general conclusions may be deduced from the principles involved :—

(1) With engines amidships, the shorter the space occupied the smaller the hogging moment of the loading vessel.

(2) Smaller hogging moments must of necessity be accompanied by increased sagging moments.

(3) A reduction of weight of machinery amidships means an increase in hogging moment.

(4) Removal of a machinery space from midships towards an end of the vessel, means its replacement by cargo in the vacated position. This means a reduction of the hogging moment when loaded, but the change of trim means an addition to the hogging moment when "light."

(5) When a vessel is alternately hogging and sagging across a given series of waves, the sum of the hogging and sagging stresses is constant and cannot be changed by any changes in distribution of cargo. Thus, for example, if the vessel is so loaded that she has a hogging stress of seven tons per square inch and a sagging stress of four tons per square inch, then no change of loading can alter that 11 tons per square inch difference. The difference is greater in broad vessels than in narrow ones.

The above conclusions refer to the statical conditions to which the usual calculations apply, but in cases where the principal bending moments are of the sagging type, error may come about in the assessed moment, unless the dynamical conditions are taken account of. The cases illustrated in figures 1 to 4 of the paper show that in certain services the loading of vessels may induce sagging to a greater extent than hogging.

In the usual calculations the vessel is assumed at rest for an instant across a wave also at rest, whereas in the actual case neither is at rest. Calculations have been made to ascertain the character of the effects produced in respect of bending, by the heaving and pitching movements of the vessel. The results of these calculations and consideration of general principles have led to the following conclusions.

(1) The vertical rise and fall of the vessel bodily, known as "heaving," results in occasional increases of virtual weight of every item throughout the vessel, these increases being specially marked in the sagging condition. It thus comes about that while the hogging moment is very little changed, the sagging bending moment may be considerably increased, even to the extent of 20 or 30 per cent.

(2) The angular rise and fall of the ends of the vessel, usually termed "pitching," produce in general only small changes in the magnitude of the bending moments, because the bending due to increase of virtual weight is opposed by the bending due to increase of water support. To make this

clearer, assume for instance that the vessel is head down in an approaching wave, and about to lift sharply forward, then the virtual weight of a 12 ton windlass may at that instant be 18 tons owing to upward acceleration. The extra six tons tends to produce a hogging moment amidships, but there is at the same time a sagging moment produced there by the extra water support which the vessel has at her fore end.

(3) Both heaving and pitching cause every item in the vessel to become a "live" load in respect of pressure upon the local structure in contact with it. Changes of virtual weight result in changes of pressure, and therefore "local" stresses are set up. These stresses tend to be specially severe at places where there is discontinuity of load or of structure, and Mr. Thomas calls attention in his paper to the undesirability of such discontinuities.

It is of great value that papers such as Mr. Thomas's present one, should be written to remind us that as changes in types, weights, and spaces occupied by machinery take place, it is necessary to bear in mind that these things have effect upon stressing forces as well as upon other features affecting design.

Dr. J. **Bruhn** (by Correspondence): It is often the case that persons, even those associated with shipping, have the idea that a ship is a thing which is provided by the builders with such structural strength that it will show no weakness during its use. The fact is that the success of a ship as far as strength is concerned, is dependent not only on the work of the maker, but also on that of the user. It is the same as with a chain, the serviceableness of which is dependent on its not being loaded to a greater extent than its scantlings admit of. If shipping is to be carried on efficiently, it is necessary that the members of the various branches in connection with it have a fair understanding of what other branches do or don't do. Those who build a ship, ought to have a good idea of how she will be used afterwards, and those who handle the finished ship, should realise what the builders can do and have done or assumed as regards providing the ship with strength. It is therefore, I think, very useful that papers such as Mr. Thomas's are read before the Institute of Marine Engineers. Those in charge of the engine department of a ship often feel the effect of structural weakness of the hull more directly than those on the bridge. and they have often to find the immediate remedies. It is therefore very desirable that they should have a good knowledge of the factors which cause the straining.

In a general way too little attention has been given to the distribution of weights on board, particularly the cargo and the ballast. A little increase in the size of a ship requires immediately—in accordance with the classification societies' regulations—an increase of the scantlings . On the other hand a distribution of ore cargo, which through some cause or other has been unfortunate, has no effect on the scantlings in spite of the very great influence it might have on the straining of the structure. It is rarely realised to what great extent the stresses with an ordinarily distributed cargo may be increased with an abnormal distribution of the weights. General cargoes and bulk cargoes usually fill the holds fairly well, and the distribution becomes therefore of necessity satisfactory. Where attention is particularly required, is in the case of heavy cargoes like ore, and of cargoes concentrated in particular spaces as liquid in bulk as well as in the case of the carrying of water ballast. It is not always easy to say which is the best distribution of the cargo and ballast weights, as this may be dependent on the condition of the weather and sea. The decision must, however, be left to those in charge of the ship. Estimates of the bending moments in the hogging and sagging conditions may give a guide as to the proper distribution, but they are not absolutely reliable, apart from the uncertain factors of the weather and sea, as our knowledge is unfortunately not sufficient to admit of a definite fixing of the relative magnitudes of the bending moments in the hogging and in the sagging conditions.

I have just at this moment before me a glaring example showing how the question of the distribution of the cargo may be neglected. A little wooden motor auxiliary vessel of some 300 tons gross took on board a cargo of lead in two heaps, one under each of the two hatchways, and resting directly on the permanent ballast. The result was, as might be expected, that the vessel got entirely out of shape and leaked extensively immediately she got into the open sea, and she had to return to port irreparably damaged. With steel vessels greater liberties may be taken, but as far as large vessels are concerned, straining may also occur in such cases both longitudinally and transversely, if care is not shown.

I agreed with Mr. Thomas in that we do not know what the magnitude of the stresses on ships is. I will add that I do not think we do know much more of the so-called longitudinal stresses (due to assumed conditions of standard bending moments, etc.) than we do of the so-called transverse stresses. I think it would be preferable not to speak of stresses at all in ships, but of relative stress figures, and then select these so large that no one will mistake them for having anything to do with real stresses.

Mr. Thomas calls the stresses due to longitudinal bending " more important " than those due to transverse straining. I do not think this expression is particularly happy, as if the material fails the consequences are about the same, whatever the cause.

It is further said that " when the ship is in the sagging condition, the presence of large machinery weights in the midship portion may suffice to give rise to serious bending moments."

This statement ought to be qualified somehow, as the sagging moment would generally be reduced if the machinery replaces cargo in the midship portion of a vessel. It seems implied in one place of the paper that " abrupt changes in the loads " cause increased stresses or bending moments. The latter are, however, as will appear from the diagrams shown, continuous, so that the stresses due to bending are not increased as a consequence of abrupt changes in the loads. The local shearing stresses are however.

I agree with the British Corporation that it is desirable to carry the full thickness of the sideplating of a vessel as high as possible, and thereby give the hull increased stiffness amidships, and thus reduce the chance of superstructures failing and leaking, I am, however, somewhat surprised at this statement that the machinery weights in modern high-powered passenger ships should make the sagging moments larger than the hogging moments. In the high-powered ships the ends are usually of fine forms, and the support of the water, therefore, small compared with the weight, which in most cases would tend to make the hogging moments large and the sagging moments small independent of what the weight of the machinery amidships might be.

Generally the sagging condition would be more severe than the hogging condition for an ore carrier, even with the engines amidships. The introduction of Diesel engines, which shorten the machinery space, would therefore seem to reduce the maximum bending moment rather than increase it.

It is undoubtedly a fact that the introduction of Diesel engines has drawn attention to the engine seating. This is, I think, however, more due to the necessity for increased strength than to a desirability of reducing vibrations. I doubt very much whether the vibrations at any rate those of the hull proper will be affected very much by the strength of the engine seating being a little greater or less.

Dr. G. **Webster** (by Correspondence): The subject with which Mr. Thomas deals in his interesting paper is one which deserves more attention than is usually given to it by shipowners and those interested in the handling and loading of ships. It should be only reasonable to expect that if a shipowner wishes to make the best use of his ship, which he endeavours to make economical in every direction, he should be prepared to pay at least a little attention to the effect on the longitudinal strength of the different conditions of loading. Unfortunately a great many ships' officers do not know the first principles of longitudinal strength and the consequent effect on the structure of a badly distributed cargo.

It would appear that the people who might be able to do most in this direction are those who, perhaps unconsciously, are as much interested as the shipowners, namely, the underwriters.

In addition to collisions, damage to ships can be caused by bad weather, bad loading, and by structural weakness. The last of these three generally speaking can be ruled out of most cases of damage, for owners usually specify that their vessels shall be built to the rules of one of the classification societies, which in most cases ensures a strong, sound ship.

A large number of cases of heavy weather damage are met with, however, but if the underwriters investigated these cases a little more deeply and insisted on loading diagrams being produced and longitudinal strength calculations being made, is it not possible that a number of these cases might be found to be due, not to heavy weather alone, but to a combination of heavy weather and bad loading? The question would then arise whether the underwriters were wholly responsible, and if the shipowner found that he frequently had to pay for damage he would naturally insist on his officers being provided by the shipbuilders with a guide as to how to avoid the damage.

It should be noted that a badly loaded ship will not necessarily be damaged, but a badly loaded ship which meets bad weather runs a very big risk of being damaged.

In the case of an oil tanker in the loaded condition carrying a cargo with a high specific gravity, such as molasses for example, when it will be necessary to leave some of the tanks empty, the distribution of the cargo can have a very serious effect on the structure and by bad distribution it is even possible to double the bending moment.

Perhaps the most important factor in the consideration of the longitudinal strength of a ship, to which Mr. Thomas rightly draws special attention, is the compressive stress on the deck which, if excessive, might cause buckling of the deck. It is well to note the serious effect of buckling. It may not stop at the mere deformation of the deck, for as the deck, due to the buckling, will shirk its share of the work in resisting the compressive stresses, it will consequently throw more on to the remaining structure with the possibility of defects in other places.

The modern cargo ship, however, with its cargo reasonably distributed is generally quite well able to withstand these stresses, for in addition to a good deck there are invariably stiff girders under the deck which, although essentially introduced to support the deck in association with widely spaced pillars, undoubtedly assist the deck appreciably under compression, and wood sheathing which has no value in tension will also assist the deck plating under compression.

The longitudinals under the deck in a longitudinally-framed oil tanker likewise ensure immunity from buckling of the deck in the sagging condition.

The AUTHOR'S REPLY: Before replying in detail to the points which several speakers have raised I have to thank the gentlemen who have taken part in the discussion for adding so much to the value and interest of the paper. I am glad to note that the general opinion seems to be that there is not sufficient knowledge of the limitations of the strength of the structure as there might be among those responsible for the handling of ships. The Chairman has rightly pointed out that the modern ship is a very much lighter and more efficient structure than the ship of a generation ago, and as such it must be treated with more consideration. I thank Mr. McConnell for having emphasised my remarks on the empirical nature of our knowledge of the structure of ships. The question of the inclusion of the superstructures in the ship girder has been raised both by Mr. McConnell and by the Chairman, and apparently requires further explanation. At one time it was thought advisable to regard the upper structures of large passenger vessels as structurally disconnected from the hull. In order that they might not be subjected to stress, the expansion joints, which the Chairman has referred to, were fitted and the continuity of the structure thereby destroyed. While this solved some of the problems which had arisen in long superstructures in that it prevented cracking at the corners of window openings, etc., it had other disadvantages. Recently instead of regarding the superstructures as independent of the hull structure they have been incorporated with it and advantage taken of the increased depth of ship girder. Such a course is only possible if proper means are taken to provide sufficient material in the superstructure decks to take the tensile or compressive stresses and also to provide material in the sides to transmit the stress to the decks without damage to themselves. This latter consideration to some extent raises Mr. McConnell's question as to whether it is better to incorporate additional material in the shell plating of a ship rather than in the decks. The shell plating is important in resisting shearing stresses, but the factor which limits the thickness is not a theoretical one but the practical necessity of providing plating which will withstand the usage to which the side of a ship is subjected.

The question of the ability of a ship's deck to resist compressive stresses has been raised by one or two speakers. Mr. Warne instances a case where deck girders had been introduced apparently to resist such stresses, but it is probable that such girders were fitted as an afterthought to stiffen a weak ship, as such a method is not likely to be used if the designer has previous knowledge of the conditions which the ship is likely to meet. Except in light decks the thickness of the plating required to resist the tensile stresses in the deck is sufficient to ensure that it will be efficient in compression. Where very light plating is fitted, if the deck is sheathed with wood and bolted between beams, the plating is held up to this work. The problem which Mr. Warne raises of a vessel 950ft. in length is one of such magnitude that it is only possible to say that the design of such a vessel should receive careful consideration from the point of view of hull strength before the proposal is proceeded with very far. We have quite recently had an example of one of the largest vessels in the world having shown unmistakable signs of lack of knowledge of the bending moments to which she is subjected at sea. Although this question of longitudinal strength of ships has been investigated very fully it is unfortunately still possible to find examples of this kind.

Mr. Evans raises the question of the effect of the weakness of the ship's structure on the machinery. I can only say that if the machinery is so affected the fault is with the design of the ship. Movement of the foundation of the machinery is preventable, and Figure 10 is an indication of the lines on which it is being prevented. In spite of this I am of the opinion that the designers of Diesel engines have not given the subject the consideration which it deserves and have been too inclined to neglect the differences in the respective problems involved in land and marine engines.

I have to thank Mr. Beckett, Mr. Alexander and Dr. Bruhn for the instances they have given which emphasise my remarks on the importance of the subject. Mr. Beckett gives us some very practical examples of the damage which may be done by varying the loading of a particular vessel. I agree with Dr. Bruhn that I should have made it clear that abrupt changes in the loads are important because they cause increased shearing stresses. As he points out the bending moment curves are continuous. In spite of his surprise I think he will find on investigation that the machinery weights in modern high-powered passenger ships have tended to increase the sagging moments. The effect of the form is undoubtedly to increase the hogging moments, but I suggest that the increase in machinery weights has more than out-balanced this effect. Mr. Alexander's remarks on the value of the coefficient which I have assumed in estimating the bending moments of normal ships are valuable. I was careful to make it plain that this factor had in the past proved sufficiently reliable, but I entirely agree that conditions of loading and the desire for economy in weight of structure have altered the position. Mr. Alexander is well known for his work on heaving and pitching. The considerations of the dynamic forces acting upon a ship in a sea-wave are most interesting, but I fear that we must first persuade the designer and owner of ships to take an interest in the simpler methods of estimating stresses. As I explained, this is one of the objects of the paper, and it is very gratifying to note that a paper on such a subject was of interest to the members of this Institute.

Doctor Webster's contribution contains an interesting suggestion that the underwriters may be the means of bringing this subject to the attention of shipowners. I have for some time held the view that the owner in the interests of economy would be forced to insist that those responsible for the loading of ships should know the first principles of longitudinal strength and the effect on the structure of the ship of a badly distributed cargo.

Mr. J. Shanks: I have much pleasure in proposing a hearty vote of thanks to the author. I was sure that when Mr. Thomas consented to give this paper it would prove to be one of great value. We engineers want to know as much as we can about naval architecture, because, if we cannot design the ships we are called upon to work and run them satisfactorily. In this paper Mr. Thomas has shown in a simple form all the knowledge that is necessary for those who are responsible for the loading of ships. The value of the paper is untold; it will travel the world over and there is no saying how far-reaching its effects will be. A great deal has been said to-night about oil tankers. I had some experience with this class of vessel in its earliest days. and was surprised to hear the author speak of the longitudinal fastenings breaking at the bulkheads. That was one of our principal troubles, and I should have thought it was now overcome.

The Chairman asked about the oil tanker in light condition. In my time the ship was trimmed to suit the weather conditions and there must have been enormous stresses set up by certain tanks being filled in a hurried and slip-shod manner, especially at sea. There is no doubt that tankers are better designed now than in my day. I am sure that we all accord Mr. Thomas a very hearty vote of thanks. (Carried with enthusiasm.)

The Hon. Secretary: Before dispersing I wish to mention that we have with us to-night a retiring Member of Council with whom we are loth to part, as he has rendered most valuable service to the Institute and his work has been highly appreciated. I refer to Mr. McConnell, who has acted as Convener of the Papers Committee for the past seven years, in addition to having undertaken a considerable amount of the work of editing the book of collected Internal Combustion Engine papers. He has also reviewed the books added to the Library during the same period, thereby conveying valuable information concerning these publications to all members through the medium of the Transactions. Mr. McConnell is leaving the Board of Trade Office in London for the Glasgow Office. We extend to him our best wishes and trust that his appointment to Glasgow may prove to be a happy change for the better. (Applause.)

Mr. F. M. Timpson: I have much pleasure in supporting the Honorary Secretary's remarks regarding Mr. McConnell. I can say from personal experience that there was no trouble too great for him in connection with the publication of the Institute Transactions and papers. His work has been a great asset to the Institute. I am sure that all of us wish him every happiness in his new sphere.

Mr. W. E. Farenden: As a fellow Member of Council I can speak in support of the preceding remarks. I hope that Mr. McConnell will still continue to think of us and that if he returns to London later on he will place his valuable services again at our disposal.

The Chairman: I think it will be a very happy recollection of the nice things which have been said about him which Mr. McConnell will take with him to Glasgow. I know that he has taken a wide interest in this Institute. I am sure that he himself will say that it has been a work of love and that he has undoubtedly profited by his experience.

Mr. W. E. McConnell: I thank you all very much for your kind remarks. I could not resist the opportunity of coming on this occasion to say good-bye before I go. I will only add that if I find in Scotland one-half of the kindness I have experienced in London, my future will be happy indeed.

Before we close, I think you will be pleased to join in expressing a hearty vote of thanks to the Chairman. In Mr. Laslett we have had a Chairman with a long experience who has been able to contribute materially to the discussion. (Carried enthusiastically.)

The Chairman: I thank you. The only regret I have is that the weather was so unfortunate to-night that more members were not present to hear Mr. Thomas's excellent paper.