from a Holtz machine to potentials of about 5000 volts as measured on an absolute electrometer. The velocity of rotation was about 200 revolutions per second. The astatised needle was protected within a metal case, and was observed in the usual way by a mirror. No deflection was observed either when the disk was still or when it rotated. Dr. Lecher intends to repeat Rowland's experiment with the original horizontal disposition of the disk.

DR. LECHER has also made another experiment of great interest. A ray of light was divided, as in many experiments on interference, into two parts, which, after passing through two parallel glass troughs, were caused to reunite, giving the usual interference-bands. The troughs contained strong solutions of nitrate of silver. By means of electrodes of silver an electric current of 6 amperes strength was carried in opposite directions along the troughs so that in one trough the current flowed *with* the light, and in the other against it. But in no case was any displacement of the fringes observed. Dr. Lecher concludes that the velocity of light is not influenced by a current flowing through the medium.

DR. LECHER has made a third and still more interesting experiment, attended, however, like the preceding, with a negative result. This was an attempt to prove whether Faraday's famous experiment of rotating the plane of polarisation by an electric current could be inverted. He has attempted to generate currents by rotating the plane of polarisation of light. The arrangement was as follows :—A ray of plane-polarised light was sent through the interior of two powerful helices of wire situated at some distance from one another. Through the first of these a powerful alternate current was sent, which impressed upon the ray a rapid oscillation of its plane of polarisation. The second helix was connected to a sensitive receiving telephone in the hope that sounds might therein be heard, as would be the case if the rapid rotations in the plane of polarisation of the ray were capable of setting up currents in the surrounding wire. Absolutely nothing was, however, heard.

BACTERIA

A VERY distinguished audience assembled at the Parkes Museum on Thursday evening, March 27, to witness Mr. Watson Cheyne's demonstration of pathogenic micro-organisms. The chair was taken by Sir Joseph Lister, Bart. After stating that the great group commonly called Bacteria might most conveniently be subdivided into four classes—(1) Micrococci (round bodies), (2) Bacteria (small oval or rod-shaped bodies), (3) Bacilli (large rod-shaped bodies), and (4) Spirochætæ and Spirilla (rods spirally twisted), and dwelling on the great variety as well as importance of the various parts played by this great group in the economy of nature, Mr. Watson Cheyne demonstrated numerous micro-photographs taken by Dr. Robert Koch, as well as some drawings by means of a limelight apparatus. He observed that great differences existed among the various bacteria in their behaviour towards the human body : some could be injected without causing any injury, others could not grow in the living body, but could develop in dead portions of tissue and the secretions of wounds, giving rise to poisonous products. The true pathogenic organisms were able to attack the living body and multiply in it; they included the organisms which found entrance through some wound, giving rise to the traumatic infective diseases, and others which could obtain entrance without observable wound. Further, certain organisms, such as the *B. anthracis*, were capable of growing outside the body in dead organic substance, while others, such as the *B. tuberculosis*, were apparently only capable of development in the living organism or under artificial conditions which reproduced to some degree those existing in the tissues of warm-blooded animals, though capable of long retaining their vitality in the dry state. With regard to the traumatic infective diseases, he thought that the most absolute proof had been furnished that the bacteria found in them, and nothing else, were the causes of these diseases. To establish such a proposition it was necessary that an organism of a definite form and with definite characteristics should always be found in the blood or in the affected part. The blood or the affected part when inoculated into another animal of the same species must produce the same disease. When the blood or the affected part was inoculated on a suitable soil outside the body, the micro-organisms grew, and must be indefinitely propagated on similar soil. When in this manner the organisms had been separated from the remains of the materials in which they were embedded, their inoculation in an animal must produce again the same disease, the same organisms being found in the diseased parts. These conditions had now been fulfilled with regard to anthrax, septicæmia of the mouse, erysipelas, tuberculosis, glanders, and acute pneumonia. With regard to typhoid fever, relapsing fever, cholera, and ague, the evidence was very strong, but not conclusive. Mr. Watson Cheyne concluded by dwelling on the importance of surrounding circumstances, chiefly those summed up in the phrase unhygienic conditions, as concomitant causes of disease by preparing the blood for the attacks of these micro-organisms.

The chairman, Sir Joseph Lister, dwelt upon the important fact that the organisms which produced particular diseases were only able to develop under very special conditions, instancing the bacillus which caused septicæmia in the house mouse, but which was unable to produce any deleterious effect on the field mouse. He thought this fact, which showed that the very slight difference in the blood of these two animals was sufficient to alter the conditions favourable to the development of the bacteria, might prove of very great interest, as it was possible to conceive that by the administration of some medicines, sufficient alteration might be produced in the blood of the human system to kill off or to prevent the development of any special bacteria on the first appearance of the symptoms of the disease in the patient. Sir Joseph Lister concluded by referring at some length to the importance of Pasteur's researches on modified virus.

Prof. Humphry paid an eloquent tribute to the great work which Sir Joseph Lister had already achieved, and looked forward with a large hope to the future of medicine.

THE STABILITY OF SHIPS

PROFESSOR ELGAR has recently made two important contributions to this important question; the first was read before the Royal Society on March 13 last. The main object of the paper was to exhibit the manner in which the stability of a ship varies with changes of load and draught of water such as merchant steamers are liable to. None of the properties possessed by a ship is more vital to her safety and efficiency than that of stability. At the same time none is dependent for its existence and amount upon so many or such diverse and variable circumstances as it. The stability of a ship, both as regards moment and range, is affected not only by the position of her centre of gravity, which largely depends upon stowage, but also by draught of water. If the centre of gravity be kept fixed in position at various draughts of water, the stability will still vary very considerably with the draught, and often in a manner that contains elements of danger.

The usual practice in investigating a ship's stability is to calculate a curve of metacentres, and one or more curves of stability at certain fixed draughts of water and with given positions of centre of gravity. The curve of metacentres gives the height at all draughts of water above which the centre of gravity cannot be raised without making the ship unstable when upright, and causing her to lie over more or less to one side. The ordinates of the curve of stability represent the lengths of the righting arms, which, multiplied by the weight of the ship, give the righting moments at all angles of inclination from the upright. The stability of numerous vessels, both of the Royal Navy and mercantile marine, have been investigated in this manner for certain draughts of water, and a great amount of information obtained respecting the variation of stability with inclination at such draughts, and the angle at which the stability vanishes in many classes of ships. The peculiar dangers attaching to low freeboard, especially when associated with a high centre of gravity, have been fully discussed and made known.

Curves of stability have been chiefly constructed for deep and moderate draughts; the character of the stability which is often to be found associated with very light draught, appears to have hitherto escaped attention. As a matter of fact, light draught is often as unfavourable to stability as low freeboard, and in some cases more so. The general opinions that have till recently prevailed upon the subject appear to have been based upon a vague impression that so long as a vessel has a high side out of water, and any metacentric height, she will have great righting moments at large angles of inclination and a large range of stability. It was shown at the *Daphne* inquiry, held by Sir E. J. Reed in

July last, that these opinions largely prevailed and were erroneous.

Prof. Elgar was called upon to make some investigations respecting the stability possessed by the *Daphne* at the time of the disaster which happened to her, and to give evidence respecting the same. He afterwards pointed out, in a letter to the *Times* of September 1 last, some of the considerations which obviously apply to light draught stability. The first, which it appears had never before been stated, is that any homogeneous floating body which is symmetrical about the three principal axes at the centre of gravity—such as a rectangular prism or an ellipsoid—will have the same moment of stability at equal angles of inclination, whether floating at a light draught with a small volume below water, or at a deep draught with a similar volume above water. For instance, if a homogeneous prism of symmetrical cross-section 5 feet high float at a draught of 1 foot, it will then have precisely the same moment of stability at equal angles of inclination, and consequently the same curve of stability throughout, as if it were loaded—without altering the position of the centre of gravity—till it had 4 feet draught of water, and 1 foot of free board. From this it follows that, in such elementary forms of floating bodies, lightness of draught has the same effect upon stability as lowness of freeboard; and if a low freeboard is unfavourable to stability, so also, and precisely to the same extent, is a correspondingly light draught of water. This proposition can be made still more general, as it applies to homogeneous bodies of any form of cross-section which revolve about an horizontal axis fixed only in direction. From this may be deduced the results given by Atwood in his papers read before the Royal Society in 1796 and 1798 respecting the positions of equilibrium and other peculiarities connected with the stability of floating bodies.

In considering the stability of a ship at various draughts of water, and comparing it with that of the class of figures above described, modifications require to be made for the departure from symmetry of form, and for the extent to which the vertical position of the centre of gravity differs from what it would be if the external surface inclosed a homogeneous volume. Prof. Elgar has done this with great fullness of detail in his paper, and shows, by means of curves, how the stability varies with draught of water at constant angles of inclination in various geometrical forms of floating bodies, and in a large passenger steamer of ordinary type. The curves thus dealt with are curves of righting moments, and not merely curves of lengths of righting arm. The ordinary curve of stability is usually made for lengths of righting arm, because the displacement is constant, and the same curve therefore gives upon different scales, either lengths of righting arm or righting moments. In the vertical or cross curves of stability, however, such as are now being dealt with, draught, and therefore displacement, is one of the variable quantities, and curves of righting moments are of a very different character from curves of righting arm. Complete cross curves for a ship, from which ordinary curves of stability can immediately be obtained for any draught of water and position of centre of gravity, can be constructed in a few days with the aid of Amsler's mechanical integrator.

Prof. Elgar shows conclusively the necessity in many cases of regarding the stability of a ship from the point of view of variation of righting moment with draught of water, the angle of inclination being constant, instead of from that of variation of righting moment with angle of inclination, the draught being constant, as is usually done; or rather of considering the subject from both points of view instead of almost exclusively from the latter. He also shows that it is necessary to investigate, more fully than has formerly been done, the moments and range of stability of ships and other structures that may be intended to float at very light draughts of water.

Prof. Elgar's second paper was read last week at the meeting of the Institute of Naval Architects; its title was "The Use of Stability Calculations in Regulating the Loading of Steamers."

The stability of ships, Prof. Elgar went on to say, is a subject that has received a considerable amount of theoretical investigation during recent years. The general character of the stability of certain classes of ships, and the circumstances which affect it, have been largely ascertained and made known; while the methods of performing the requisite calculations—especially when large angles of inclination are being dealt with—have been greatly improved. Curves of stability have been constructed and made public for numerous ships of various classes, both for war and mercantile purposes.

The results of the investigations that have thus been made are of great value to naval architects and men of science, and enable them to know much more respecting the actual stability often possessed by ships than was possible with the imperfect data available in former years. In the case of ships that are built for purely war and some other special purposes, the ordinary stability calculations enable instructions to be readily framed respecting the stability they possess under ordinary working conditions, or in such critical circumstances as may possibly occur during their career. Any risks of instability that may exist, or arise in certain contingencies, may be ascertained, and the precautionary measures necessary for counteracting them devised and pointed out.

The problem that has to be dealt with in advising those in charge of war ships how to effectually guard against instability, is well within the grasp of the naval architect. In such vessels the loading is mainly of a permanent character, while that part of it which is subject to variation, such as coals, stores, ammunition, &c., varies in a manner which can be readily taken into account in the calculations. Curves of stability that are constructed for war ships for three leading conditions, viz. (1) the fully-laden condition; (2) the same, but with all the coals consumed; and (3) the light condition with all coals, ammunition, and consumable stores expended, are usually sufficient to enable full instructions to be framed for the prevention of instability. In some war ships there are other critical conditions which may require consideration, such as the possible injury and laying open to the sea, of compartments not protected by armour; but in all these cases the conditions are comparatively fixed, and may be allowed for in the calculations. When curves of stability have once been constructed for a war ship to represent the various critical conditions to which she may be subjected, they are always applicable, and may be relied upon to furnish, at any time, a safe guide to her stability.

In the case of mercantile steamers, however, except such as carry no appreciable weight of cargo, the problem of how to apply the results of stability calculations to the guidance of those who have to work and stow them is of an entirely different character. The naval architect cannot control, or even estimate, the amounts and positions of centre of gravity of the various items of weight that make up the loading to anything like the same degree of certainty as in war ships. There are many steamers afloat in which the cargo is nearly or quite twice the total weight of the vessel, together with her machinery and equipment. In such cases the naval architect can only control in the design about one-third of the total weight of the vessel and her cargo, leaving the remaining two-thirds in the hands of the owner, master, or stevedore. It is obvious, therefore, that whatever may be the qualities of the empty vessel in respect of stability, these may be greatly modified or entirely altered by the manner in which she is loaded. It is the loading to which we must look in the large proportion of cargo-carrying steamers for the due preservation of such stability as is necessary for safety at sea.

It is in this direction also that we have to look for the cause of a great many of those losses which have occurred at sea during recent years, and to which attention was first prominently called by Mr. B. Martell, the Chief Surveyor of Lloyd's Register Society, in a paper read before this Institution in 1880 upon the causes of unseaworthiness in merchant steamers. Mr. Martell attributed, and quite rightly so, a great many of the losses of steamers to instability; and there can be no doubt that this cause of loss still continues to operate very largely. The evidence given at Board of Trade inquiries in cases of missing steamers is constantly pointing to instability as the cause of loss, although the full meaning and weight of the evidence may not always be fully and accurately appreciated at these inquiries. It often diverts attention from the main cause of loss to say that it occurred because the ship was unstable. The fact is, that the ship has frequently so little to do with the matter, and the stowage so much, that it is the latter which should be blamed for the instability, and not the ship herself. When a ship is built for a particular trade and for the purpose of carrying certain specific cargoes she may then, of course, be so designed as to be quite stable, in all conditions, while thus employed; but when vessels are built, as they often are, to dimensions fixed by owners, for general trading purposes, it is seldom possible for the designer to provide against instability arising in some possible or conceivable circumstances of loading. The due preservation of stability in such cases requires to be watched and provided for by those who control the loading.

It is erroneous to suppose, as appears to be sometimes done, that a cargo-carrying steamer should be so constructed and proportioned as to run no risk of becoming unstable, however she may be laden. If this idea were acted upon, such a mode of preventing instability, however easy and plausible it may at first sight appear to be, would only defeat the desired object of promoting safety at sea, because it would make many vessels dangerously stiff when laden with some classes of cargo. The true and reasonable mode of procedure is not to attempt to construct a ship so that she will be stable however she may be laden, but to see that any tendency she may have towards instability—if any such exist—is understood by those in charge of her, and that she is always laden with careful reference to it. There are no steamers afloat, whatever tendency they may have towards instability as sometimes laden, that they may not be kept perfectly safe if treated with full knowledge of what their stability is, and the stowage regulated accordingly. One great problem that the mercantile naval architect has just now to solve is, how any dangerous features of a ship's stability are to be made clearly known to those in charge of her, and in what manner they can be best taught to regulate the loading in cases where special care may be required.

It is sometimes supposed that owners and masters are not only negligent, but indifferent in this matter; and that they deliberately refrain from any consideration of it. It has been stated that there are no owners who avail themselves of the knowledge of stability now readily obtainable as a guide in the stowage and safe working of their ships. These are views which my experience does not enable me to indorse. I have found, on the contrary, that many of our leading owners of passenger and cargo steamers are extremely anxious about the matter; and not only anxious, but they adopt all means that lie within their power of dealing practically with it. The great stumbling-block they usually meet with, however, is the intrinsic difficulty of the subject.

Owners and masters have their own modes of thought and their own practical methods of ascertaining and regulating the stability of their ships, which are often quite sufficient for the purpose. They can very well comprehend whether a vessel will stand up when light without ballast, and, if not, how much it will require to make her do so. They can also understand if she is too stiff when laden with heavy dead-weight cargoes placed low down in the hold; or if she becomes unduly tender when laden with light cargoes of which more than a certain quantity is placed in the 'tween decks. They have not, however, had the technical training and experience which is requisite to enable them to understand and deal with metacentres, centres of gravity, and curves of stability; and to make all those allowances for constant variations in draught of water and position of centre of gravity which the different cargoes they carry render necessary. Some owners have recently obtained curves of metacentres and curves of stability for their ships, constructed for certain draughts of water and descriptions of cargo. These curves, as a rule, are put to no real practical use by them, as they find themselves unable to apply stability information in this highly specialised form to the accurate and reliable treatment of the various questions that arise in loading, or to compare it with the results of their own judgment and experience.

The above course has lately been taken in many cases because of the opinions which have been expressed that the way to prevent ships being lost through want of stability is to supply the masters with particulars of the metacentric height and a curve or curves of stability. The Wreck Commissioner advocates this course, and appears to entertain no doubt as to its desirability and practical efficacy. His object is a most praiseworthy one, but I do not believe it to be possible to carry it out in the way he suggests. The advice he gives is based upon the belief that shipmasters and others who have to do with the loading of ships can readily be made to understand what curves of stability represent, and to use them correctly in practice. I have during the last two or three years frequently tried to carry out this view, but have never yet met with a shipmaster—and I have had to do with some of the most capable and intelligent of the class—who could be got to understand curves of stability sufficiently well to be trusted to work with them in practice, or who would even profess that he could do so.

If mercantile steamers could always be loaded in a uniform manner, it might be possible to represent their stability in all conditions with sufficient accuracy and completeness for all working requirements by means of a curve or curves; but as regards the vast bulk of merchant shipping there are no curves of stability which could possibly be constructed, except that for the absolutely light condition, which would be likely to represent the actual stability of the ship except on a very few occasions during the whole of her career. The only use to which any curves of stability that might be furnished could, as a rule, be put is to furnish data for enabling the stability under different conditions from those for which they were constructed to be estimated. This is an operation which masters of ships cannot perform, and which would only be likely to confuse and mislead them if they were to attempt it.

The Wreck Commissioner laid great stress upon the use it would have been to the captain of the *Austral* at the time of the accident if he had been in possession of curves of stability and calculations which had been constructed for that condition, and laid before the Court. It does not appear to have been seen that, whatever particulars of calculations and curves of stability had been supplied to the captain, he could not by any possibility have had those which related to the condition of the ship at or somewhat prior to the time in question. Her stability on that occasion was determined by the amount of weight she happened to have in her, and the position of its centre of gravity; and this was the result of a chance state of things which only existed at that precise moment, and which may hardly occur again during the existence of the ship. If we assume that this information would have taught the captain more about her stiffness than he already knew through his previous experience of the vessel, still it could not have been supplied to him beforehand by any one. All that could have been done was to supply him with particulars of the stability at other draughts and with other positions of the centre of gravity, leaving it to him to estimate from these what it would be at the time in question if he thought it desirable to do so.

I need hardly say again that the operation of constructing curves of stability for a particular draught of water, and position of centre of gravity from the results of calculations made in the usual way for certain other draughts of water and positions of centre of gravity, is an operation which requires a well-trained naval architect to perform. No one knowing the subject can suppose that masters of vessels have had either the training or the experience to qualify them for performing such an operation, or can help fearing that the result of their attempting it might be misleading. As I have already said, I have never been able to discover a shipmaster who could be safely trusted to do it, or who cared for it to be supposed that he could. It is hopeless, at present, to expect either shipowners or shipmasters to use metacentric heights and curves of stability as a practical guide in stowage; and it is necessary to put stability information before them in a simpler form, and one which fits in better with their own ideas and modes of procedure, if it is to be utilised in furnishing any real guide towards safety in loading. It is quite unnecessary for us to require such persons to become specialists in the science of naval architecture before applying the results of scientific calculations to safeguarding the stability of their ships. I have myself been obliged to give up all attempts to deal satisfactorily with the question by supplying curves of stability and other information of that class.

The method which I have adopted is the following, and I now lay it before the Institution, chiefly for the purpose of eliciting opinions upon the subject, and as a suggestion to others who may be working in the same direction and have experienced similar difficulties with myself. In advising upon how a steamer should be treated and loaded so as to be kept safe in respect of stability, I state (1) the quantity of ballast, if any, that is required to enable her to stand up when quite empty, without water in boilers or tanks, coal in bunkers, and with a clean-swept hold, and to be stiff enough for all working requirements in dock or river; (2) if she is to be employed in carrying homogeneous cargoes, what proportion of the space in the 'tween decks it is safe to fill with such cargo, after the holds are full, and what weight of ballast is required in the bottom to enable the vessel to be loaded to her maximum draught with such cargo; (3) if required to carry two or more kinds of homogeneous cargo, such as grain and cotton, grain and wool, grain, meat, and wool, &c., the best mode of stowage, and whether or not the space in the 'tween decks can be filled with the lightest of the cargoes, and in what circumstances ballast, and how much of it, will be required; (4) if not intended for homogeneous cargoes, but for general cargoes, or partly homogeneous and partly general, the average densities of the general goods for various ports is arrived at after a little experience, and the same system adopted. The main point is, to state what space, if any, must be left unfilled in the 'tween deck cargo spaces, with the different descriptions of cargo, and what ballast, if any, is necessary if the vessel is to be loaded to her maximum draught; (5) if the consumption of the coal diminishes the stability materially, as is often the case in some classes of steamers, to call prominent attention to this fact, in order that the captain may not be misled by finding his ship appear to be rather stiff on commencing a voyage. The possible consumption of coal is, of course, taken into account in fixing upon the limits that should be imposed upon the stowage in all the conditions named; and (6) if there appear to be any circumstances in which a tendency towards instability may arise they are described, and suitable precautions suggested. I believe that Lloyd's Register Society, in fixing a load-line for vessels that may in some conditions be laden so as to have insufficient stability, describe the stowage that is requisite for safety in somewhat similar terms to the above.

General particulars, such as these, respecting the character of a ship's stability in different conditions, may be made to convey all the information that is necessary for the effective prevention of instability, and I find that they are appreciated by owners and masters, and actually used as a guide in the loading of ships. They may be made to fully define all the essential points upon which stability depends, and are expressed in a form and language that is understood by those who have to use them. This is shown by the fact that telegrams are sometimes received from foreign ports respecting ships which are to be laden with cargoes somewhat different from those to which the specific instructions apply, describing the cargoes that are to be carried, and asking whether any different arrangement of ballast or proportion of weight in the 'tween decks from what has been prescribed for some other cargo is necessary. Such inquiries show that intelligent use is being made of the information supplied, and that it is being utilised for practical guidance in loading.

One of the main reasons why it is better to give information in this simple form is that it obviously fits in with a shipmaster's own practical modes of thought and ideas respecting stability. It is a mistake to suppose, because owners and masters cannot express their views respecting the stability of ships in scientific language, that they therefore have no views that are worth anything. The fact is, that the masters of ships very often have quite correct ideas respecting the stability of their vessels and how to load them. If they see a vessel quite empty in dock, and observe the effect of moving weights in and out when light, they often acquire as much knowledge of her stability in the light condition as is requisite for all purposes of safety and efficient working. They also, by means of experience obtained in loading, frequently get to know as much about the stability of certain classes of vessels in the laden condition as is necessary for practical purposes, and certainly for all purposes of safety. Whether sufficient knowledge can be gained in this way or not for all possible requirements depends largely upon the type and peculiarities of a vessel. As a rule, it is all that is applied to the purpose, and there can be no doubt that in many cases it may be sufficient. It is in vessels which contain elements of danger that cannot be discovered in this practical manner that a different and more scientific mode of treatment becomes requisite.

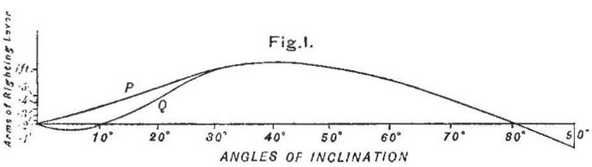
The proper use of stability calculations is not to supersede or interfere with that knowledge of a vessel's qualities which may be gained by experience but to supplement and complete it in certain cases where it may be necessary. As an illustration I may refer to the small range of stability sometimes found to be possessed by deep vessels of low freeboard. The discovery of the dangers to which such ships are liable may perhaps be successfully made in some instances by simply observing their behaviour at sea; but probably it is more often made only when the ship capsizes. Then, again, many ships become unstable at sea through the consumption of their bunker coal, particularly when a large portion of such coal is carried, as it sometimes is, in a reserve bunker under the lower deck. There are cases in which the metacentric heights of cargo-carrying steamers are reduced by 1½ feet by the mere consumption of the bunker coal. In such cases instability may very readily arise at sea in a manner of which the captain is unable to form any accurate conception when merely judging by the results of his own experience. This is particularly likely to be the case when alterations are made in bunkers, or when portions of the hold are added as reserve bunkers for enabling voyages of longer duration to be made than have previously been contemplated. I certainly believe, as the result of an examination of the stability of many mercantile steamers, that a great number of vessels are lost at sea from each of these causes, viz. through capsizing on account of low freeboard and consequent small range of stability, and also through loss of stability by reason of the consumption of coal. In both of these classes of cases the danger is aggravated if the ships are flush-decked, without any or with but small water-tight erections above the upper deck.

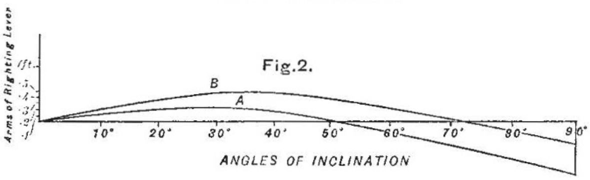
It is very difficult to make a complete analysis of the various causes of loss at sea, and to show conclusively what is the relative mortality of vessels of various types and different descriptions of cargo. The difficulty is due to the fact that the Board of Trade returns are not compiled in a manner which enables all the necessary information to be extracted from them. So far as it is possible to judge, however, by the particulars available, it appears that the types of steamers that are least subject to mysterious losses at sea are those which have long ranges of water-tight erections on deck, and are therefore least liable to become unstable. I believe that the comparative immunity against loss which appears to be possessed by many efficiently built and protected "well-deck" steamers, is largely due not only to their comparatively low centre of gravity of cargo, but to the righting power furnished at large angles of inclination by their extensive deck erections. This is undoubtedly the case, notwithstanding the fact that seas may break into the well, and often fill it with water. It may be somewhat startling to persons familiar with the loading of flush-decked steamers, to find many well-decked vessels making voyages across the Atlantic with portions of their decks so near to the water as they sometimes carry them; but a little examination suffices to show that the fact of the water entering a properly constructed and fitted and moderately sized well cannot do much to endanger the safety of the ship. Any effect it may have upon the stability is only at small angles of inclination.

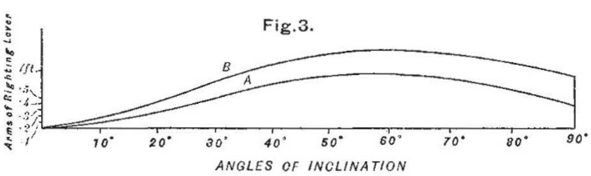
In order to show how small is the effect of water in the well of an ordinary first-class steamer of this type upon her stability, I have given two curves of stability in Fig. 1 for such a vessel. That marked P is for the condition of no water being in the well till the vessel is inclined sufficiently for the edge of the deck to become immersed, and that marked Q for the condition of the well being filled with water before the inclination commences. Mr. Martell was good enough to have these curves calculated for me, in order that I might have them in time for the reading of this paper. They are for a raised quarter-deck vessel 257 feet by 35 feet 6 inches by 18 feet 6 inches, with a well 60 feet in length, and bulwarks over 5 feet high; the freeboard amidships to the main deck being 2 feet 2 inches. Prior to the water entering the well the vessel is assumed to be at her usual trim of about a foot by the stern, and a correction is made for the change of trim caused by the filling of the well. No allowance is made for the quantity of water that would be thrown out of the well by the movements of the ship, but it is assumed to be possible to completely fill it with water to the height of the rail at the fore end of the bridge, and for no other way of escape to exist for the water but that of pouring over the rail as the vessel inclines. The freeing ports and scuppers are not assumed to have any effect in clearing the deck of water. The weight of water which the well will hold when the vessel is upright is 186 tons, but when she is inclined to 10° it will only hold 98 tons, and when inclined to 20° it becomes reduced to 28 tons. These figures and the curves in Fig. 1 show that water in the well of such a vessel cannot materially affect her stability after a small angle of inclination has been reached, and that so far as stability is concerned the well cannot be regarded as a serious element of danger.

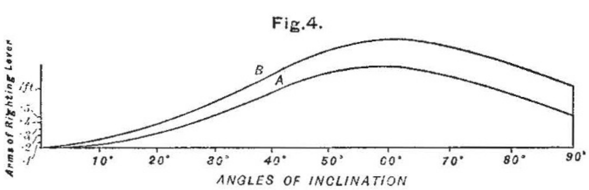
A practical point of great importance in determining the amount of stability a ship should possess at sea is the minimum metacentric height that may be regarded as sufficient for safety. Different types of vessels have quite different characteristics in respect of stability. War ships, and some classes of merchant steamers, require large metacentric heights in order to insure sufficient righting moments at moderate angles of inclination, and a safe range of stability. The curves of stability given in Fig. 2 apply to such a case. Those curves belong to a typical three-decked steamer, without any water-tight deck erections, 280 feet by 34 feet 6 inches, by 24 feet 6 inches. The mean load draught is 22 feet 6 inches, and displacement 4400 tons; the freeboard being 5 feet 4 inches. The metacentric height is 6 inches for the curve A, and 1 foot for the curve B. It is obvious that, in judging of the safety of small metacentric height for such a vessel, the range of stability is an important factor to be considered. The range necessary for seaworthiness largely determines and often fixes the limit below which the metacentric height should not be reduced in such a type of vessel and in many others.

But there are very large numbers of steamers, such as passenger liners and cargo steamers, of the spar and awning-deck classes, which generally have very large ranges of stability, and large righting moments at great angles of inclination, whatever the metacentric height may be; and in many cases, even with no metacentric height at all. In such cases the minimum metacentric height which is essential to safety and efficiency has to be determined by entirely different considerations from those which apply to war ships, and those classes of mercantile steamers whose stability is of the character shown by the curves in Fig. 2. When we have to deal with vessels which even with no metacentric height will return to the upright, provided water does not get into the ship, and no large weights shift, whatever angle of inclination may be reached, the conditions of the problem are entirely changed. The principal object which then has to be









considered is to prevent too easy an inclination from the upright by the action of the wind and other forces which may operate upon her; and the question mainly turns upon what may fairly be considered sufficient for this purpose.

Many persons have been surprised on first learning how little metacentric height many high-sided mercantile steamers are in the habit of working with in safety. There are many steamers of the spar and awning-deck classes employed in carrying homogeneous cargoes, which have been performing their work for years, not only with perfect safety but without showing any signs of what nautical men call tenderness, the metacentric heights of which, during certain periods of their voyages, are frequently not more than 8 inches or even 6 inches. The latter figure may probably be regarded as about the minimum which such vessels approach without indicating to those on board that they are becoming unduly tender: but it is quite certain that many never show any such signs, and appear to be perfectly safe with 8 inches of metacentric height.

Vessels of this class have curves of stability of which those shown in Figs. 3 and 4 are types. The curves in Fig. 3 are for a spar-decked steamer 318 feet by 40 feet by 22 feet. The load draught is 23 feet 6 inches, and displacement 5760 tons; the freeboard being 8 feet 6 inches. Those in Fig. 4 are also for a spar-decked steamer 220 feet by 30 feet by 23 feet. The load draught is 16 feet, and displacement 2000 tons; the freeboard being 8 feet 6 inches. The curves marked A in each of these figures are constructed for 6 inches of metacentric height, and those marked B for 1 foot, in order that they may be compared with the corresponding curves in Fig. 2. The metacentric height of 6 inches is about what each of these vessels would have if laden to the draughts named with homogeneous cargoes, such as they frequently carry; and the metacentric heights of 1 foot are obtained by leaving a portion of such cargo out of the 'tween decks, and replacing it by an equal weight of ballast in the bottom.

It will be seen that the increase of righting moment in Figs. 3 and 4 continues up to a very large angle of inclination. This increase of righting moment tends to prevent dangerous inclinations being reached, while the smallness of the metacentric height causes such vessels to be very easy and comfortable in a seaway. Some steamers whose stability is of this character are vessels which carry cargoes liable to shift, such as grain or coals, and it may be thought that with cargoes of this class a small metacentric height is particularly unsafe, and that considerable initial stiffness is necessary to prevent any danger arising through shifting of cargo. Any opinions that may be formed upon this point are necessarily more or less speculative, as we have but little exact information to go by; but it should be borne in mind, in considering the question of initial stiffness in connection with shifting cargoes, that, although such stiffness increases the resistance to inclination, it increases at the same time the tendency to roll, and to displace or shift the cargo.

The question of the minimum metacentric height which may be regarded as consistent with safety in those types of ships where it is not governed in any degree by the necessity of providing range of stability, as shown by Figs. 3 and 4, is a subject which has never been much discussed, and which, on account of its important and immediate bearing upon the safety of many vessels at sea, is, in my opinion, deserving of the consideration of this Institution. If any of the remarks contained in this paper should serve to elicit opinions, information, or facts bearing upon the subject, my purpose in making them will be answered.

I may add, in conclusion, that the following are the main points which I have desired to lay before the Institution in this paper:—(1) The form in which the results of stability calculations can be put before owners and masters of mercantile steamers, so as to be of the greatest practical use in loading such steamers, and regulating their stability in accordance with the requirements that may arise; (2) the fundamental difference which exists between the relation of righting moments at large angles of inclination and range of stability to metacentric height in the various types of steamers, as shown by Figs. 2, 3, and 4, such relation making it necessary to fix the minimum metacentric height that should be allowed with due regard to the righting moments at large angles of inclination in some cases and unnecessary to do so in others; and (3) the minimum metacentric height that may be regarded as consistent with safety in cases where range of stability and the righting moments at large angles of inclination are so ample as not to call for consideration. The two latter points are so intimately connected with the first that they naturally require to be considered along with it.

THE INSTITUTION OF NAVAL ARCHITECTS

THE Institution of Naval Architects held its twenty-fifth Session at the Rooms of the Society of Arts on April 2, 3, and 4, Lord Ravensworth in the chair. Whilst the papers read were of course mainly on technical questions of naval construction, equipment, &c., some of them possessed points of general scientific interest, of which a brief account may be given. The President's address dealt mainly with what may be called the economic side of the shipping industry, dwelling on such points as the Merchant Shipping Bill, the length of time occupied in building ships of war, the depression of the carrying trade, &c. Passing on to the papers contributed, the first read was by Mr. J. D. Samuda on the *Riachuelo*, a steel armour-clad twin screw turret-ship of 6000 tons displacement, and 6000 horse-power, lately built by his firm for the Brazilian Government.

The second paper, by Mr. A. F. Yarrow, was on an Electrical Launch tried last year both on the Thames and on the Danube,