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Description of the G. M. Balance or Stability Indicator for Ships.

(WITH DEMONSTRATION.)

On Monday, October 3, 1910.

By Mr. C. W. FREDERICKS (assisted by Mr. Edwin Tate).

Chairman: Mr. J. CLARK (Convener of Experimental Committee).

The proper stowage of a ship's cargo with relation to stability has up to the present time been left entirely to the discretion of the masters, officers, and stevedores, with little or nothing to assist or guide them beyond their own experience and judgment. It is true that some ships are supplied by the builders with curves of metacentres, displacement scales, etc., but unless those concerned have had special opportunities for mastering the necessary calculations of naval architecture, the information, as supplied, is of little or no practical value. Furthermore, assuming that those responsible for the proper loading of the ship have made themselves proficient in the necessary calculations, enabling them to satisfy themselves as to her condition of stability at any given moment, the process of arriving at a result desired, under many conditions of loading and certain defined circumstances, is an intricate and long one; the liability to err being consequently great. The Merchant Shipping Act of 1894 empowers the Committee of Lloyd's Register to assign certain and defined freeboards to ships, based upon a percentage of spare or reserve buoyancy; and by the observance of the corresponding Regulations, all actual overloading is prevented—in itself a very important factor of safety.

The freeboard of a ship as defined by Regulations, however, does not assure, or even indicate, her condition of stability, for should the centre of gravity be brought too high by a wrong stowage of cargo, the fact of the ship having, or going to sea with, the freeboard assigned could not prevent her from capsizing. The G.M. Balance or Stability Indicator is designed with the object of indicating, by a most simple, efficient, and reliable method, the state of stability of a ship under any condition of loading—actual or contemplated—and at any given moment—thus constituting a further and most important factor of safety and seaworthiness.

Without much doubt, in the majority of instances, the many ships that put to sea and of which nothing more is heard have met disaster in capsizing—turning turtle—through a lack of stability due to a wrong distribution or stowage of cargo, combined with a want of knowledge, on the part of those responsible, of the stability conditions of ships concerned prior to leaving port. This more especially in the instance of a ship on her maiden voyage; and, or, of others, where those responsible for the stowage of the cargo have not had sufficient opportunities of judging, or studying, the behaviour of their vessels under different conditions of loading, and particularly when encountering heavy weather. Further, the casualties due to founderings at sea are brought about principally during heavy weather by excessive rolling, causing the shifting and breaking loose of cargo, straining and opening of seams, and similar disasters, all attributable initially to the wrong distribution or stowage of cargo and want of knowledge of the actual condition of the ship's stability prior to leaving port. As is well known and acknowledged by all, the most carefully designed and built ship can be rendered absolutely unseaworthy and exposed to dire disaster at any time by bad stowage of cargo—i.e. its wrong vertical distribution—while it is equally well known that what is considered a crank vessel can be made perfectly seaworthy and safe in as far as that most important point stability is concerned, by a proper vertical distribution on board of the deadweight she is destined to carry. This particularly in the case of the modern cargo steamer fitted with water-ballast tanks, by means of which, in the majority of instances, the height of the centre of gravity of ship and cargo, upon which the entire question of stability depends—once the design of ship has been definitely decided upon—can be so considerably and easily influenced. Most interesting facts were elicited bearing on the foregoing points at the discussion following the reading at this Institute by Mr. Tate (Inventor of the Stability Indicator) of a paper on the Stability of Ships on April 4.

To emphasize the importance that stowage bears to stability and of the extent of the disasters known to have occurred to ships, it is only necessary to add that during the five years 1902–3–1906-7 embraced by the Official Returns of the Board of Trade, no fewer than 119 British steamers of a net register of 72,532 tons were totally lost by founderings at sea and included in the missing lists. The casualties resulted in the loss of 1,606 lives, the value of the ships and cargoes amounting initially to several millions of pounds ; this, it should be borne in mind, during the short period of five years only—and British steamers alone considered. Of course the deplorable fact about these figures is the loss of life, especially when we consider that the masters and officers, and in some cases part of the crews, constituted some of the finest seamen of our Mercantile marine ; fellow countrymen whose importance in the event of a maritime war into which we might be drawn, it would perhaps be impossible to overestimate.

The construction of the Stability Indicator is based upon the buoyancy, transverse metacentre, displacement, and other naval architectural calculations, and by a careful study of the instructions for use, supplied with the instrument, its method of working and utility can be readily understood. The results of the calculations alluded to are so combined and demonstrated, that the practical information required is obtained by the most simple of mechanical operations ; the calculations necessary being reduced to a minimum. For the information of those unacquainted with the knowledge of stability calculations and terms, it is necessary to state that :—

The centre of gravity of a ship is the point at which the whole weight of the ship and everything on board is centred, and alters in position as the ship is being loaded or unloaded.

The transverse metacentre is an imaginary point which may be considered the fulcrum or point of suspension below which the centre of gravity of ship and cargo swings when the vessel is heeling over or oscillating amongst waves.

The movement of a pendulum may be taken as most easily and truthfully illustrating the heeling or rolling of a ship in a seaway, the bob of the pendulum representing the centre of gravity of the ship and cargo and the fulcrum or pivot upon which it swings representing the metacentre. The metacentre changes with the draught, but at defined draughts is always at the same distance above the keel in a vertical line drawn from the keel upward through the centre of the ship—this up to from 12° to 15° angle of heel. At greater angles of heel the metacentre is not a fixed point but changes in position according as the underwater form of the ship alters at different and wide angles of heel.

The centre of gravity must be kept below the transverse metacentre, otherwise the ship would be in an unstable condition.

The metacentric height, "G.M." or margin of safety—all synonymous terms—may be termed or considered for practical purposes connected with the G.M. Balance, the measure of the vessel's stability, and is the distance the centre of gravity of ship and cargo is below the metacentre. Thus, if the centre of gravity of a ship and cargo is found by the G.M. Balance to be at 18 feet above top of keel and the metacentre for draught corresponding to deadweight on board is shown by scale to be at 19 feet, then the metacentric height or measure of ship's stability would be 1 foot. The Stability Indicator is especially invented to provide a simple, easy and absolutely reliable method of finding the metacentric height under any and all conditions of loading, actual or proposed. Apart entirely from the all-important relation its use must bear upon the increased safety to life and property, the instrument will also be the means of obviating much unnecessary work and anxiety, as well as saving of time and consequent needless expenditure. With regard to the latter factors, take for example a ship obliged to put to sea with a specified quantity of cargo ; a certain proportion of which, for adequate reasons, is stowed in upper holds or on deck. The master is not satisfied that the ship will be sufficiently stable without ballast, and to be on the safe side he fills his ballast tanks. With a Stability Indicator he could, in a very few minutes, ascertain if his ship would be safe without the ballast, and if such were the case, the time, consumption of fuel, wear and tear of machinery, etc., in filling, and subsequently emptying, the ballast tanks would be avoided, as well as the loss of speed, equivalent to loss of time and increased consumption of coal brought about by the additional displacement consequent on carrying the ballast. Again, there are some ships which are thought to be crank, and there are occasions when stevedores refuse to unload such ships before their ballast tanks are filled, or ballast is put into some of the holds as the cargo is taken out. The master may be unable to satisfy the stevedores that this is unnecessary and may not be certain of the point himself. By the use of the G.M. Balance he could, at once, place the matter beyond all question, with the result that, if unnecessary, the filling of the ballast tanks or taking on board other ballast would be avoided. The positions in the foregoing instances may be reversed. The ship may be unsafe in a certain condition to which it is proposed to bring her either in loading or discharging cargo, when considered to be perfectly stable. Under these circumstances, a reference to the Stability Indicator beforehand would be the means of obviating a most serious disaster. Again, a ship often goes to sea, when loaded, in a condition of stability far too stiff—i.e. with too great a metacentric height—and rolls very heavily even when the sea is comparatively calm. There is, in this instance, great discomfort to passengers ; a waste of power and consequent loss of speed, as well as, should heavy weather be experienced, severe rolling strains to hull of ship.

This could be obviated and absolute and proper stability assured by a judicious stowage of cargo made simple by the use of the Stability Indicator.

The instrument is compact and simple, and by its use the master of a ship in his cabin, or the superintendent in his office, can so gauge the loading of his ship that she may be enabled to put to sea under the best conditions of seaworthiness as regards stability and freedom from excessive rolling. The G.M. Balance consists of a beam, the length of which, from approximately 2 feet to 3 feet, is made in proportion to the depth of the ship concerned, from any reasonable height above the uppermost deck, as may be required, to the keel. On this beam is marked, to scale, the positions of the tank top, decks, etc. ; also a scale of the positions of the transverse metacentre at different draughts from the light condition of the ship to the load line, and a scale of the deadweights corresponding to the respective draughts. At the bottom of the beam is a bar, on which weights can be suspended at any desired point, the centres of the cubic capacities of the different holds, coal bunkers, and ballast tanks, being given for this purpose, and indicated on the beam.

The beam represents the ship when in light condition, and the weights referred to represent deadweight, i.e. cargo, coal, and water ballast, and are proportionate to same. The weights range in number and size with the dimensions of the ship concerned, and have hooks by means of which they can be attached in position on the bar. Two side davits support the beam, whilst a centre one is utilized for balancing purposes by means of a lever attachment. When the beam is balanced at this lever, the indicator on the latter denotes the position of the centre of gravity of the ship ; whilst the metacentric height is demonstrated by the distance the last mentioned (centre of gravity) is below (nearer the keel) the metacentre mark corresponding to the draught concerned. Weights can be placed on the bar of the balance representing all the cargo, coal, etc., to be taken on board, and this equally as well prior to loading as during or subsequent to same. The stowage can be so arranged that the required margin of safety, or satisfactory condition of stability and seaworthiness, be arrived at with all certainty under any or all conditions or circumstances. With regard to mixed cargo, and, or partially filled holds, the positions on the bar of the Balance of weights corresponding to such cargo can be readily ascertained by following the detailed instructions supplied with each instrument. It will be understood that the Stability Indicator and weights must be specially constructed for each individual ship, based on her dimensions, lines, etc., necessitating specific additional information, peculiar to the ship for which it is intended.

It is essential to bear in mind in connection with the Balance that the centre of gravity must always be below the metacentre for the draught concerned. If the centre of gravity comes above the metacentre, i.e. if the metacentre mark for the draught concerned is nearer the keel than the indicator on the balancing lever when the beam is balanced (or what may be termed a minus G.M. demonstrated), it indicates that the ship would, under such conditions of loading, be unstable, and would be most liable to turn turtle. It is evident that should the minus G.M. be sufficiently pronounced, the ship would undoubtedly capsize. When loading with homogeneous cargo (i.e. cargo of the same bulk and weight) and the holds are entirely filled, the weights representing same are to be hung directly below the arrow marks on the beam, indicating the centres of the volume of the respective holds. In like manner the weights representing coal on board (when bunkers are full) are to be hung in the centres—as indicated—of the cubic capacities of the respective bunkers. When the vessel is loaded with cargo of different weights, each kind of cargo should be treated separately, and weights representing same should be placed on the bar in the calculated positions of the centres of the weights of the separate stowages. Similarly, when bunkers are partially emptied, the weights representing coal must be placed on the bar in a corresponding position, i.e. in the calculated centre of the weight remaining. A small (or no) metacentric height would prove a ship to be *tender* and unfit for putting to sea.

The metacentric height should never be less than 9 *inches.* A loaded steamer with a metacentric height of from 9 inches to 2 feet 6 inches, according to the type of vessel, would be perfectly safe as regards stability with an easy motion and free from excessive rolling; while a metacentric height of several feet would indicate her to be stiff and in bad weather liable to become dirty, uncomfortable, and subject to heavy rolling strains. It is advisable when a ship is putting to sea in a very light condition that the metacentric height be a relatively ample one. No general hard and fast rule, however, can be laid down as to the behaviour of ships; but special information is furnished with each balance based upon the calculations for getting out the G.Z. righting levers—giving minimum and maximum G.M.s or metacentric heights most suitable for the ship concerned, enabling those responsible, if directions are followed, to leave port under the most favourable seaworthy conditions possible at any draught.

Additional information peculiar to each separate ship, to facilitate the working of the Balance when loading with mixed cargo in varying quantities, is also supplied with each Balance as sent out for use, together with Book of Rules to be observed when using the instrument, if in doubt at any time as to method of arriving at height above keel of the centre of gravity of any particular stowage comprising part of deadweight on board. The advantages derived from the use of the Stability Indicator are of the greatest importance, embracing as they do :—The all-important factor of increased safety to the lives of seamen and passengers ; less liability of total loss of ship and cargo, and consequent monetary saving to owners, underwriters, and insurance companies ; saving of time and labour, etc., for shipmasters in matters of ballasting to ensure stability ; freedom from anxiety to the masters, and others responsible, with regard to the stability of their ships under (possibly to all concerned) new and dubious conditions of loading ; a factor for ensuring the best possible speed of the ship at an economical consumption of coal ; the possibility of always ascertaining with all accuracy the maximum quantity of cargo, and minimum of water ballast, ship can load while retaining perfectly seaworthy conditions ; a preventative against undue straining, and consequent liability to repairs, by excessive rolling, as well as possibly avoiding the most serious disasters brought about by shifting of cargo ; increased comfort to passengers ; and in particular, be the means of ascertaining, at any given moment, the safe or otherwise condition of a ship, thereby assisting materially the prevention of disaster by capsizing.

A demonstration was then given with the instrument, weights representing the cargo being suspended on the balance in position according to the distribution of the cargo in the vessel throughout the different holds, tanks, etc. On the whole of the cargo being represented the beam was balanced and the metacentric height ascertained, showing that the cargo was distributed in such a manner as to give a good margin of safety.

DISCUSSION.

Mr. F. M. Timpson: Is an Indicator required for every vessel ?

Mr. Fredericks: Yes, it should be carried on board the vessel and taken away with her. It is designed according to the lines and dimensions of the vessel.

Mr. Timpson: How would it be used on a ship rolling about when loading up say in an open roadstead.

Mr. Fredericks: If the officer took the instrument ashore he would be able to use it, as he would know the load he was putting in. If the ship were pitching or rolling, it would be impossible to use it on board, but no doubt the officer would have opportunities of taking it ashore.

Mr. Cruickshank: It could be hung upon gimbals.

Mr. Fredericks: Yes, that would enable one to arrive at an approximate result.

Mr. Timpson: In some cases it would be rather difficult to get ashore.

Mr. Fredericks: It would be difficult in some cases, but in the majority of cases it could be done.

Mr. Timpson: It would be on that class of vessel that the Indicator should be of the greatest service.

Mr. Fredericks: That is so with ships loading cargo here and there, and stowing it on deck or between decks the instrument should be of great service. There might be cases of loading in which some difficulty may be experienced in obtaining results, but surely to ascertain a knowledge of the stability conditions of a ship warrants some little inconvenience or trouble. Where there is homogeneity of cargo there would be little or no trouble in securing results.

Mr. Cruickshank: What would be the cost of the instrument ?

Mr. Fredericks: The price is according to the size of the ship, from thirty to fifty guineas.

Mr. Cruickshank: That would include all the weights for the particular ship?

Mr. Fredericks: Yes, we also give a paper of special instructions with each Indicator. We work out the righting levers when necessary, and so arrive at the proper metacentric height to suit the type of vessel concerned and for each ship recommend a minimum and maximum metacentric height.

Chairman: You work out your calculations from the original drawings of the ship, I presume, and those particulars enable you to make the instrument to suit the ship.

Mr. Fredericks: Yes, that is right; and any information influencing the stability that is peculiar to the ship we give.

Mr. D. Hulme: There is one question I would like to put in reference to the stability. We have found in ships that were discharging and taking in cargo, that the tunnel bearings in connection with the engines used to change temperatures according to the strains put on by the motions of the cargo; but I was wondering what effect such would have on the stability of the ship. I have known boats raised 6 feet by the head or dipped by the stern; what difference would this make to the stability when the boat is inclined to this extent from an even keel? These were torpedo boat destroyers.

Mr. Fredericks: With reference to the trim of the ship, unless this were very excessive there would be very little difference as far as the readings of the G.M. Balance are concerned. I do not think the trim of a ship would ever be so excessive as to make any difference to her stability. It would be quite a negligible factor.

Mr. Timpson: I suppose the instrument is all based on the midship section?

Mr. Fredericks: Not merely on the midship section. It is designed on the lines of the ship and her dimensions and made to scale.

Mr. Timpson: I think there is no doubt that in the future there will be more inquiry into the stability of ships. What official body decides the stability; is there any authority?

Mr. FREDERICKS : None whatever.

CHAIRMAN : It is just possible that it is due to you naval architects yourselves. In one case you say there should be a good metacentric height and in the other case you say if it is too much it will be a dirty, wet boat. Have you an instrument for yachts ?

Mr. FREDERICKS : No, not yachts, but we have for turret ships and other special types.

CHAIRMAN : Of course in all ships the body sections are pretty much the same. In yachts there are different forms of midship sections, which perhaps influence their behaviour in a seaway even as much as the metacentric height.

Mr. FREDERICKS : By that I take it you mean what metacentric height should a yacht have, what stability ? Of course the question of the metacentric height depends a great deal on what reserve, or spare buoyancy, a ship has. If there is very little, the metacentric height should be greater because her righting power decreases quickly with the angles of heel ; if there is a great deal of reserve buoyancy the metacentric height can be correspondingly low.

CHAIRMAN : Some yachts would have about 3 feet metacentric height ; that would no doubt be considered high in a steamer. As a rule in yachts we do not find a wet boat with a big metacentric height, provided the freeboard is right.

Mr. FREDERICKS : Of course a sailing vessel should have a big metacentric height. The sails have a steadying effect and prevent excessive rolling which might take place in a steamer with a large metacentric height.

CHAIRMAN : Have you applied the instrument to a sailing ship ?

Mr. FREDERICKS : We have not done so yet, but we could if required. We should ascertain the wind pressure on the sails and recommend a metacentric height which would give sufficient righting power to withstand that pressure.

CHAIRMAN : Have you ever actually tested the instruments.

Mr. FREDERICKS : The instrument can be tested by calculations. We never send one out unless it is absolutely correct and we are certain it gives correct results. You are thinking of the heeling experiment, no doubt.

CHAIRMAN : Yes.

Mr. FREDERICKS : The instrument is based on the heeling experiment in the first instance. The important factor in its design is the knowledge of the vertical position of the centre of gravity of the light ship and that is found by the heeling experiment. No instrument can be made unless the heeling experiment has been carried out or the vertical position of the centre of gravity of ship in light condition otherwise ascertained by the corresponding elaborate calculation.

Mr. TIMPSON : Do you consider the tendency in modern vessels is to make a more stable ship ?

Mr. FREDERICKS : Yes, I think that is the tendency. They are increasing the beam, and it is the beam that is the chief factor in raising the metacentre.

Mr. TIMPSON : Do you consider then that the square hulls are more stable than the more deep ones ?

Mr. FREDERICKS : I will not say that. Ships are now built with little rise of floor. That of itself was good for making a stable ship, and in taking away the rise of floor increase in beam is made accordingly. But certainly the tendency now is to give more beam.

Mr. CRUICKSHANK : But is not the effect of the extra beam reduced by the extra top weights ?

Mr. FREDERICKS : Of course it is sometimes counteracted in that way.

Mr. CRUICKSHANK : In many cases the extra top weights seem to be more than the extra beam.

Mr. FREDERICKS : That is certainly the case in some instances, but naval architects calculate out the amount of top weight and ascertain the position of the centre of gravity. By keeping the centre of gravity low in the vertical distribution of deadweight powerful righting levers are secured. The centre of gravity should be kept sufficiently low by a discreet vertical distribution of the deadweight to give righting levers of sufficient power to withstand any stress of weather that may be put upon the top hamper. In the old days the sails were very high and very large, but the centre of gravity must have been low in proportion. In some cases those sailing ships would have from 6 to 7 feet metacentric height.

Mr. CRUICKSHANK : The old ships were lofty, but there was no squareness about them.

Mr. FREDERICKS : No, but the higher the masts and sails the greater leverage would be set up by the wind pressure.

Mr. CRUICKSHANK : It is only within the last twenty-five to thirty years that they have had the big square yards as the sailing ships have now.

Mr. FREDERICKS : In steamers that carry square sails the centre of gravity should be kept low. The important thing is that officers should know where the centre of gravity of a ship is, and what righting levers and what stability she has.

CHAIRMAN : We are very much indebted to Mr. Fredericks and Mr. Tate for coming to-night. It has been a most interesting demonstration and perhaps preferable to what was down on the syllabus, viz. a fuel test. There are certainly more present than we would have got for the coal test. We are much indebted to these gentlemen, and I beg to move a hearty vote of thanks to them.

Mr. JAS. ADAMSON (Hon. Secretary) : I have much pleasure in seconding this vote of thanks to these gentlemen for coming to-night and placing this before us. I do not know whether it would be possible to have a tank and a model body so that we might actually demonstrate what difference is made through the different positions of the weights in draught, trim and heeling tendency. I think it would be an interesting ocular demonstration that would make the subject clearer.

Mr. E. TATE : It could be done with a wooden model.

Mr. ADAMSON : With regard to the remarks made by Mr. Timpson, I believe the instrument before us is going out this week with the ship which has been used for demonstration, so that it may be utilized not only in London for the outward cargo, but also at outports for the homeward cargo. Evidently, therefore, the use of the instrument is not confined to this part of the world. I have much pleasure in seconding the vote of thanks to Mr. Fredericks and Mr. Tate for coming here to-night.