THE ROYAL INSTITUTION OF NAVAL ARCHITECTS
AUSTRALIAN DIVISION

DISCUSSION PAPER NO. 1

SIMPLIFIED STABILITY DATA

FOR

SMALL CRAFT

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BRIEF

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FAX No : 03 9722 2234 PAGE 1 OF 1 DATE: 27 March 1996

TO : Mr R J Herd FROM: N T Riley

SUBJECT: SIMPLIFIED STABILITY DATA FOR SMALL VESSELS

Bob,

You may recall that in the few words I made after you handed the meeting over to me last week I mentioned the perceived need to revisit the presentation of stability data for small vessels that are registered under the USL Code.

In recent times I have run across the situation where a vessel has been provided with a complete stability book and the personnel operating the vessel do not have the training or background to comprehend the information contained therein let alone prepare alternative conditions. I think that you will agree that the preparation of a formal stability books in applications such as this is a pointless exercise and that RINA should be looking at bringing in a system that can be of use to vessel operators.

The sort of thing that I have in mind is to prepare a simplified book that gives a table of limiting KG's against displacement and a worked example on how to arrive at an operating KG.

If you agree with this approach I could think of no one better qualified and experienced than yourself to bring this project to fruition. Once we have something to show then we could arrange to have a meeting with the various authorities and get their reaction.

I will be grateful for your comments.

Regards

N T Riley

FOREWORD

I have taken up the challenge expressed in the President's brief and after considering all aspects of the subject and discussing it with some of those in regular contact with the operation of small craft in Australia have prepared this Discussion Paper.

It is my earnest hope that this paper will stimulate informed discussion among our members which will result in the presentation of an Institution proposal to be made to the Regulatory Authorities.

It is my further hope that this paper will be the first in a series of such Discussion Papers directed towards developing Institution views on subjects of topical interest, particularly in respect of Marine Safety.

R. J. Herd

CONCLUSIONS AND COMMENTS

This paper is a short review of the different approaches which have been made to the preparation, presentation and usage of simplified stability data.

To fully develop all the issues which have been raised would require a much longer paper than appears to be warranted at this stage.

It is proposed that after consideration by the members, a round table discussion could be advantageous. For such an occasion, particular facets of the subject could be developed in more detail.

It should be noted that at this stage no attempt has been made to extend the paper to cover stability after damage.

As a result of the investigations made for the purposes of this paper, a number of points are worthy of stress:

- Whatever form of stability information is adopted, this should be incorporated into the education and training of those personnel whose responsibility it will be to use it.

- Free surface effects must be allowed for in determining limiting KG and GM curves.

- Because IMO criteria are minima and all hydrostatic and stability calculations have a tolerance this should be incorporated into limiting data provided to the ships.

- In the absence of significant data for radii of gyration for local types of vessel, it is unwise to use the rolling period as other than a check on GM values determined by calculation.

- The rolling period test should only be used at sea as a check on GM or radius of gyration, not as a first determination of stability.

Conclusions and Comments (Cont.)

- All simplified stability data must be accompanied by full data which should be available on board to enable consultation with more experienced mariners in the event of queries arising.

- Consideration must be given to the effects of severe wind and rolling, water on deck, loss of stability in longitudinal waves and allowance made for these effects.

INTRODUCTION

The quest for simplified presentation of stability data has extended over many years and been considered in a number of countries without so far as is known achieving resolution satisfactory to all parties.

Approaches adopted by some of the countries where the problem has been studied will be reviewed briefly and conclusions drawn where possible.

For the purpose of this paper "small craft" will be defined as being less than 60 m in length, without, so far as is practicable, differentiation as to type of vessel.

INTERNATIONAL REQUIREMENTS

There are various International Maritime Organisation instruments which spell out the type of information which should be provided for the guidance of the Master in loading and operating his vessel safely. These include:

1. **SOLAS 1960**
   Chapter II Part B Regulation 19

"The master shall be supplied with such reliable information as is necessary to enable him by rapid and simple processes to obtain accurate guidance as to the stability of the ship under varying conditions of service ....."

2. **SOLAS 1974**
   Chapter II - 1, Part B, Regulation 19

As for SOLAS 1960

International Requirements (Cont.)

3. TORREMOLINOS INTERNATIONAL CONVENTION FOR THE SAFETY OF FISHING VESSELS AS CONSOLIDATED BY THE 1993 TORREMOLINOS PROTOCOL.

Chapter III Regulation 10 (Identical Text To Regulation 36 In The 1977 Convention).

"Suitable stability information shall be supplied to enable the skipper to assess with ease and certainty the stability of the vessel under various operating conditions. Such information shall include specific instructions to the skipper warning him of those operating conditions which could adversely affect either the stability or the trim of the vessel."

Recommendation 3 made by the Conference spells out in more detail the information and instructions which should be provided. In particular information as required by the following alternatives is detailed:

a) If GZ calculations are intended.
b) When rolling tests are used.
c) Simplified information.

4. CODE OF SAFETY FOR FISHERMEN AND FISHING VESSELS, PART B, SAFETY AND HEALTH REQUIREMENTS FOR THE CONSTRUCTION AND EQUIPMENT OF FISHING VESSELS

Chapter IV Stability Includes Under 4.4. Stability Information -

4.4.1 The skipper should have on board information which will enable him to assess with ease and certainty the stability of the vessel in different service conditions and to verify whether the stability is sufficient in conditions differing from the standard ones in 4.6.

International Requirements (Cont.)

5. FAO/ILO/IMCO VOLUNTARY GUIDELINES FOR THE DESIGN, CONSTRUCTION AND EQUIPMENT OF SMALL FISHING VESSELS.

"Small" applies to new decked fishing vessels of 12 metres in length and over, but less than 24 metres in length. (The documents listed under 3 and 4 above apply to vessels of 24 metres length and above).

While 3.2.1 states that
"Normally full stability information should be developed ..."
no descriptive comments on the stability information to be placed on board are provided.

6. CODE ON INTACT STABILITY FOR ALL TYPES OF SHIPS COVERED BY IMO INSTRUMENTS.

Chapter 2 Addresses General Provisions Against Capsizing And Information For The Master

Section 2.1 Stability Booklet, in 2.1.3 gives detailed instructions on the format of the booklet.
2.1.4 provides that
As an alternative to the stability booklet mentioned in 2.1.2, a simplified booklet in an approved form containing sufficient information to enable the master to operate the ship in compliance with the applicable provisions of the Code may be provided at the discretion of the authority concerned".

AUSTRALIAN REQUIREMENTS

1. COMMONWEALTH OF AUSTRALIA NAVIGATION ACT 1912

Marine Orders Part 13, Ship Stability and Subdivision made under Section 425 (1AA) of the Navigation Act 1912.

3. Intact Stability Information, supplemented by Appendix 1 discusses the requirements for stability books. Except in respect of non-Load Line Convention ships complete information is required. In respect of non-Load Line Convention ships, 3.3 includes provision for

"a) detailed instructions as to limitations on acceptable safe loading, tank handling, use of cargo gear and closure of openings;

b) tables or diagrams showing limited loaded KG, GM or deadweight moments, together with lightship, tank and cargo space particulars to enable those tables or diagrams to be related to actual conditions of loading; or

c) a combination of (a) and (b) or a combination of 3.2 and 3.3 (a) and (b)".

2. UNIFORM SHIPPING LAWS CODE

Section 8 of the Uniform Shipping Laws Code deals with Stability.

Sub-Section A in Clause A4 spells out in detail the requirements for presentation of stability data for vessels other than those subject to Clause B.2 of Section 8.

Clause B.1 requires that where simplified stability information is to be posted in the wheelhouse, submission of full information should accompany the submission of the simplified data to the Authority.

Clause B.2, Form of Simplified Stability Data states -

Uniform Shipping Laws Code (Cont.)

"This simplified stability information may take the form of either:

a) instructions as to limitations on loading, tank capacities, use of cargo gear, closure of openings etc. together with a statement as to the responsibility of the Master in maintaining the vessel in a satisfactory state of stability at all times; or

b) diagrams showing limiting deadweight moments at various draughts, together with the assumptions as to the state of the vessel's tanks on which the diagrams are based. (Particularly useful in the case of vessels carrying deck cargoes); or

c) a diagram showing a limiting GM value plotted against draught or displacement. (Some notations concerning assumptions as to free surface and/or appropriate correction may be necessary).

GENERAL CONSIDERATION OF THE PROBLEM

In the operation of any vessel there are two main areas of responsibility:

- The naval architect should provide the owner and master with a vessel which is seaworthy and can be operated safely.
- The master must load and handle his vessel so that it is at all times safe and seaworthy.

The link between these two responsibilities lies in the provision by the naval architect of information and instructions in the stability book to enable the master to load his vessel safely.

The stability book should contain information which

- is complete
- is reliable
- can be used with ease and certainty
- contains warnings about operating conditions which could adversely affect trim and/or stability

General Consideration of the Problems (Cont.)

In order to achieve these aims the stability book must be in a form compatible with the education and training of the master and officers. In order to propose a format which meets this requirement it is necessary to examine the syllabi for seagoing certificates to determine what is expected of the holders of those certificates.

Reference to Section 2 Examinations and Certificates of Competency, of the Uniform Shipping Laws Code reveals the following requirements:

- The stability knowledge required for Class I, II and III Certificates is such that holders of those Certificates should have no problem in using a complete stability book.

- For Class IV Certificates while the ability to understand and use a stability book is not specified, some appreciation of the information to be derived from curves of righting lever is required.

- For Class V Certificates, a Master Class V (Trading) is required interalia to have.

"a general understanding of stability data carried by small vessels and its use".
A Master Class V (Fishing) is not so required.

Discussion with officers of some State Marine Authorities about the standard of <u>actual</u> practical knowledge of stability books and their application in small vessels by Master IV and V candidates was discouraging. Even where stability data is presented so that establishing stability for a condition of loading by inserting figures in a number of boxes as per instructions could not be expected to be completed with any degree of confidence in the result.

Doubt was expressed about the ability of candidates generally to determine moments, estimate centres of gravity etc. (The writer has been asked recently, admittedly by a builder rather than a seaman, "what is a centre of gravity?" when endeavouring to establish light ship characteristics).

General Consideration of the Problems (Cont.)

While any proposals for simplified presentation of stability data must initially be based on the current state of knowledge and facility with handling stability books, it is clear that part of any submission to the Regulatory Authorities must be based on an upgrading of the knowledge of candidates for the lower grade certificates.

It is also considered that simplified stability data should be an adjunct to and not in place of complete stability information. This is to enable the master with the lower grade certificate to seek guidance from others familiar with the complete presentation when problems may arise.

Since the aim of having a standardised stability book when first introduced some years ago was to enable a ship's officer to find on any Australian vessel data presented in the same format, despite individual characteristics of any ships in which he may serve, this philosophy has been maintained and is expressed in Marine Orders Part 13, Ship Stability and Subdivision.

The problem of simplification of stability data is not unique to Australia, and has been addressed in other countries. A review of past approaches to the problem will be helpful in considering a new approach for Australia.

APPROACHES TO SIMPLIFIED STABILITY DATA MADE BY SOME COUNTRIES

1. U.S.A.

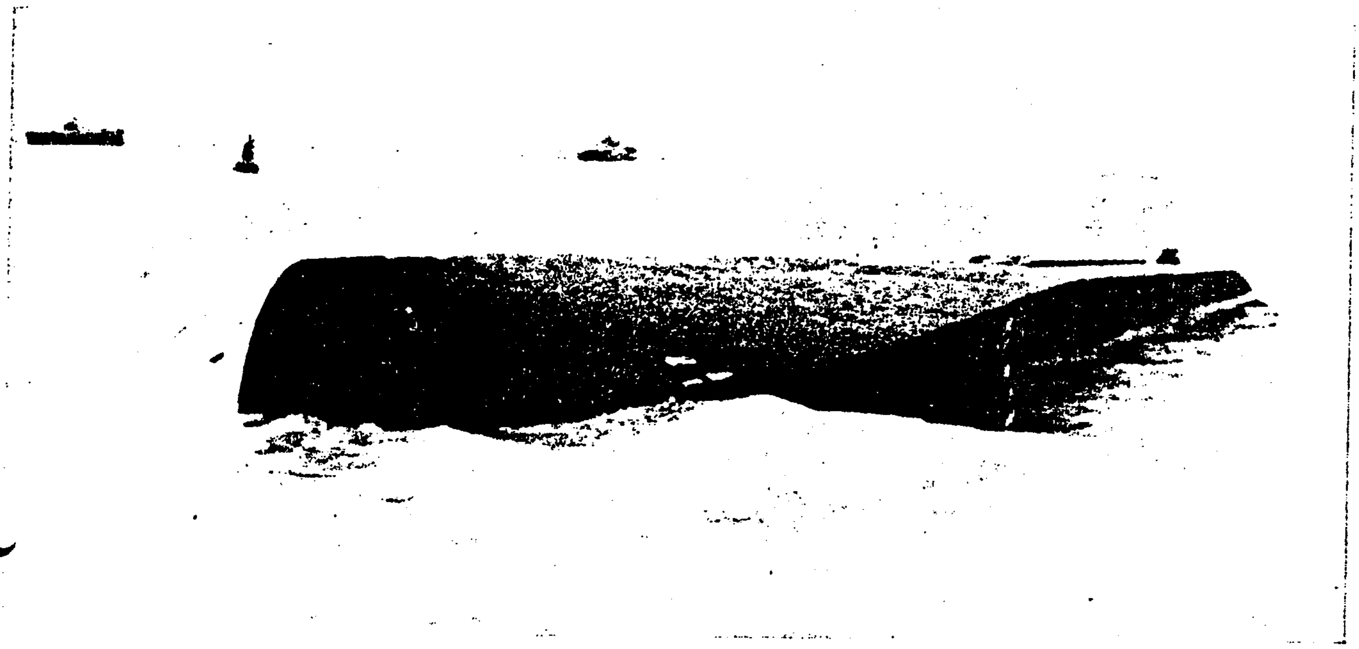
In about 1962, the ":National Pride" a shallow draught supply vessel capsized. The investigation into the loss was extended to cover a range of similar vessels. The investigation was based on the work of Professor Rahola supplemented by the work of Professor Paulling on the effects of longitudinal waves on stability.

The philosophy is explained in the attached article "Stability of Offshore Supply Vessels" taken from the Proceedings of the Merchant Marine Council, Volume 21. No.9 of September 1964.

Attachments 1 to 3 to MMT Note No.4 - 64 detail the application of the approach and give a worked example.

The letter and accompanying stability information sheet for M.V. "Recoverer 1" illustrate how the system works in practice. The stability information sheet(s) (two sheets are sometimes needed) are to be placed under a transparent sheet on the wheelhouse bulkhead of the subject vessel.

While this application relates to offshore supply vessels, an examination of the stability characteristics of any small vessel with limited tanks and cargo capacity could lead to a similar form of presentation for that vessel. It is important to note that a full stability examination to establish the validity of the stability information sheet is necessary and that the assigned load lines could be stability controlled.



THE ABOVE picture shows what happens when the stability of a flat bottomed supply vessel is impaired by overloading or improper cargo stowage.

STABILITY OF OFFSHORE SUPPLY VESSELS

BY LCDR WILFRED R. BLEAKLEY, JR., USCG
MERCHANT MARINE TECHNICAL DIVISION, HEADQUARTERS

A DESIGNER OF A SHIP has a problem in combining into a workable whole the many characteristics desired by the intended owner. Speed vs. sea-keeping, cargo capacity vs. limiting draft in harbors to be visited, cargo capacity vs. endurance, and cargo capacity vs. exemption from admeasured tonnage are some of the many conflicting aspects of a marine design. Compromises are forced upon the designer and the owner in order to obtain a ship satisfying both the needs of the owner and the expected service conditions.

Just as the designer must appreciate the owner's and operator's intended use of the vessel, so too must the owner and operator appreciate the limitations of the design.

This article discusses in nontechnical terms the stability of the small, broad, shallow-draft vessels which have evolved along the Gulf of Mexico as mobile support vehicles for the offshore drilling sites. It was originally prepared to give operators of these vessels a better appreciation of the limitations and peculiarities of that design. It is included in the PROCEEDINGS because the basic principles discussed herein are of general application.

The principal features of a typical offshore supply vessel are:

- LOA 120′ to 130′
- Beam 32′
- Depth 10′
- Load Draft 8′-4″
- Freeboard at load draft 20″
- Displacement at load draft 700 long tons
- Lightship weight 235 long tons
- Deadweight 465 long tons

The major portion of the deadweight is for cargo on deck and liquids in the "ballast tanks"—a very minor part is crew, supplies for the crew and the ship, and fuel: (about 7 to 10 tons). If peak tanks forward and aft are filled, this nonpaying deadweight would be about 45 to 50 tons. This boils down to about 400 long tons of paying cargo at 20″ freeboard.

Basically the ship type is a deck barge which has been fined up in the bow for streamlining and cut away at the stern for the propellers. Pilothouse and crew quarters are forward above the main deck. Machinery exhaust, intake and access are contained in trunks projecting up through the deck aft in an outboard position so as not to clutter the cargo area.

Cargo is carried on the broad open deck area bounded with rails, pipe stanchions, or closed bulwarks at the sides. From the quarters forward to the machinery space aft there usually is a below deck tunnel, centerline, which is flanked by large "ballast" deeptanks that extend from the bottom shell to the cargo deck. These tanks are used to transport liquids to the offshore rig.

SOME BASIC DEFINITIONS

The details of a vessel's stability can be quite technical and involved. An effort has been made to keep this discussion simple. As a first step we should review some basic terms:

- Draft: Distance from keel to waterline.
- Freeboard: Distance from waterline to deck—how close we are to being underwater.
- Metacentric height: GM—It is a measure of initial stability. As it gets numerically smaller, stability is reduced.

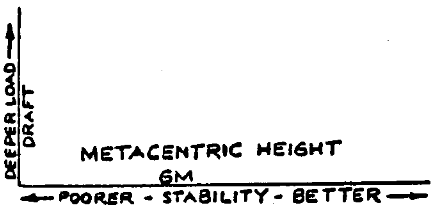


Figure 1.

Figure 1 represents coordinate axis upon which stability is commonly shown in graphical form.

Figure 2 represents a transverse section of a vessel showing the relationship of G, the center of gravity; B, the center of buoyancy; M, the metacenter, the point through which B acts.

Figure 3 is representative of a typical offshore supply vessel. We are interested in trends and not specific numbers at this point. Specific numbers are left to the naval architect. In figure three:

1. The loadline: Defines the maximum draft or more correctly the minimum freeboard. (How close we are to being under the water.)

2. The *required* GM curve (S-S): This defines the minimum stability for survival at sea, assuming the cargo is well secured.

3. The "shaded" area of the graph is the area to avoid. If we are interested in survival we stay in the unshaded area.

NOW FOR THE SHIP AND ITS LOADING (FIG. THREE)

1. Place the "bareboat" ship on the graph as A. This is the basic ship without ballast, crew, cargo, fuel, etc.

2. Put on crew, fuel and supplies and we move to point B.

3. Add a given tonnage of pipe cargo stowed 4 feet high on deck and we move to point C.

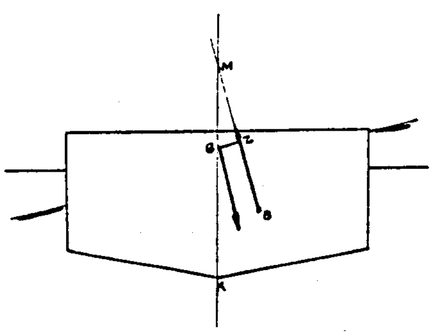


Figure 2.

4. Add drilling water in two below deck tanks till they are each half full; we move to D.

5. Press up those two "ballast" tanks and move to E. So far so good.

6. Now let us go back to point B and assume that instead of pipe we are transporting drilling mud in containers 7' x 7' x 18' or 8' x 8' x 16' mounted on skids which raise them another 6 inches off the deck. From point B load an identical tonnage to what we had before but this time the tonnage is in full or nearly full mud tanks. Since the center of gravity of the cargo is higher than before, we move to point C1.

7. Add same amount of "ballast" as before and move to D1 and E1. As you see, we are now into the shaded area. Numbers have intentionally been omitted, the principle is the important thing and that is all that is being demonstrated. It is definitely possible to load these vessels dangerously.

TO EMPHASIZE THE ABOVE

1. In adding cargo on deck we have moved toward the shaded area of the graph. *Both* freeboard and stability have decreased.

2. In adding ballast in these vessels, contrary to what you might think, the same thing happens; *both* stability and freeboard decrease. Certainly the stability did not decrease as fast as it would have if we had added more deck cargo, but it did decrease.

3. In a conventional cargo vessel when you add low ballast you get a gain in GM shown in figure 4.

4. Such is not the case when you consider an offshore supply vessel with a broad shallow-draft hull form. One nontechnical reason is because, in these vessels, adding ballast does not appreciably lower the center of gravity. In these vessels, tonnage exemption considerations plus a required capability of transporting large quantities of river water "ballast" to the drilling site (to be used as drilling water) do not provide a tankage arrangement which improves stability. The addition of liquids in the deep "ballast" tanks of these vessels never improves stability. The only thing you can say of merit is that stability decreases less than if an equal amount of deck cargo had been added. A more sophisticated reason is that, in this hull form, the displacement is increasing without significant change in the waterplane. These effects combine to reduce GM drastically.

ABOUT THE AUTHOR

LCDR Bleakley was recently assigned to the Technical Staff of CCGD9(m). He graduated from the Coast Guard Academy in 1951 and completed post graduate training in Naval Construction and Marine Engineering at M.I.T. in 1957. On previous duty assignments in the Coast Guard he has served in the Merchant Marine Technical Division at USCGHQ, in deck and engineering billets on both Atlantic and Pacific Ocean station vessels, and as a Ship Superintendent at the CG Yard.

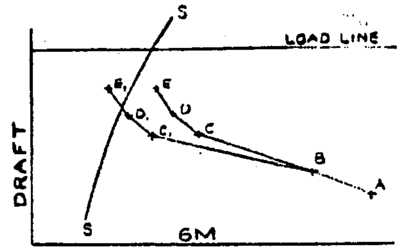


Figure 3.

HOW MUCH STABILITY IS NEEDED?

Our goal is to stay out of the shaded area. To do this we must know the boundaries of the shaded area—this is for the naval architect to determine. After the boundaries are known, we must:

1. Assign the responsibility for maintenance of stability. There must

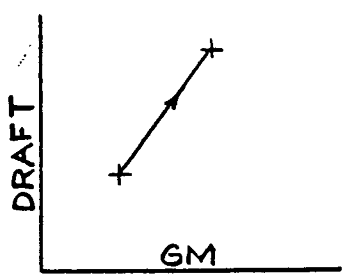


Figure 4.

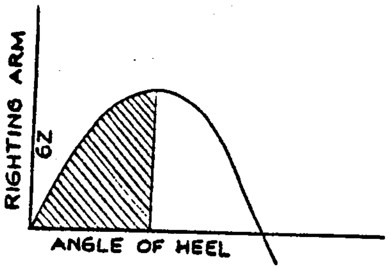


Figure 5.

be a man who knows the condition of the vessel at all times, i.e., someone in charge on board the vessel. This has customarily been the Master.

2. Give the Master a set of simple rules so that he can keep the vessel's stability "out of the shaded area."

The required GM curve which the Coast Guard feels is applicable to this type vessel is based on the work of Rahola (a professor at Helsinki) with a slight modification to take into account more recent studies by J. R. Paulling (a professor of the University of California). Paulling's studies concern the decrease in stability experienced when a ship has a wave crest amidships. For these broad shallow draft hull forms the stability decrease associated with a wave crest amidships is much more significant than in conventional forms. An example of when this stability decrease would be experienced is when running before a sea, where the vessel will be on the crest of a wave for a relatively long time in relation to the roll period.

RAHOLA CRITERIA AND DYNAMIC STABILITY

It has been mentioned earlier in this discussion that metacentric height (GM) is a measure—a yardstick if you will—of initial stability, which for convenience can be considered as stability with no heel on the vessel.

Rahola uses another yardstick, related to GM, but taking into account other factors, such as the behavior in the sea. Rahola's yardstick is called dynamic stability.

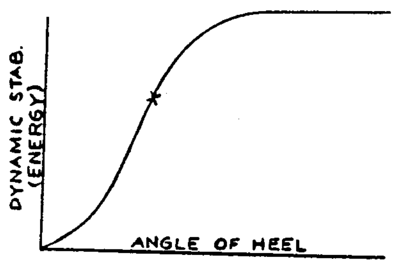


Figure 6.

Definition: Dynamic stability is a measure of the energy required to heel a vessel from upright to a given angle. Figure 5 shows the relation of the righting arm, GZ, to the angle of inclination of a vessel. This is a static stability curve.

Graphically, dynamic stability, at any point, is the area under the static stability curve up to that point, and it usually looks something like figure 6.

Rahola says, essentially, that a ship needs a certain amount (15 foot degrees) of dynamic stability to survive in a seaway. He measures this dynamic stability up to a critical angle which is determined by:

(a) A point where the dynamic stability ceases to increase appreciably with more heel; in other words, where the tendency or desire of the vessel to return to the upright condition begins to decrease. Rahola used the point where the angle of maximum righting arm or 40 degrees (whichever is less) has been reached.

If the vessel starts to flood before the previously mentioned point is reached, then "signals are off." The reason is that the vessel does not get the chance to develop its full survival capabilities which it otherwise would have if all openings were closed and the vessel did not flood. So Rahola adds the following:

(b) Or to the angle at which openings admit flood water—the down flooding angle.

A required GM curve can be computed which meets the Rahola criteria. If all openings are closed at all times the general shape of the required GM curve for this type vessel is shown by curve ABC of figure 7. But, if flooding will occur through hull openings then the vessel's heel must be limited to avoid exposing those openings, and the curve would then look something like ABD.

From this we can see that two points about openings on deck should be stressed.

1. The Master must see to it that openings which could flood the ship are kept closed. This is essential in this class of vessel where a roll of 6–10° puts the deck edge under.

2. The designer should assume that if something could go wrong it will go wrong. People will leave doors open, especially in situations with poor ventilation. Doors and other openings should be located well inboard or high up where they have less chance of being awash.

VESSEL'S TRIM IN RELATION TO LOADLINE

Sometime in your childhood days, you may well have gone swimming with other children on a raft. You noticed when the raft got crowded, that as long as you were all evenly distributed or were all near the center of the raft, you were still afloat and the raft was level. If, however, you all went to one end of the raft (mind you, the same number of people on the raft in both cases) you quickly found that the crowded end went under and maybe even scooted out from under you.

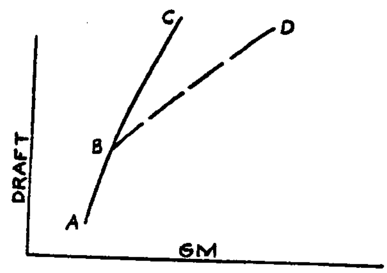


Figure 7.

A similar trimming action happens with the typical offshore supply vessel, or with any vessel for that matter. For example, load a barge evenly with cargo. The vessel is level and just has its loadline at the surface of the water. Now move the cargo to the stern. What happens? The freeboard decreases at the stern, but the loadline mark is still above water. The same thing would have happened if you had initially placed the same cargo at the stern.

The consequences of this are numerous and more significant in a vessel without a poop deck. Obviously, any hatches, such as access openings to the steering gear room, are that much closer to being under water or being washed over by waves, and any water on deck tends to reduce stability.

CARGO SHIFT

A ship with properly secured cargo can operate in the unshaded area of the previous diagram and be safe. The required GM curve shown on the left of the diagram assumes that the cargo is secured. But if the cargo is not secured and large heavy objects are allowed to careen across the deck, *you are in trouble,* and following all the other rules in the book won't help once the cargo has shifted and the vessel capsized.

Again we are back to the raft story, except that instead of moving the load to the stern we have moved it to the side of the ship. The results are generally more severe and the response quicker since there is less resistance to heeling than to trimming.

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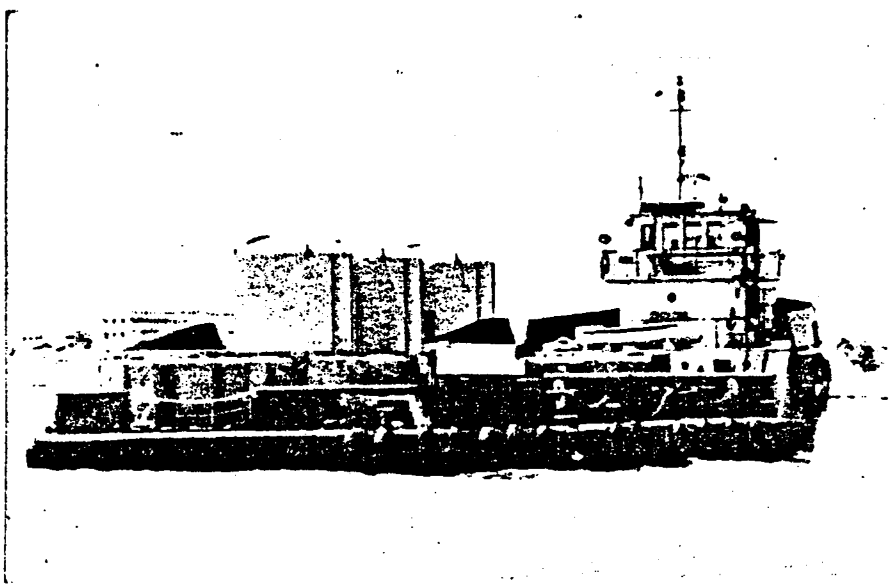


ONE EXAMPLE of an offshore supply vessel carrying heavy weights high above the waterline.

FREE SURFACE

A liquid free surface acts to the detriment of stability in a manner similar to a cargo shift. It is, however, a hidden free roving stability thief out of sight in a tank or a bilge.

Compare the trip from the kitchen sink to the refrigerator with an ice tray full of water, first without and then with the cube divider. This example of the effects of a free surface has a direct parallel to the conditions on a ship with a cross connection between the two wing tanks open or closed.

Two partially full tanks side by side in a ship with an open cross connection between them create a stability loss due to free surface which is four times that which would occur without a cross connection.

Liquid free surfaces do rob you of stability; they must be controlled by elimination of bilge water and control of tank contents.

BLOCKED FREEING PORTS:

Water on deck, held there by bulwarks, is just like tons of deck cargo except that it is also moving. This reduces both freeboard and stability. Therefore, an important design detail is the requirement for an adequate amount of freeing ports to allow the water to drain clear. The operator must insure that freeing ports are not blocked by cargo.

DOWNFLOODING

Water flooded into the internal portions of a ship is a load which reduces freeboard and also reduces stability due to sloshing back and forth or "free surface" effect.

CONCLUDING REMARKS

We have brushed over the high spots of stability, as it affects the offshore supply vessels, in an attempt to describe a rather technical subject in nontechnical terms.

From the stability viewpoint, we still have three basic things to do:

1. Determine the boundaries of the shaded area which we want to avoid. (This is the naval architect's job.)

2. Assign the responsibility for the maintenance of stability.

3. Provide the responsible person with some rules for assuring himself that he does have adequate stability at all times.

Some progress has been made on step 1. This beginning involves a series of calculations done at USCG HQ for one hull form similar to figure 2 which is representative of this type of vessel. This information is currently being used as a basis for approving stability calculations submitted to the Coast Guard for inspected and certificated vessels of this type. Because the hull forms do vary, additional work has been scheduled to include hard chine forms with more deadrise, less deadrise, a double chine form and a conventional gradual turn of the bilge form, all of which are currently in service.

The aim of these analyses is to shortstop the calculations presently necessary to determine a Rahola required GM curve by devising a family of curves from which an appropriate curve for a particular vessel may be selected without calculation. Ultimately it would be desirable to derive a simple formula using principal dimensions such as beam, draft, depth and midship section shape which would provide a curve equal to a Rahola required GM curve.

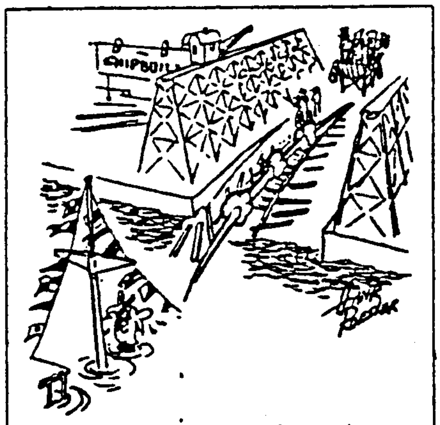
In addition to giving the owners and operators a better appreciation of the stability limitations and peculiarities of these vessels, it is hoped this article will generate additional interest and progress in the areas of steps 2 and 3 which are vital to assured, rather than chance, operation in the zone of adequate stability.

REFERENCES

1. "The Judging of Stability of Ships and the Determination of the Minimum Amount of Stability"—Rahola—Helsinki 1939.

2. "The Transverse Stability of a Ship In a Longitudinal Seaway"—J. R. Paulling—pp. 37–47—Journal of Ship Research—Vol. 4, No. 4, March 1961, published by the Society of Naval Architects and Marine Engineers, 74 Trinity Place, New York, N.Y.

3. "Transverse Stability on Tuna Clippers"—J. R. Paulling Jr.—pp. 489–495—Fishing Boats of the World: 2—Published by Fishing News (Books) Ltd., 110 Fleet Street, London, E.C. 4.



"C'MON IN!—THE WATER'S FINE!"

Courtesy Maritime Reporter

ATTACHMENT (1) TO MMT NOTE NO. 4-64

I RAHOLA STABILITY CRITERIA

A minimum standard of intact stability outlined by Professor Jaake Rahola on pages 107, 108 and 118 of his publication "The Judging of the Stability of Ships and the Determination of the Minimum Amount of Stability", Helsinki, Finland, 1939

1. Professor Rahola did a statistical and theoretical analysis of vessel casualties and arrived at certain conclusions as to the dynamic stability necessary for vessel survival. His standard is based on the operating vessel possessing a minimum amount of reserve dynamic stability when heeled to a specified angle. The criteria is that the area under the righting arm curve must equal 15 foot-degrees up to the least of the following angles:

a. 40 degrees.

b. The angle corresponding to maximum righting arm.

c. The angle at which openings immerse (down flooding).

2. The righting arms curves are based upon the vessels vertical center of gravity after correction for free surface.

3. This standard does not include the effect of moveable cargo.

II PLANS AND STABILITY INFORMATION REQUIRED FOR STABILITY ASSESSMENT OF OFFSHORE SUPPLY VESSELS

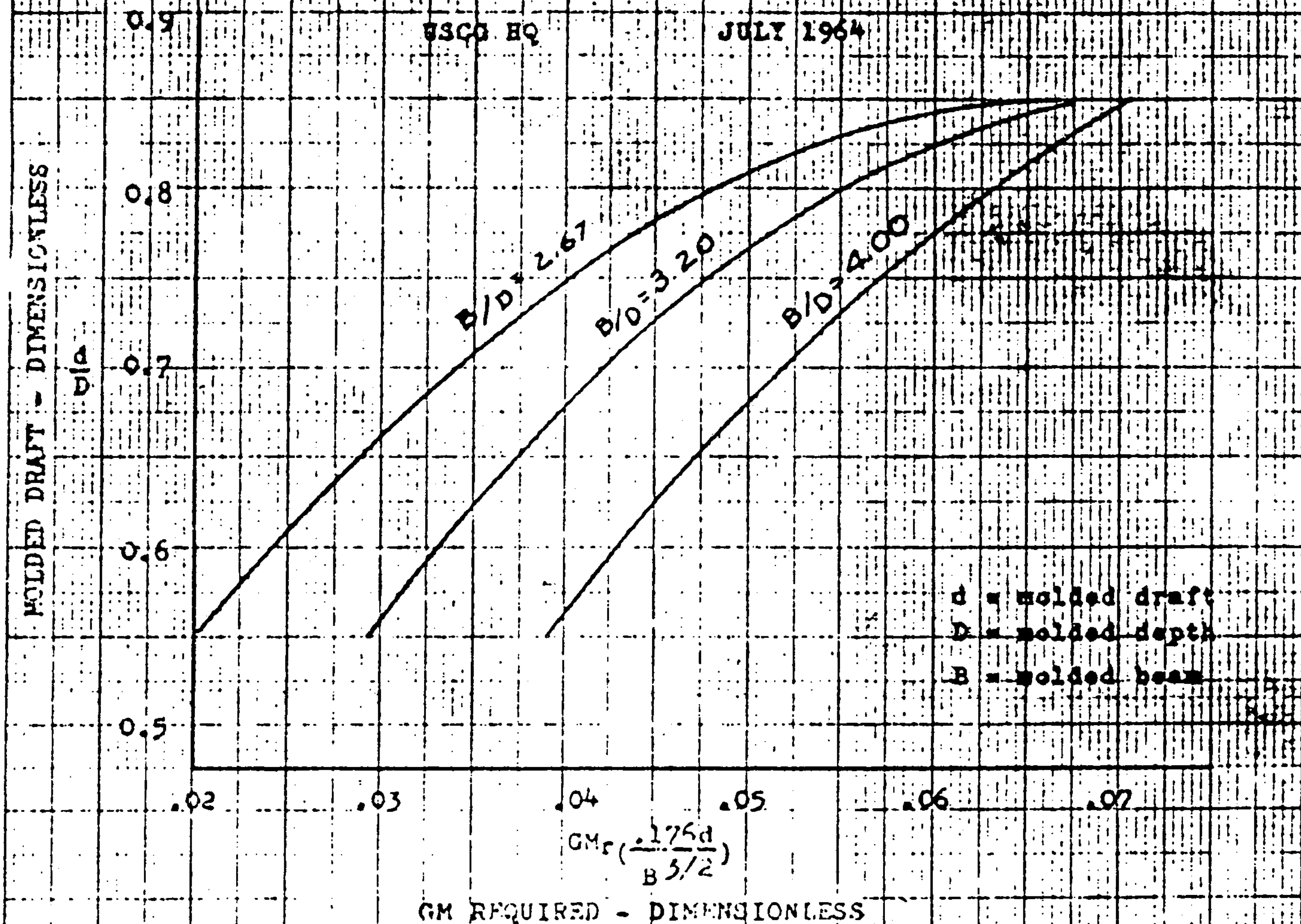
1. A stability test as per Subchapter I, Section 93.05 is required to determine lightship weight and centers. The plans listed in 93.05-5(b) must be submitted prior to the test. Sufficient time should be allowed for plan review.

2. Based upon the information derived from the stability test, a group of realistic loading condition calculations must be submitted. The calculations shall show that under all operating conditions the vessel will meet the required stability standard. The load line assignment will be limited by the deepest, safe, load condition submitted by the owner.

3. The stability standard for subject vessels is based on the Rahola criteria which require that cross curves of stability be prepared. A Rahola analysis must be made in order to determine a curve of required GM. The required GM curve with supporting calculations, including cross curves of stability, must be submitted for review. However, the Merchant Marine Technical Division of the Coast Guard has prepared a set of curves which may be used to obtain required GM curves for most offshore supply vessels. For applicable vessels the owner may use the data from these curves in lieu of doing a complete Rahola study. The final decision as to whether or not the curves are applicable to a particular vessel shall be made by the Commandant, U. S. Coast Guard, or his representative.

CURVES OF REQUIRED GM FOR BROAD SHALLOW DRAFT VESSELS OF THE NATIONAL PRIDE TYPE BASED ON RAHOLA'S CRITERIA

USCG HQ JULY 1964



NOTES: (1) The use of these curves is restricted to vessels which have the following characteristics:

a. They must have a superstructure forward of approximately .25L.
b. B must be within the range of 24 to 36 feet.
c. D must be within the range of 6.0 to 13.5 feet.
d. The B/D ratio must be within the range of 2.67 to 4.00 feet.

(2) It is assumed that there is no downflooding up to a heel angle of about 25°.

(3) A constant deadrise equal to B/25.6 was used in deriving the curves. For vessels having a lesser deadrise, the curves may be used by entering with drafts and depths corrected by adding to each, half the difference between a deadrise equal to B/25.6 and the actual deadrise. For vessels having a greater deadrise the reverse applies.

(4) There is no restriction on vessel length or hull form, however, the Commandant, U. S. Coast Guard reserves the right to restrict the use of these curves if it is felt that they will not give data of the desired reliability. This could be due to a very unusual hull form, peculiar operating conditions, or for any other reason not now foreseeable.

ATTACHMENT (3) TO MMT NOTE NO. 4-64

SAMPLE CALCULATION using "Curves of Required GM for Broad Shallow Draft Vessels of the NATIONAL PRIDE type based on Rahola's Criteria"

Vessel characteristics needed for calculations

B = 36'0"　　D = 10'0"　　Deadrise = 0

Step 1　Deadrise correction

Normal deadrise = B/25.6 = 1.405'

Deadrise correction = $\frac{1.40}{2}$ = +.70

Corrected Depth (Dc) = 10.0' + .7 = 10.7'

Step 2　Entering Argument for Curves

For draft (d) = 6.0' corrected draft (dc) = 6.0 + .7 = 6.7'

Therefore, (d/D) corrected = 6.7/10.7 = .625

Step 3　Data from curves for B/Dc = 36/10.7 = 3.36

Enter curves with (d/D) corrected = .625

Interpolate for B/D = 3.36 to obtain a value of the abscissa equal to .0371 which equals $GM_r\left(\frac{.176d}{B\ 3/2}\right)$

$$GM_r\left(\frac{.176d}{B\ 3/2}\right) = .0371$$

Solving for GM_r　　$GM_r = \frac{.0371\ B\ 3/2}{.176d}$ where d is the corrected draft.

$$GM_r = 6.80$$

Therefore at d = 6.0;　required GM = 6.80'

JAN 29 1970 CENTRAL OFFICE

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

Address reply to:
COMMANDER (mmt)
Eighth Coast Guard District
Customhouse
New Orleans, La. 70130

For the use of members only and not for publication.

Document USL G 3 73/6

Eastman Consult.
5940/M/V ~~RECOVERER I~~
Ser 149
28 January 1970

RES
AEA
FG
MMG
WMK
RSL
FILE

Schuller & Allan, Inc.
5012 Telephone Road
Houston, Texas 77017

Attn: Mr. R. E. Schuller, Jr.

Subj: M/V RECOVERER I
Corpus Christi Hull 111
118' x 26' x 12' Utility Vessel (uninspected)
Ocean Service
Stability Pursuant to Load Line

Ref: (a) Schuller & Allan, Inc.'s letter of 7 January 1970

Gentlemen:

Enclosure (1) is approved.

The stability of this vessel is considered satisfactory for a freeboard assignment of 2 feet 2½ inches, provided the operating restrictions in the enclosed stability information sheet are observed. The stability information sheet shall be furnished the Master of the vessel and should be posted in the pilothouse.

A copy of the stability information sheet has been sent to the load line assigning authority to be attached to the load line certificate. A statement will be placed on the face of the certificate which states:

> "This certificate is valid only so long as the operating restrictions on the attached stability information sheet dated 28 January 1970 are observed."

Very truly yours,

R C Hill
R. C. HILL
Commander, USCG
Chief, Merchant Marine Technical Branch
By direction of Commander
Eighth Coast Guard District

Encl: (1) Stability Information Sheet for M/V RECOVERER I

Copy to:
ABS, NOLA, w/1 copy of encl. (1)
ABS, Galveston, w/1 copy of encl. (1)

APPROVED
SUBJECT TO COMMENTS IN
CCGD8 (MMT) LETTER

JAN 28 1970

Merchant Marine Technical Branch
By Direction of Commander
Eighth Coast Guard District

28 January 1970

STABILITY INFORMATION FOR
M/V RECOVERER I

A stability test supervised by the U. S. Coast Guard was performed on the M/V WAPITI, a sistership of this vessel, at Corpus Christi, Texas on 27 February 1969. On the basis of this test stability calculations have been performed. Results indicate that the stability of the M/V RECOVERER I as presently outfitted and equipped, is satisfactory for operation in Ocean Service provided the following restrictions are adhered to:

1. A maximum of 55 long tons of deck cargo may be carried on board this vessel. The forward and after wing tanks P/S, the #2 and #3 double bottoms P/S and the #4 tanks P/S may be carried full.

2. If no deck cargo is carried, tanks #5 P/S may be used trimming purposes.

3. Trim should be minimized and should always result in a freeboard of at least 18 inches at the stern.

4. The maximum vertical center of gravity permitted for deck cargo as stowed is 3 feet above the deck. Such cargo must be positively secured against shifting in a seaway prior to leaving protected waters.

5. Partially filled ballast tanks shall never be carried less than ½ full. There shall never be more than one pair of partially filled ballast tanks at any one time.

6. Cross-connections between all port and starboard wing tank pairs shall be kept closed at all times when in operation.

7. Main deck hatches and weather doors to forecastle and machinery space shall be kept closed and fully secured at all times when underway, except when actually used for transit under safe conditions.

8. Main deck freeing ports shall be maintained operable and completely unobstructed at all times.

9. Bilges shall be kept pumped to minimum content at all times.

It shall be the Master's responsibility to maintain the vessel in a satisfactory stability condition at all times. The Master shall notify the load line assigning authority of any alteration which significantly affects the stability of the vessel.

2. UNITED KINGDOM

On 6 February 1970, the single screw motor coaster 'Lairdsfield' capsized at the mouth of the River Tees with the loss of all hands and without any distress signal having been sent. It was felt that the heel induced by a turn to starboard round a buoy was sufficient to overcome what little stability it was calculated that she possessed.

The ship was loaded with a full cargo of steel plates and hollow hexagonal columns. There were 375 tons of columns over stowed by 254 tons of steel plates filling a substantial portion of the hatch, most of the plates being above deck level.

The vessel was built in the Netherlands, and carried some stability data in Dutch and some in English, apparently unapproved by the B.O.T. The situation in respect of the stability data held on board was very confused.

The subject of stability data was considered at some length by the Court who commented, interalia,

> "The presentation must be adequate but simple, and appropriate to the standard of knowledge of seagoing officers".

Following the loss of 'Lairdsfield' and the Court's comments on stability, the Department of Trade and Industry issued Merchant Shipping Notice No. 627 dated November 1971, which incorporated the Court's recommendations together with some Departmental advice to owners.

After some years of experience with various methods of presentation of simplified stability data, the Department of Trade issued Merchant Shipping Notice No. M867 in November 1978. Precautions to be taken in the use of such data and the dependence of ship stability on appropriate closure of openings which should be weathertight is highlighted.

The Department, following the issue of Notice No.627, issued advice on a convenient method for developing a curve or tabular statement indicating maximum permissible dead weight moment which can be applied to a ship at a given displacement.

DEPARTMENT OF TRADE AND INDUSTRY

MERCHANT SHIPPING NOTICE No. 627

SIMPLIFIED STABILITY INFORMATION FOR SMALL SHIPS

Notice to Shipowners and Shipbuilders

The Court investigating the loss of "Lairdsfield" found she was lost because of totally inadequate stability resulting from the improper loading and stowage of her cargo. It recommended that owners should endeavour to conform to the agreed criteria as laid down in the 1968 Load Line Rules even though they may not be required to do so by law. The Court further recommended that the presentation of the data, particularly on small ships, should be simplified. It suggested that the data required by the Load Line Rules should be in tabular form, rather than in the form of curves, and that an additional column giving the minimum GMs required to comply with the criteria at regular intervals of draft from the light to the loaded condition would be useful.

The Department agrees with both these recommendations, and would further suggest that an additional method that may be adopted is a table giving the maximum permissible deadweight moment above the keel, also at regular intervals of draft. This latter method obviates the need for any calculation of GM values, and is particularly useful for ships carrying deck cargoes.

The above recommendations are aimed particularly at small ships (up to 100m in length) where the operating circumstances leave little time for the ships' officers to deal with involved stability calculations; nevertheless, owners of larger ships may also find it useful to add such simplified data to the stability booklets.

The Court also recommended that owners should institute suitable means whereby they can satisfy themselves that their officers are capable of calculating the stability of their ships and that they do in fact carry out stability calculations when necessary.

The Department wishes to stress the value of the above recommendations and urges owners to adopt them as soon as possible.

MS 67/15/017

Department of Trade and Industry
Marine Division
November 1971

Printed by Her Majesty's Stationery Office Press, Harrow
161578 Dd 832535 21M 1/72

DEPARTMENT OF TRADE MERCHANT SHIPPING NOTICE No. M.867

SIMPLIFIED STABILITY INFORMATION

Notice to Shipowners, Masters and Shipbuilders

1. It has become evident that the master's task of ensuring that his ship complies with the minimum statutory standards of stability is in many instances not being adequately carried out. A feature of this is that undue traditional reliance is being placed on the value of GM alone, while other important criteria which govern the righting lever GZ curve are not being assessed as they should be. For this reason the Department, appreciating that the process of deriving and evaluating GZ curves is often difficult and time consuming, strongly recommends that in future simplified stability information be incorporated into ships' stability booklets. In this way masters can more readily assure themselves that safe standards of stability are met.

2. Following the loss of the *Lairdsfield*, referred to in Notice M.627, the Court of Inquiry recommended that simplified stability information be provided. This simplified presentation of stability information has been adopted in a large number of small ships and is considered suitable for wider application in order to overcome the difficulties referred to in paragraph 1.

3. Simplified stability information eliminates the need to use cross curves of stability and develop righting lever GZ curves for varying loading conditions by enabling a ship's stability to be quickly assessed, to show whether or not all statutory criteria are complied with, by means of a single diagram or table. Considerable experience has now been gained and three methods of presentation are in common use. These are:

(*a*) The Maximum Deadweight Moment Diagram or Table;
(*b*) The Minimum Permissible GM Diagram or Table;
(*c*) The Maximum Permissible KG Diagram or Table.

In all three methods the limiting values are related to salt water displacement or draught. Free surface allowances for slack tanks are however applied slightly differently.

4. Consultation with the industry has revealed a general preference for the Maximum Permissible KG approach and graphical presentation also appears to be preferred rather than a tabular format. The Department's view is that any of the methods may be adopted subject to:

(*a*) clear guidance notes for their use being provided and
(*b*) submission for approval being made in association with all other basic data and sample loading conditions.

In company fleets it is however recommended that a single method be utilized throughout.

5. It is further recommended that the use of a *Simplified Stability Diagram* as an adjunct to the *Deadweight Scale* be adopted to provide a direct means of comparing stability relative to other loading characteristics. Standard work forms for calculating loading conditions should also be provided.

6. It is essential for masters to be aware that the standards of stability obtainable in a vessel are wholly dependent on exposed openings such as hatches, doorways, air pipes and ventilators being securely closed weathertight; or in the case of automatic closing appliances such as airpipe ball valves that these are properly maintained in order to function as designed.

7. Shipowners bear the responsibility to ensure that adequate, accurate and up-to-date stability information for the master's use is provided. It follows that it should be in a form which should enable it to be readily used in the trade in which the vessel is engaged.

Department of Trade
Marine Division
London WC1V 6LP
November 1978

Printed in Scotland by Her Majesty's Stationery Office at HMSO Press, Edinburgh
Dd 563514 15,005 11/78 (15950)

SIMPLIFIED STABILITY INFORMATION

Marine Notice No 627 recommends that on small ships a simplified form of stability information should be provided which will enable the master to load his ship both safely and quickly. This information should take the form of either a curve or tabular statement indicating the maximum permissible deadweight moment (ie the maximum combination of weight and height of cargo, fuel, stores and water) that can be safely applied to the ship at a particular displacement.

To construct such a curve or table it is of course necessary to have hydrostatic information, cross curves of stability and lightship particulars. Many computer programs are already designed to supply the "maximum permissible deadweight moment" as a normal function of operation, however even without the aid of a computer such information can be readily obtained, see pages 2,3 + 4.

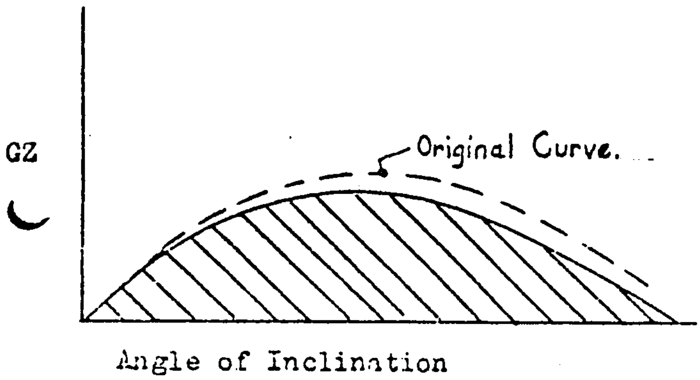
A recommended method of presenting this information together with a suggested Loading Sheet to be completed for each voyage are illustrated on pages 5 + 6.

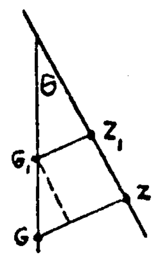
SIMPLIFIED STABILITY INFORMATION

A suggested method of constructing a curve of Maximum Permissible Deadweight Moments

The prime need in constructing such a curve is to obtain themaximum value of KG that can be used in association with a particular displacement, in order that a statical stability curve complying with the 1967 Load Line Rules criteria can be produced.

It will be appreciated that unless a computer is employed it will not be possible to select the maximum KG value to satisfy the criteria immediately and that a degree of trial and error will be necessary. The following approach should however greatly assist in reducing the time taken to obtain the required KG Value.





$$G_1Z_1 = GZ - GG_1 \sin\theta$$

Assume that the dotted line represents the curve produced by the KG value initially selected and that this curve is in excess of the criteria requirement - represented b the shaded curve:-

then area under original curve up to θ^o = $\int_0^\theta GZ\, d\theta$

and " " criteria " " " θ^o = $\int_0^\theta G_1Z\, d\theta$

$= \int_0^\theta GZ\, d\theta - \int_0^\theta GG_1 \sin\theta\, d\theta$

now the difference in area between the two curves up to θ^o = dA and

$$dA = \int_0^\theta GZ\, d\theta - \left[\int_0^\theta GZ\, d\theta - \int_0^\theta GG_1 \sin\theta\, d\theta \right]$$

$$dA = \int_0^\theta GG_1 \sin\theta\, d\theta$$

$$dA = GG_1 \left[-\cos\theta \right]_0^\theta$$

$$\underline{dA = GG_1 \left[1 - \cos\theta \right]}$$

then the increase in KG which will still meet area criteria = $GG_1 = \dfrac{dA}{\left[1 - \cos\theta\right]}$

thus for area under curve up to 30°; $GG_1 = \dfrac{dA}{1 - \cos 30^\circ} = \underline{7.46\ dA}$

" " " " " " " 40°; $GG_1 = \dfrac{dA}{1 - \cos 40^\circ} = \underline{4.27\ dA}$

" " " " " " " 30° & 40°; $dA = GG_1 \displaystyle\int_{30^\circ}^{40^\circ} \sin\theta\, d\theta$

$$= GG_1 \left[- \cos\theta \right]_{30^\circ}^{40^\circ}$$

$$= GG_1 \left[0.866 - 0.766 \right]$$

$$dA = 0.1\ GG_1$$

$$\therefore\ GG_1 = \underline{10.0\ dA}$$

Using this information it should then be possible to ascertain the maximum KG value which will meet the stability criteria for any displacement. By selecting a number of displacements to cover the lightship to summer-load range, a curve of Maximum Permissable Deadweight Moments can be constructed.

See example on next page.

Typical worked example using foregoing information.

Assume for a given draught the displacement of ship = 600 tonnes and KM value 3.87 met
Then after examination and trial assume that the maximum value of KG to meet criteria = 3.67 metres.

Stage 1; Check GM criterion; GM = KM - KG = 0.20 metres this meets criterion.

Stage 2; Construct Statical Stability Curve, assume this is in excess of criteria suc that area up to 30° = 0.061 metre radians (0.006 mr in excess of criterion)

area up to	30°	= 0.061	metre radians	(0.006 mr in excess of criterion)
" " "	40°	= 0.099	" "	(0.009 mr " " " ")
area between	30° & 40°	= 0.038	" "	(0.008 mr " " " ")

Stage 3; Use formulae developed earlier to obtain the value by which the KG could be increased such that criteria will still be achieved, ie

Permissable rise in KG to meet criteria at 30°	=	7.46 dA	= .045 m
" " " " " " " " 40°	=	4.27 dA	= .038 m
" " " " " " " " between 30° & 40°	=	10.0 dA	= .08 m

Then by inspection it can be seen that the maximum permissible increase in KG will be 0.038 metres
Therefore maximum KG value = (3.67 + 0.038)

= 3.708 metres

Stage 4; Reproduce statical stability curve with KG value of 3.708 metres and check to see that all other criteria are satisfied; if so this KG value and displacement of 600 tonnes are used to obtain one spot for the Maximum Permissable Deadweight Moment curve, vis

Maximum Permissable Deadweight Moment at displacement of 600 tonnes

$$= [(\Delta \times KG) - (\text{Lightship } \Delta \times KG^*)]$$

$$= [(600 \times 3.708) - (\text{say } 200 \text{ tonnes} \times 4.0 \text{ m})]$$

$$= 2{,}250 - 800$$

$$= 1{,}450 \text{ tonnes metres}$$

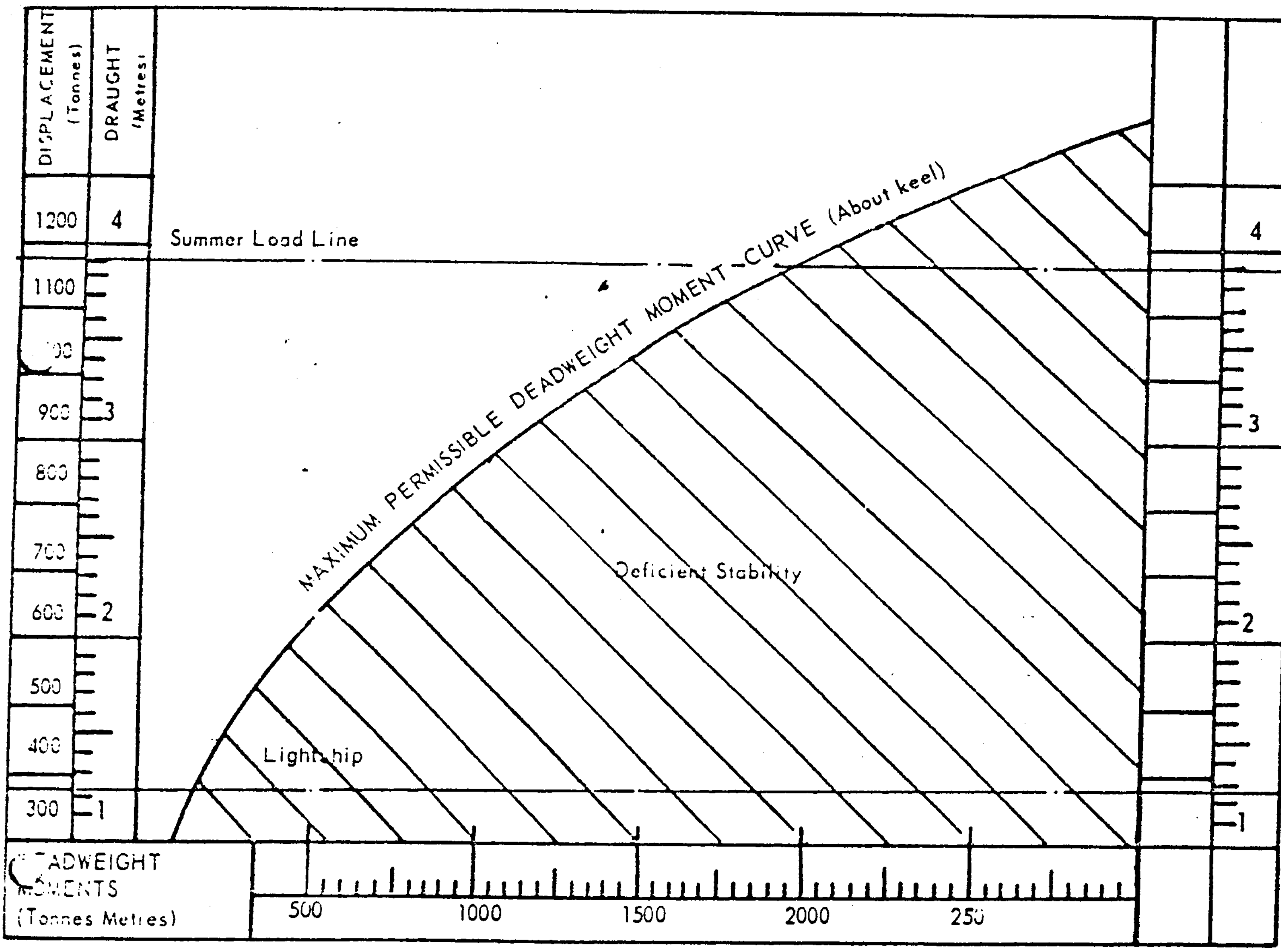
*(It is recommended that a maximum free surface correction be added to the Lightship KG to eliminate such corrections at a later stage. If this is not practicable then a table giving free-surface corrections at varying displacements will be necessary).

SIMPLIFIED STABILITY INFORMATION

A suggested method of presenting stability information in a simplified manner as recommended by Marine Notice No.627 is shown on the next two pages. If required, advice on the method of preparing such information can be obtained from any Marine Survey Office.

SIMPLIFIED STABILITY INFORMATION

Deadweight Moment Curve

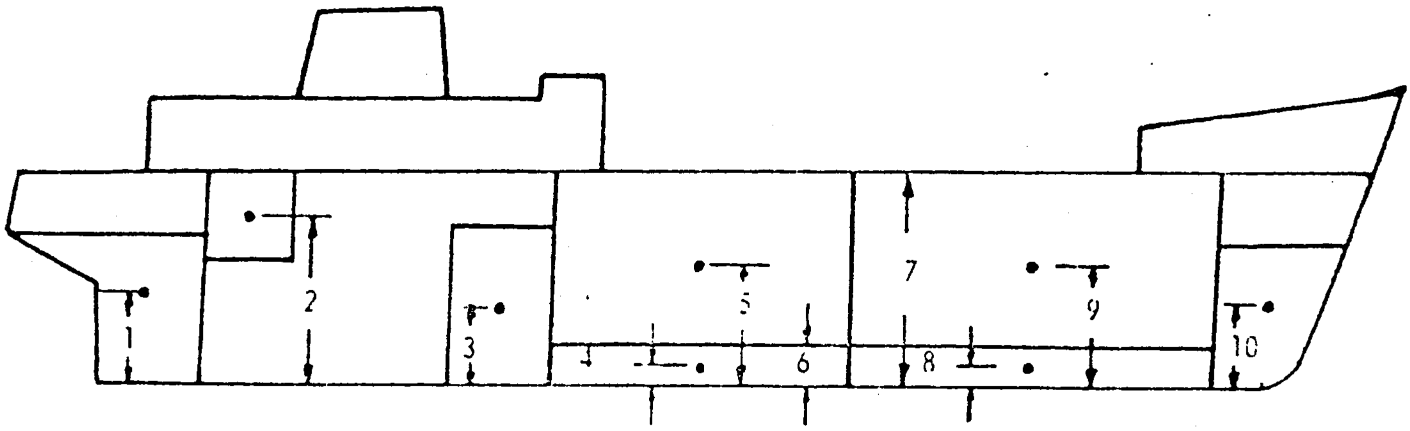


Using this information a simplified "Deadweight Moment Scale" could be produced e.g.

Deadweight Moment Scale

MAX. PERMISSIBLE DEADWEIGHT MOMENT (Tonnes Metres)	2050	2025	2000	1975	1950	1925												
DISPLACEMENT (Tonnes)	1230	1192.5	1185	1177.5	1170	1162.5												
DRAUGHT (Metres)	4.000	3.975	.950	.925	.900	.875	etc.											

Typical Loading Sheet



Heights 'h' 1 ; 2 , 3 , 4 ; 5 .

6 , 7 , 8 ; 9 ; 10 .

Items of Deadweight	Weight 'w'	Height above keel to centre 'h'	Deadweight Moment w x h
Cargo in Hold...			
Cargo on Deck			
Oil Fuel			
Water Ballast in F. Peak			
etc.			
TOTAL DEADWEIGHT		TOTAL DEADWEIGHT MOMENT	
LIGHTSHIP			
DISPLACEMENT *			

N.B.* At this Displacement the "Total Deadweight Moment" must not exceed the value of .... , as shown by the Deadweight Moment Scale.

3. SWEDEN

The U.K. Merchant Shipping Notice No.627 in paragraph 3 states.

> "The above recommendations are aimed [particularly at small ships (up to 100mm length) where the operating circumstances leave little time for the ships' officers to deal with involved stability calculations; never the less, owners of larger ships may also find it useful to add such simplified data to the stability booklets".

This problem of time constraints was also addressed by Ralph Norrby in his paper "The Stability of Coastal Vessels", Transactions of the Royal Institution of Naval Architects, Volume 104, 1962, p.517:

> "When the last "heave" is taken on board, it is usually time for the ship to sail and there is no opportunity to carry out either re-stowing of the cargo or stability calculations.
>
> The Master should therefore have the opportunity of judging the stability directly on the basis of the behaviour of the ship during loading, unloading, or at sea, without needing to carry out any laborious calculations based on theoretical cases of loading".

Norrby considered the question of judging stability with the aid only of metacentric height GM. He indicates the disadvantages of this by highlighting a casualty which had a high GM but also had a double hump stability curve withy very low righting lever values. He indicated that this short coming could be overcome provided the GM criterion is based on an extended stability criterion which would make up for the shortcomings of the use of GM solely.

Norrby used Rahola's criteria, with some small modifications. He compared Rahola modified with other criteria in regular usage and decided that this could give satisfactory results.

In order to study stability on board, Norrby considered 3 methods of simplified stability determination:

Sweden (Cont.)

- Moment calculation
- Heeling Test
- Rolling Test

Norrby recommends the adoption of the moment calculation despite the desk work involved, but with the aid of the rolling test for confirmation.

The heeling test which is in effect an inclining test should be carried out alongside rather than at sea where the wave forces can influence the result. To be useful the test needs to be carried out at a late stage in loading. However if the result is unsatisfactory then a cargo re-stow is indicated. Because of the time, trouble, and expense involved there will be a temptation to ignore the results of the heeling test.

Thirdly, Norrby recommends the rolling test. The mechanics and value of the rolling test are elaborated below. It is recommended that the test be carried out either alongside or at sea where the vessel can roll in its natural period. Again the difficulty lies in the action to be taken if the roll period indicates an insufficiency of initial stability, particularly if the test is carried out at sea.

Norrby carried out tests to determine the influence of quay walls and sea bottoms on the radius of gyration and hence on the period of roll.

Rolling period diagrams showing safe and unsafe operating areas are demonstrated. The paper concludes with a list of 17 conclusions in the matter of judging the stability of coasters.

The types of vessel considered appear to be what was known as a typical North Sea coaster, a type of vessel not often seen on the Australian Coast. An example once well known in Australian waters was M.V. "Blythe Star".

4. AUSTRALIA

During the deliberations which led to the production of the Uniform Shipping Laws Code, in particular Section 8 Stability, two States submitted draft simplified stability books. Although these were directed towards use in fishing vessels, the same principles could have been used for cargo vessels.

Due to their detailed presentation it was not felt that they were effective in simplifying the standard stability book.

At the same time, a presentation which would have produced limiting curves of KG_F and LCG_F was discussed. Access to the appropriate records is not possible, but it is felt that this was discussed and it was not proceeded with at the time due to the winding down of the U.S.L. activities.

In 1986, a document "Simplified Presentation of Stability" was circulated to Industry for comment. Though based on a fishing vessel, the method would have been equally applicable to vessels of other types.

Guidance was provided on the calculation of curves of limiting KG and LCG.

All formulae in the Guidance were based on just meeting IMO criteria. No margins of any sort for water on deck, wind and waves, inaccuracy etc are included. This is particularly important in the light of the deficiencies in the IMO Criteria demonstrated by casualties throughout the world.

It is not known what was the outcome of the Industry comments. So far as is known this proposal has never been adopted.

5. DENMARK

In 1974 Denmark made proposals to IMCO (now IMO) concerning methods for determining stability criteria and for determining curves of limiting KG and GM.

These were based on the use of the MS and C_{RS} concepts espoused by Professor Prohaska. In 1981 they were presented in a more advanced form, but due to lack of association with IMO in recent years it is not known what developments were made in these concepts.

It is known that because of refinements made since the first introduction of the MS concept in 1947, the application of the method has become more complex.

So far as is known MS and C_{RS} have never been widely applied in Australia and no knowledge of local application is held by the writer.

ACCURACY, PRECISION AND UNCERTAINTY

Accuracy, precision and uncertainty have always been of prime importance in stability calculations, not least in determining light ship characteristics, because of their influence on all subsequent stability calculations.

For example a conservative determination of light ship KM can result in a calculated KG value lower than the actual, with the potential for subsequent over estimation of stability in working conditions.

Possibly the most comprehensive study was carried out by E.V. Lewis in USA and published in 1941, "Precision in Naval Architectural Calculations". Lewis considered all conceivable factors which could be involved, and assigned probable errors to each factor.

With the increasing interest in ship motions which developed after World War ll, came a particular concern with rolling. Bonebakker appreciated the particular importance of safe rolling for small ships and explored the accuracy of determination of GM which is a major factor in the equation for rolling period. He found a significant number of inaccuracies in the practices adopted at that time.

Prohaska in 1947, proposed a standardised method for the presentation of stability information. To determine the uncertainty of ship calculations, students over a number of years were asked to perform stability calculations for the same ship using different instruments and different methods. He presented diagrams demonstrating the wide variation in the results.

With the current usage of computer programmes and the limited use of hand methods, a review of the uncertainty to be found in computer methods became necessary.

Miller at the University of Glasgow carried out such an investigation which he reported on in 1963. It would seem that despite the 30 years which have elapsed since Miller's paper, the uncertainty in stability calculations still exists, but now from different sources.

Accuracy, Precision and Uncertainty (Cont.)

In the intervening years examination of the accuracy of inclining experiments and determination of GM has been a recurring problem. Some studies which have been published have been recorded in the list of References.

The accuracy of GM for various conditions of loading seems to be critical for at least two reasons.

- where rolling periods or heeling tests are used to determine GM, then a high order of accuracy is essential.

- for small vessels which have a high GM and are therefore initially stiff, but have low values of GZ, possibly with a double-humped shape of stability curve, knowledge of the initial GM again must be known to a high degree of accuracy.

Where a series of values of one quantity is determined by measurement, eg, GM for various shifts of inclining weights or roll periods recorded during rolling tests, the method proposed by Logan for assessing the acceptability of those values can be helpful.

ROLLING PERIOD TEST

The equation for period of roll is

$$T = \frac{2 \pi k}{\sqrt{gGM}}$$

where K = transverse radius of gyration

Rewriting we find that

$$GM = \frac{4 \pi^2 k^2}{g T^2}$$

The equation for GM is not exact because of the variation of the radius of gyration with the geometry of the vessel, its draught, load distribution and distance from boundaries such as quay walls and the sea or harbour bottom.

Values of radius of gyration are commonly expressed as a proportion of the beam of the ship, different values applying to ships of different types.

For ships of one type it was found for example that the average value of k was 0.44B, the range of values being from 0.41B to 0.46B.

A commonly held belief is that a significant influence on K can be achieved by "winging out" the heaviest units of cargo.

Manning in Principles of Naval Architecture Volume Il, showed that to increase k appreciably without affecting GM is impracticable. Manning takes the case of a vessel of 10,000 tons displacement with T = 15 seconds and GM = 3 feet. By moving 1,000 tons symmetrically away from G by a mean distance of 10 feet to a mean distance of 20 feet increases k from 23.45 feet to 24.08 feet and increases T from 15 seconds to 15.40 seconds.

Therefore to increase T by any appreciable amount without involving movement of G is impracticable.

Rolling Period Test (Cont.)

Norrby has made an intensive study of rolling period formula, investigating in particular approaches to the determination of the radius of gyration by Weiss, Kempf, Laurenson and Kato. He also studied the influence of proximity of a vessel to a quay wall and to the bottom, on the value of radius of gyration. In addition he explored the influence of deck load.

From this study, Norrby developed diagrams relating rolling period to draught for conditions of hold and deck cargo. Further information is provided by the discussers of the paper.

A recent study of radius of gyration has been conducted by R.W. Peach on behalf of the US Maritime Administration. He examined the actual values for 3 ship types, Ro/Ro, Lash and LNG, using relevant information for every individual piece of structure, outfit and equipment, involving between 20,000 and 40,000 items. He examined values traditionally used as well as considering values appropriate to thin walled tubes.

Mr. Brook on behalf of British Maritime Technology presented his findings as a user of this type of information compared with Mr. Peach who was an analyst. Mr. Brook gave the results of a sensitivity study involving errors in roll radii of gyration and their effect on roll response of ships.

While Norrby and others recommend determination of stability through roll motion at sea, it is not considered that this is a practice to be recommended.

The October 1996 Naval Architect contains notice of a paper W8 (1996) for written discussion, titled "Estimation of Vessel Stability at Sea Using Roll Motions Record".

The main uses for rolling period checks at sea should be at least twofold:

- to confirm GM determination made by KG calculation or moment calculation
- to determine a value for k for a known GM value

It does not seem reasonable to wait till the ship goes to sea to determine the GM value for the loading condition applicable at the time.

LIMITING KG CURVE

A widely preferred method of presenting simplified stability data is by means of a curve of limiting KG plotted against draught or displacement.

Such a curve can be developed for the range of draughts from lightship to loaded using the IMO criteria to develop curves of righting lever and raising the value of KG until the criteria are just met. The KG values at each draught selected can then be plotted to form a limiting curve.

For safety, a free surface correction should be introduced into the KG values adopted and account should be taken of the fact that IMO stability criteria are minima and that some ships have capsized even where their stability was in excess of the IMO requirements (eg "Edith Terkol").

Additionally having regard to the tolerance in all values of KG so determined if allowance is made for this then the curve of limiting KG should really be a band of limiting KG having a width corresponding to the likely errors in the values.

Once the data has been assembled it should be plotted on a scale such as to give a diagram which can be read and used easily.

The Curves of Maximum Permissible KG for a Ro/Ro ferry of some 31,000 Gross Tonnage measure 80 x 210 mm for one passenger condition and 140 x 220 mm for the other passenger condition. After distortion in reproduction, these diagrams are difficult to use effectively.

If moment calculations are to be made by ship's personnel, then KG Curves can offer a satisfactory method of stability control.

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