CERTIFICATE

By Authority Of
THE UNITED STATES OF AMERICA
Legally Binding Document

By the Authority Vested By Part 5 of the United States Code § 552(a) and Part 1 of the Code of Regulations § 51 the attached document has been duly INCORPORATED BY REFERENCE and shall be considered legally binding upon all citizens and residents of the United States of America. _HEED THIS NOTICE_: Criminal penalties may apply for noncompliance.

Document Name: ASTM F1321: Standard Guide for Conducting a Stability Test (Lightweight Survey and Inclining Experiment) to Determine Light Ship Displacement and Centers of Gravity of a Vessel

CFR Section(s): 46 CFR 28.535(d)

Standards Body: American Society for Testing and Materials

Official Incorporator:
THE EXECUTIVE DIRECTOR
OFFICE OF THE FEDERAL REGISTER
WASHINGTON, D.C.

APPROVED

Designation: F 1321 – 92

Standard Guide for Conducting a Stability Test (Lightweight Survey and Inclining Experiment) to Determine the Light Ship Displacement and Centers of Gravity of a Vessel[1]

This standard is issued under the fixed designation F 1321; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This guide provides the marine industry with a basic understanding of the various aspects of a stability test. It contains procedures for conducting a stability test in order to ensure that valid results are obtained with maximum precision at a minimal cost to owners, shipyards, and the government. This guide is not intended to instruct a person in the actual calculation of the light ship displacement and centers of gravity, but rather to be a guide to the necessary procedures to be followed to gather accurate data for use in the calculation of the light ship characteristics. A complete understanding of the correct procedures used to perform a stability test is imperative in order to ensure that the test is conducted properly and so that results can be examined for accuracy as the inclining experiment is conducted. It is recommended that these procedures be used on all vessels and marine craft.

1. Scope

1.1 This guide covers the determination of a vessel's light ship characteristics. The stability test can be considered to be two separate tasks; the lightweight survey and the inclining experiment. The stability test is required for most vessels upon their completion and after major conversions. It is normally conducted inshore in calm weather conditions and usually requires the vessel be taken out of service to prepare for and conduct the stability test. The three light ship characteristics determined from the stability test for conventional (symmetrical) ships are displacement (displ), longitudinal center of gravity (LCG), and the vertical center of gravity (KG). The transverse center of gravity (TCG) may also be determined for mobile offshore drilling units (MODUs) and other vessels which are asymmetrical about the centerline or whose internal arrangement or outfitting is such that an inherent list may develop from off-center weight. Because of their nature, other special considerations not specifically addressed in this guide may be necessary for some MODUs.

1.2 *This standard does not purport to address the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Terminology

2.1 *Definitions:*

2.1.1 *inclining experiment*—involves moving a series of known weights, normally in the transverse direction, and then measuring the resulting change in the equilibrium heel angle of the vessel. By using this information and applying basic naval architecture principles, the vessel's vertical center of gravity (KG) is determined.

2.1.2 *light ship*—a vessel in the light ship condition (Condition I) is a vessel complete in all respects, but without consumables, stores, cargo, crew and effects, and without any liquids on board except that machinery fluids, such as lubricants and hydraulics, are at operating levels.

2.1.3 *lightweight survey*—this task involves taking an audit of all items which must be added, deducted, or relocated on the vessel at the time of the stability test so that the observed condition of the vessel can be adjusted to the light ship condition. The weight, longitudinal, transverse and vertical location of each item must be accurately determined and recorded. Using this information, the static waterline of the ship at the time of the stability test as determined from measuring the freeboard or verified draft marks of the vessel, the vessel's hydrostatic data, and the sea water density; the light ship displacement and longitudinal center of gravity can be obtained. The transverse center of gravity may also be calculated, if necessary.

3. Significance and Use

3.1 From the light ship characteristics one is able to calculate the stability characteristics of the vessel for all conditions of loading, and thereby determine whether the vessel satisfies the applicable stability criteria. Accurate results from a stability test may in some cases determine the future survival of the vessel and its crew, so the accuracy with which the test is conducted cannot be overemphasized. The condition of the vessel and the environment during the test is rarely ideal and consequently, the stability test is infrequently conducted exactly as planned. If the vessel isn't 100 % complete, the weather isn't perfect, there ends up being water or shipyard trash in a tank that was supposed to

---

[1] This guide is under the jurisdiction of ASTM Committee F-25 on Shipbuilding and is the direct responsibility of Subcommittee F25.01 on Structures.
Current edition approved Dec. 15, 1992. Published February 1993. Originally published as F 1321 – 90. Last previous edition F 1321 – 91.

be clean and dry, etc., then the person in charge must make immediate decisions as to the acceptability of variances from the plan. A complete understanding of the principles behind the stability test and a knowledge of the factors which affect the results is necessary.

4. Theory

4.1 *The Metacenter*—(See Fig. 1). The transverse metacenter (M) is based on the hull form of a vessel and is the point around which the vessel's center of buoyancy (B) swings for small angles of inclination (0 to 4° unless there are abrupt changes in the shape of the hull). The location of B is fixed for any draft, trim and heel, but it shifts appreciably as heel increases. The location of B shifts off the centerline for small angles of inclination, but its height above the molded keel (K) will stay essentially the same. The location of M, on the other hand, is essentially fixed over a range of heeling angles up to about 4°, as the ship is inclined at constant displacement and trim. The height of M above K, known as KM, is often plotted versus draft as one of the vessel's curves of form. If the difference from the design trim of the vessel is less than 1 % of its length, the KM can be taken directly from either the vessel's curves of form or hydrostatic tables. Because KM varies with trim, the KM must be computed using the trim of the ship at the time of the stability test when the difference from the design trim of the vessel is greater than 1 % of its length. Caution should be exercised when applying the "1 % rule of thumb" to ensure that excessive error, as would result from a significant change in the waterplane area during heeling, is not introduced into the stability calculations.

4.2 *Metacentric Height*—The vertical distance between the center of gravity (G) and M is called the metacentric height (GM). At small angles of heel, GM is equal to the initial slope of the righting arm (GZ) curve and is calculated using the relationship, $GZ = GM \sin \theta$. GM is a measure of vessel stability that can be calculated during an inclining experiment. As shown in Fig. 2, moving a weight (W) across the deck a distance (x) will cause a shift in the overall center of gravity $(G-G')$ of the vessel equal to $(W)(x)/\text{displ}$ and parallel to the movement of W. The vessel will heel over to a new equilibrium heel angle where the center of buoyancy (B') will once again be directly under the center of gravity (G'). Because the angle of inclination during the inclining experiment is small, the shift in G can be approximated by $GM \tan \theta$ and then equated to $(W)(x)/\text{displ}$. Rearranging this equation slightly results in the following equation:
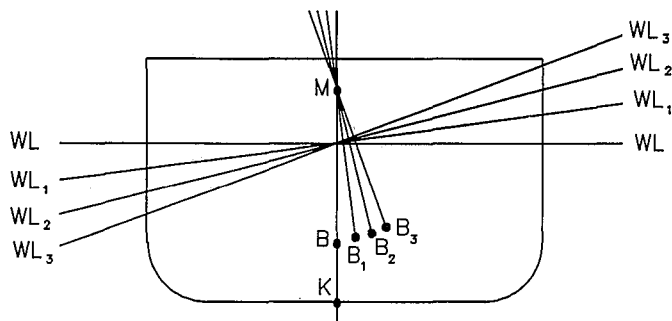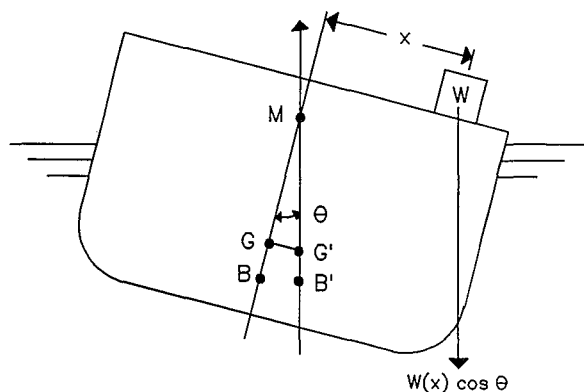

FIG. 2 Metacentric Height

$$GM = \frac{(W)(x)}{(\text{displ})(\tan \theta)} \qquad (1)$$

Since GM and displ remain constant throughout the inclining experiment the ratio $(W)(x)/\tan \theta$ will be a constant. By carefully planning a series of weight movements a plot of tangents is made at the appropriate moments. The ratio is measured as the slope of the best represented straight line drawn through the plotted points as shown in Fig. 3, where three angle indicating devices have been used. This line does not necessarily pass through the origin or any other particular point, for no single point is more significant than any other point. A linear regression analysis is often used to fit the straight line.

4.3 *Calculating the Height of the Center of Gravity Above the Keel*—KM is known for the draft and trim of the vessel during the stability test. The metacentric height (GM), as calculated above, is determined from the inclining experi-
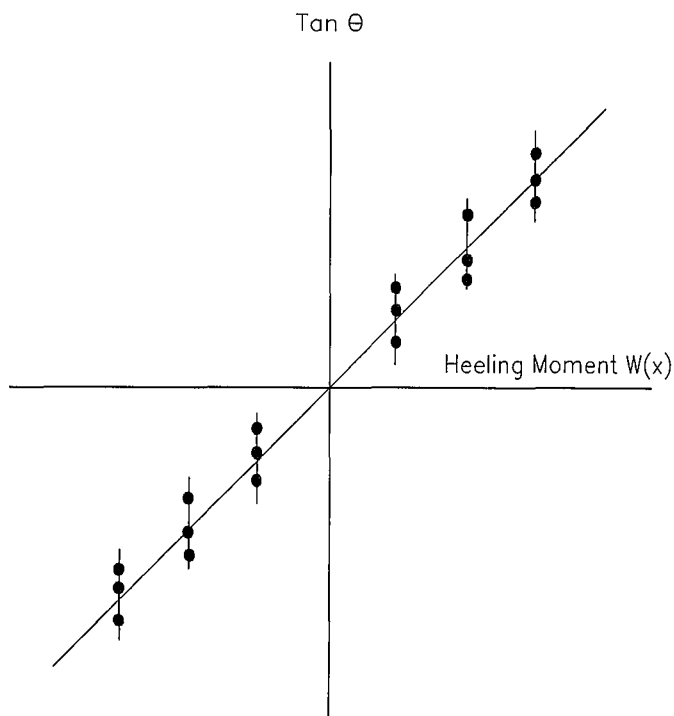

FIG. 1 Movement of the Center of Buoyancy
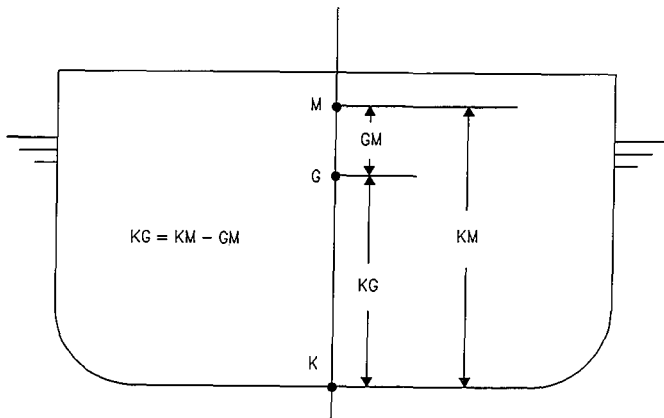

FIG. 3 A Typical Incline Plot

FIG. 4   Relationship between GM, KM, and KG

ment. The difference between the height *KM* and the distance *GM* is the height of the center of gravity above the keel (*KG*). See Fig. 4.

4.4 *Measuring the Angle of Inclination*—(See Fig. 5.) Each time an inclining weight (*W*) is shifted a distance (*x*), the vessel will settle to some equilibrium heel angle, *θ*. In order to accurately measure this angle (*θ*), pendulums or other precise instruments are used on the vessel. When pendulums are used, the two sides of the triangle defined by the pendulum are measured. *Y* is the length of the pendulum wire from the pivot point to the batten and *Z* is the distance the wire deflects from the reference position at the point along the pendulum length where transverse deflections are measured. Tangent *θ* is then calculated:

$$\tan\theta = Z/Y \qquad (2)$$

Plotting all of the readings for each of the pendulums during the inclining experiment aids in the discovery of bad readings. Since (*W*)(*x*)/tan *θ* should be constant, the plotted line should be straight. Deviations from a straight line are an indication that there were other moments acting on the vessel during the inclining. These other moments must be identified, the cause corrected, and the weight movements repeated until a straight line is achieved. Figures 6 through 9 illustrate examples of how to detect some of these other moments during the inclining, and a recommended solution for each case. For simplicity, only the average of the readings is shown on the inclining plots.

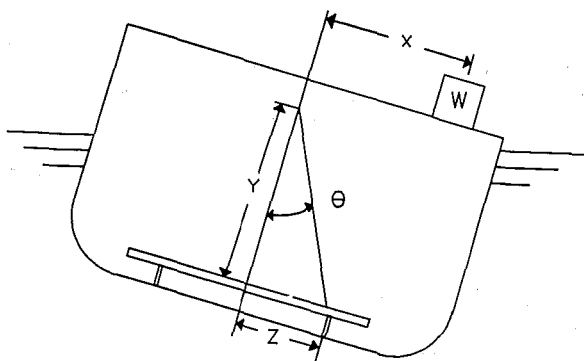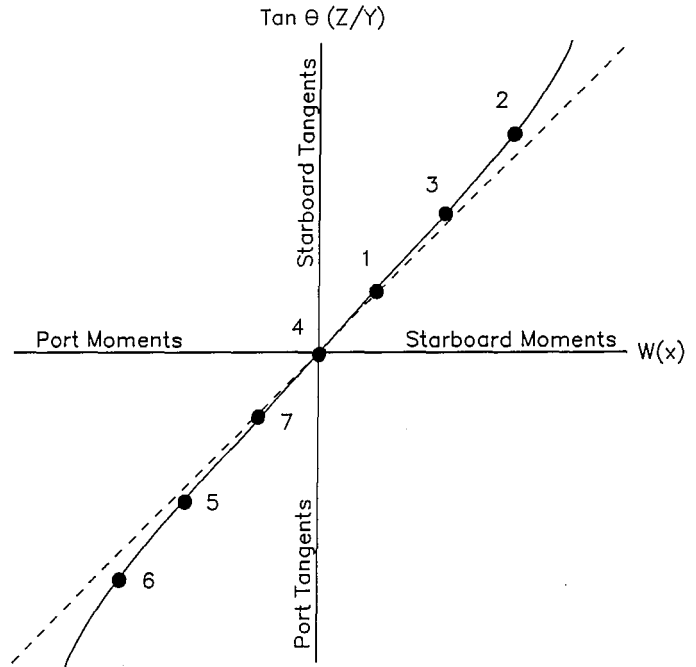4.5 *Free Surface*—During the stability test, the inclining

FIG. 5   Measuring the Angle of Inclination

NOTE—Re-check all tanks and voids and pump out as necessary; Re-do all weight movements and re-check freeboard and draft readings

FIG. 6   Excessive Free Liquids

of the vessel should result solely from the moving of the inclining weights. It should not be inhibited or exaggerated by unknown moments or the shifting of liquids on board. However, some liquids will be aboard the vessel in slack tanks so a discussion of "free surface" is appropriate.

4.5.1 *Standing Water on Deck*—Decks should be free of water. Water trapped on deck may shift and pocket in a
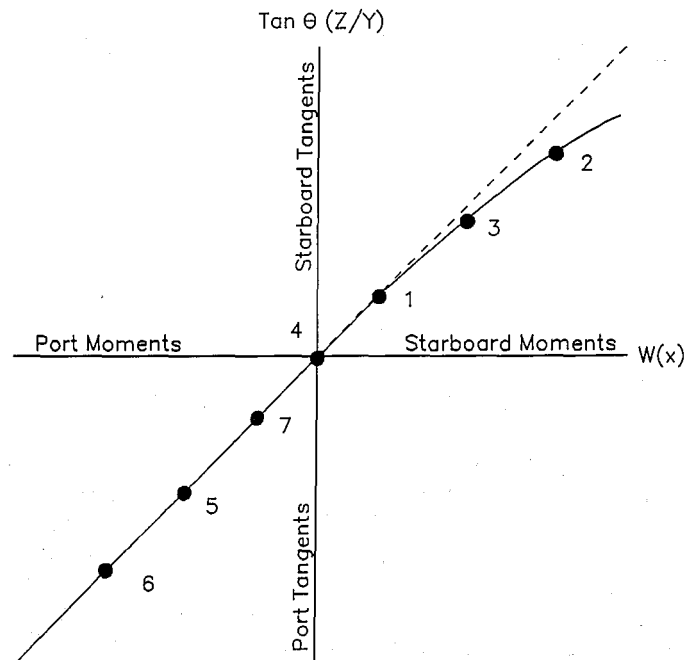
NOTE—Take water soundings and check lines; re-do weight movements 2 and 3.

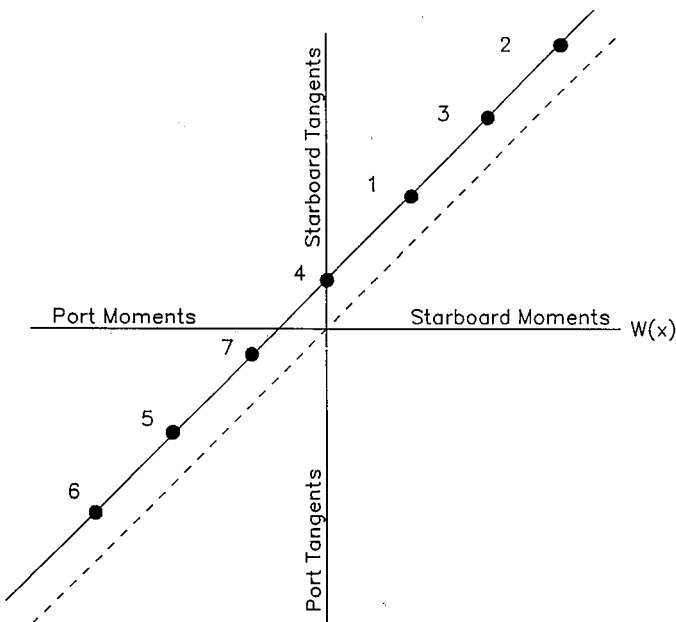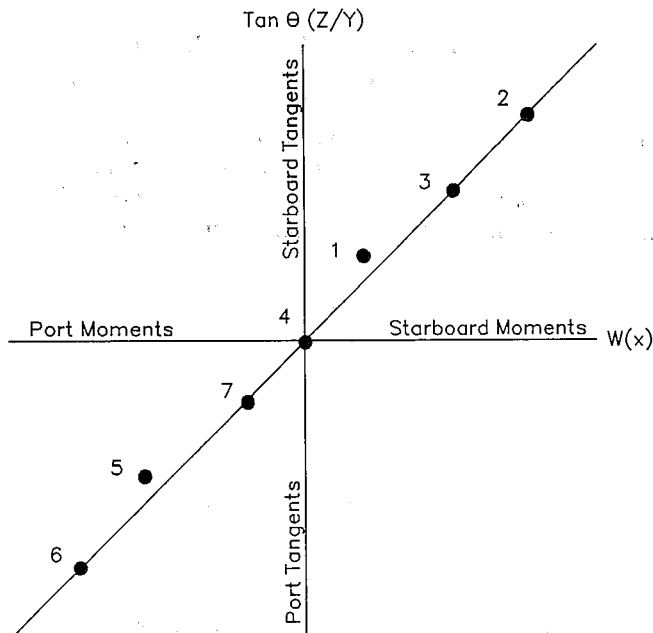FIG. 7   Vessel Touching Bottom or Restrained by Mooring Lines

779

FIG. 8 Steady Wind From Port Side Came Up After Initial Zero Point Taken (Plot Acceptable)

NOTE—Re-do weight movements 1 and 5.

FIG. 9 Gusty Wind From Port Side

fashion similar to liquids in a tank.

4.5.2 *Tankage During the Inclining*—If there are liquids on board the vessel when it is inclined, whether in the bilges or in the tanks, it will shift to the low side when the vessel heels. This shift of liquids will exaggerate the heel of the vessel. Unless the exact weight and distance of liquid shifted can be precisely calculated, the *GM* from formula (1) will be in error. Free surface should be minimized by emptying the tanks completely and making sure all bilges are dry; or by completely filling the tanks so that no shift of liquid is

possible. The latter method is not the optimum because air pockets are difficult to remove from between structural members of a tank, and the weight and center of the liquid in a full tank must be accurately determined in order to adjust the light ship values accordingly. When tanks must be left slack, it is desirable that the sides of the tanks be parallel vertical planes and the tanks be regular in shape (that is, rectangular, trapezoidal, etc.) when viewed from above, so that the free surface moment of the liquid can be accurately determined. The free surface moment of the liquid in a tank with parallel vertical sides can be readily calculated by the formula:

$$\text{Free surface (ft-tons)} = lb^3/12Q \qquad (3)$$

where:

l = length of tank, ft,
b = breadth of tank, ft, and
Q = specific volume of liquid in tank (ft^3/ton)
(See Annex A3 for fuel oil conversions or measure Q directly with a hydrometer.).

Free surface correction is independent of the height of the tank in the ship, location of the tank, and direction of heel. 4.5.3 As the width of the tank increases, the value of free surface moment increases by the third power. The distance available for the liquid to shift is the predominant factor. This is why even the smallest amount of liquid in the bottom of a wide tank or bilge is normally unacceptable and should be removed prior to the inclining experiment. Insignificant amounts of liquids in V-shaped tanks or voids (for example, a chain locker in the bow), where the potential shift is negligible, may remain if removal of the liquid would be difficult or would cause extensive delays.

5. Preparations for the Stability Test

5.1 *General Condition of the Vessel*—A vessel should be as complete as possible at the time of the stability test. Schedule the test to minimize the disruption in the vessel's delivery date or its operational commitments. The amount and type of work left to be completed (weights to be added) affects the accuracy of the light ship characteristics, so good judgment must be used. If the weight or center of gravity of an item to be added cannot be determined with confidence, it is best to conduct the stability test after the item is added. Temporary material, tool boxes, staging, trash, sand, debris, etc. on board should be reduced to absolute minimum during the stability test.

5.2 *Tankage*—Include the anticipated liquid loading for the test in the planning for the test. Preferably, all tanks should be empty and clean, or completely full. Keep the number of slack tanks to a minimum. The viscosity of the fluid and the shape of the tank should be such that the free surface effect can be accurately determined.

5.2.1 *Slack Tanks:*

5.2.1.1 The number of slack tanks should normally be limited to one pair of port and starboard tanks or one centerline tank of the following:

(a) Fresh water reserve feed tanks,
(b) Fuel/diesel oil storage tanks,
(c) Fuel/diesel oil day tanks,
(d) Lube oil tanks,
(e) Sanitary tanks, or

(f) Potable water tanks.

5.2.1.2 To avoid pocketing, slack tanks should normally be of regular (that is, rectangular, trapezoidal, etc.) cross section and be 20 to 80 % full if they are deep tanks and 40 to 60 % full if they are double bottom tanks. These levels ensure that the rate of shifting of liquid remains constant throughout the heel angles of the stability test. If the trim changes as the vessel is inclined, then consideration must also be given to longitudinal pocketing. Slack tanks containing liquids of sufficient viscosity to prevent free movement of the liquids, as the vessel is inclined (such as Bunker C at low temperature), should be avoided since the free surface cannot be calculated accurately. A free surface correction for such tanks should not be used unless the tanks are heated to reduce viscosity. Communication between tanks should never be allowed. Cross connections, including those via manifolds, should be closed. Equal liquid levels in slack tank pairs can be a warning sign of open cross connections. A bilge, ballast, and fuel oil piping plan can be referred to, when checking for cross-connection closures.

5.2.2 *Pressed Up Tanks*—*Pressed up* means completely full with no voids caused by trim or inadequate venting. Anything less than 100 % full, for example, the 98 % condition regarded as full for operational purposes, is not acceptable. The vessel should be rolled from side to side to eliminate entrapped air before taking the final sounding. Special care should be taken when pressing fuel oil tanks to prevent accidental pollution. An example of a tank that would appear "pressed up," but actually contained entrapped air is shown in Fig. 10.

5.2.3 *Empty Tanks*—It is generally not sufficient to simply pump tanks until suction is lost. Enter the tank after pumping to determine if final stripping with portable pumps or by hand is necessary. The exceptions are very narrow tanks or tanks where there is a sharp deadrise, since free surface would be negligible. Since all empty tanks must be inspected, all manholes must be open and the tanks well ventilated and certified as safe for entry. A safe testing device should be on hand to test for sufficient oxygen and minimum toxic levels.

5.3 *Mooring Arrangements*—The importance of good mooring arrangements cannot be overemphasized. The arrangement selection will be dependent upon many factors.
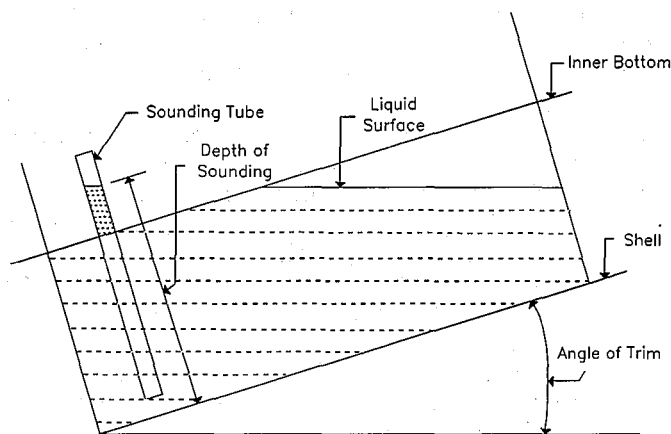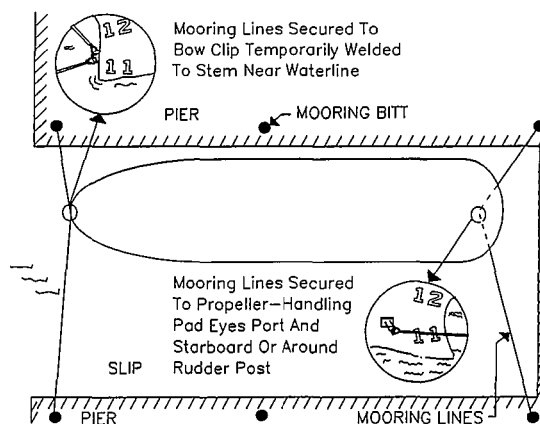

FIG. 11 The Preferred Mooring Arrangement

Among the most important are depth of water, wind, and current effects. Whenever possible the vessel should be moored in a quiet, sheltered area free of extraneous forces such as propeller wash from passing tugs, or sudden discharges from shore side pumps. The depth of water under the hull should be sufficient to ensure that the hull will be entirely free of the bottom. The tide conditions and the trim of the vessel during the test must be considered. Prior to the test, measure the depth of water and record in as many locations as necessary to ensure the vessel will not contact the bottom. If marginal, conduct the test during high tide or move the vessel to deeper water.

5.3.1 The vessel should be held by lines at the bow and the stern, attached to temporary pad eyes installed as close as possible to the centerline of the vessel and as near the waterline as practical. If temporary pad eyes are not feasible then lines can be secured to bollards or cleats, or both, on the deck. This arrangement requires that the lines be slackened when the ship is heeled away from the dock. The preferred arrangement is with the vessel lying in a slip where it can be moored as shown in Fig. 11. In this case, the lines can be kept taut to hold the vessel in place, yet allowing unrestricted heeling. Note, however, that wind or current, or both, may cause a superimposed heeling moment to act on the vessel throughout the test. For steady conditions this will not affect the results. Gusty wind or uniformly varying wind or current, or both, will cause these superimposed heeling moments to change, which may require additional test points to obtain a valid test. The need for additional test points can be determined by plotting test points as they are obtained.

5.3.2 Where the vessel can be moored to one side only, it is good practice to supplement the bow and stern lines with two spring lines in order to maintain positive control of the vessel, as shown in Fig. 12. The leads of the spring lines should be as long as practicable. Provide cylindrical camels between the vessel and the dock. All lines should be slack, with the vessel free of the pier and camels, when taking readings.

5.3.2.1 If the vessel is held off the pier by the combined effect of the wind and current, and the bow and stern lines are secured at centerline near the waterline, they can be taut. This is essentially the same as the preferred arrangement
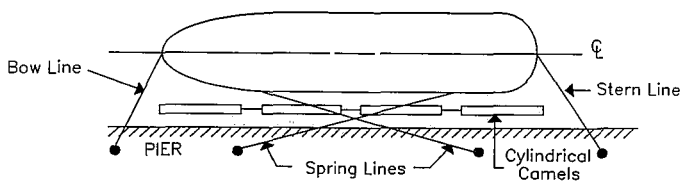

FIG. 10 Tank Containing Entrapped Air

FIG. 12 An Acceptable Alternate Mooring Arrangement

described in 5.3.1. As in 5.3.1, varying wind or current, or both, will cause some distortion of the plot.

5.3.2.2 If the vessel is pressed against the camels by wind or current, or both, all lines should be slack. The cylindrical camels will prevent binding but again there will be an unavoidable superimposed heeling moment due to the ship bearing against the camels. This condition should be avoided but when used, give consideration to pulling the ship free of the dock and camels, and letting the ship drift as readings are taken.

5.3.2.3 Another acceptable arrangement is where the combined wind and current are such that the ship may be controlled by only one line at either the bow or the stern. In this case the control line need not be attached near the waterline, but it should be led from on or near the center line of the ship. With all lines but one slack, the ship is free to veer with the wind or current, or both, as readings are taken. This can sometimes be troublesome because varying wind or current, or both, can cause distortion of the plot.

5.3.3 If a floating crane is used for handling inclining weights it should not be moored to the ship.

5.3.4 Remove the access ramps. Power lines, hoses, etc. connected to shore should be at a minimum, and kept slack at all times.

5.4 *List and Trim*—In order to simplify calculations the vessel should be as close as possible to even list and design trim and have sufficient draft so that any abrupt changes in the waterplane will be avoided as the ship is inclined from side to side. If the vessel has a bow appendage, such as a bulbous bow or sonar dome, hard chine, or transom stern at the waterline, then give consideration to changing the draft or trim to ensure there is a minimum change in the waterplane area as the vessel is heeled from side to side. Trim different from design of up to 1 % of LBP (length between perpendiculars) is normally acceptable when using hydrostatic data calculated at design trim. Exercise caution when applying the "1 % rule of thumb" to ensure that excessive error, as would result from a significant change in the waterplane area during heeling, is not introduced into the stability calculations. With inclining weights in the initial position, up to $\frac{1}{2}°$ of list is acceptable. If the list exceeds this, use leveling weights to put the vessel in an acceptable condition.

5.5 *Test Weights*—The total weight used should be sufficient to provide a minimum inclination of 1° and a maximum of 4° of heel.

5.5.1 One approach that can be taken to estimate how much weight is needed follows:

5.5.1.1 Measure the maximum athwartships distance (x) that is available on deck to shift the weights as shown in Fig. 13.

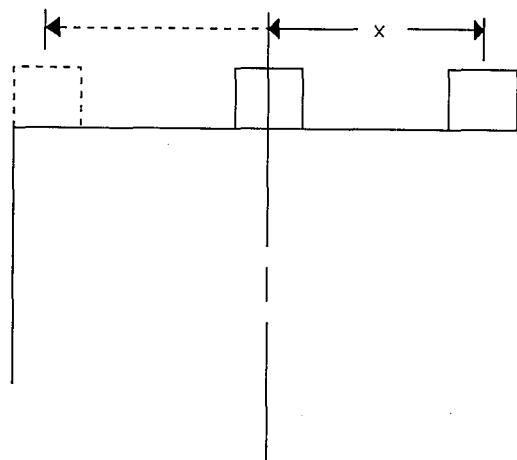5.5.1.2 Estimate the draft the vessel will be at for the

FIG. 13 Movement of the Test Weights

stability test and find the corresponding displacement from the vessel's hydrostatic data.

5.5.1.3 Estimate the GM of the vessel by estimating its center of gravity (KG) and subtracting that value from KM, obtained from the hydrostatic data for the appropriate draft;

$$GM = KM - KG \qquad (3)$$

5.5.1.4 Estimate the total weight (W) required by the following formula:

$$W = \frac{GM \, (\tan \theta) \, \text{displ}}{x} \qquad (4)$$

where θ is the desired angle of inclination between 1 and 4°.

5.5.1.5 It would be prudent to have additional weights readily available to compensate for any inaccurate estimates.

5.5.2 Test weights should be compact and of such a configuration that the KG (vertical center of gravity) of the weights can be accurately determined. Weights, such as porous concrete, that can absorb significant amounts of moisture, should only be used if they were weighed just prior to the stability test or if recent weight certificates are presented. Mark each weight with an identification number and weight. For small vessels, drums completely filled with water may be used. Drums should normally be full and capped to allow accurate weight control.

5.5.2.1 Certify test weights using a certificated scale. Perform the weighing close enough in time to the stability test to ensure the measured weight is accurate. The time since weighing depends on the construction of the weight.

5.5.3 A crane of sufficient capacity and reach, or some other means, must be available during the stability test to shift weights on the deck in an expeditious and safe manner.

5.5.4 Take precautions to ensure that the decks are not overloaded during weight movements. If deck strength is questionable then perform a structural analysis to determine if existing framing can support the weight.

5.5.5 The test weights should be on board and in place prior to the scheduled time of the stability test.
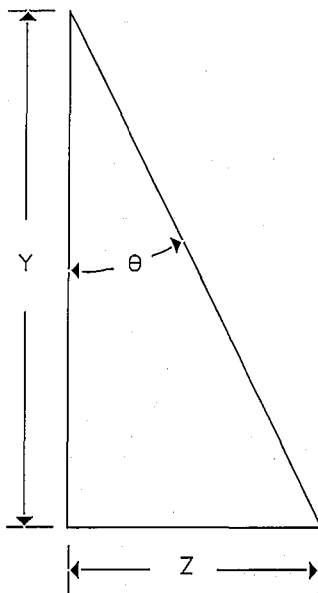
5.6 *Pendulums:*

5.6.1 Use a minimum of three pendulums to allow identification of bad readings at any one pendulum station. They should each be located in an area protected from the wind. If this is not possible, then erect a screen around the

exposed portions of the pendulums. Good locations for pendulums are ladder trunks, elevator shafts, hatchways, or any access way passing through decks.

5.6.2 The pendulums should be long enough to give a measured deflection, to each side of upright, of at least 6 in. Generally, this will require a pendulum length of at least 10 ft. Usually, the longer the pendulum the greater the accuracy of the test; however, if excessively long pendulums are used on a tender ship the pendulums may not settle down and the accuracy of the pendulums would then be questionable. On smaller vessels, where there is insufficient headroom to hang long pendulums, obtain the 6-in. deflection by increasing the test weight so as to increase the list. The typical inclination is between 2 and 3° but, in no case, should the maximum angle of list be greater than 4°. As shown in Fig. 14, the pendulums must be at least 87 in. long to get at least 6 in. of deflection without exceeding the 4° maximum heel.

5.6.3 If the pendulums are of different lengths, the possibility of collusion between station recorders is avoided. The pendulum wire should be piano wire or other monofilament material. The top connection of the pendulum should afford unrestricted rotation of the pivot point. An example is that of a washer with the pendulum wire attached suspended from a nail.

5.6.4 Provide a trough filled with a thick oil to dampen oscillations of the pendulum after each weight movement. It should be deep enough to prevent the pendulum weight from touching the bottom.

5.6.5 The use of a winged plumb bob at the end of the pendulum wire can also help to dampen the pendulum oscillations in the oil.

5.6.6 The battens should be smooth, light-colored wood, ½ to ¾ in. thick, and should be securely fixed in position so that an inadvertent contact will not cause them to shift. The batten should be aligned close to the pendulum wire but not in contact with it.

5.6.7 The pendulums should be in place prior to the scheduled time of the stability test.

5.6.8 A typical satisfactory arrangement is shown in Fig. 15. The pendulums may be placed in any location on the vessel, longitudinally and transversely.

5.6.9 If the person conducting the test desires to substitute inclinometers or other measuring devices for the pendulums, complete prior testing of the measuring devices to verify their accuracy before actual substitution for the pendulums. It is recommended that the inclinometers or other measuring devices be used in conjunction with the pendulums instead of using only other devices and no pendulums.

5.7 *Communications Arrangements:*

5.7.1 One person at a central control station should have complete control over all personnel involved in the test.

5.7.2 There should be efficient two-way communications between central control and the weight handlers and between central control and each pendulum station.

5.7.3 Shelter the central control station from the elements, and have adequate lighting so that a plot of tangents versus heeling moments can be made during the test. It is desirable that the weight handlers be directly observed from the control station.

5.8 *Additional Requirements:*

5.8.1 Annex A1 contains additional requirements that must be met, if U.S. Coast Guard approval of the stability test is needed.

5.8.2 Annex A2 contains additional requirements that must be met for stability tests on U.S. Navy vessels.

6. Plans and Equipment Required

6.1 *Plans*—The person in charge of the inclining should

$$\tan \theta = Z/Y$$
$$\tan 4° = 6 \text{ in.}/Y$$
$$Y = 6 \text{ in.}/\tan 4°$$
$$Y = 6 \text{ in.}/0.0699$$
$$Y = 87 \text{ in.}$$
$$\tan 3° = 6 \text{ in.}/Y$$
$$Y = 6 \text{ in.}/\tan 3°$$
$$Y = 6 \text{ in.}/0.0524$$
$$Y = 114 \text{ in.}$$
$$\tan 2° = 6 \text{ in.}/Y$$
$$Y = 6 \text{ in.}/\tan 2°$$
$$Y = 6 \text{ in.}/0.0349$$
$$Y = 172 \text{ in.}$$

FIG. 14   Angle of Inclination versus Pendulum Length

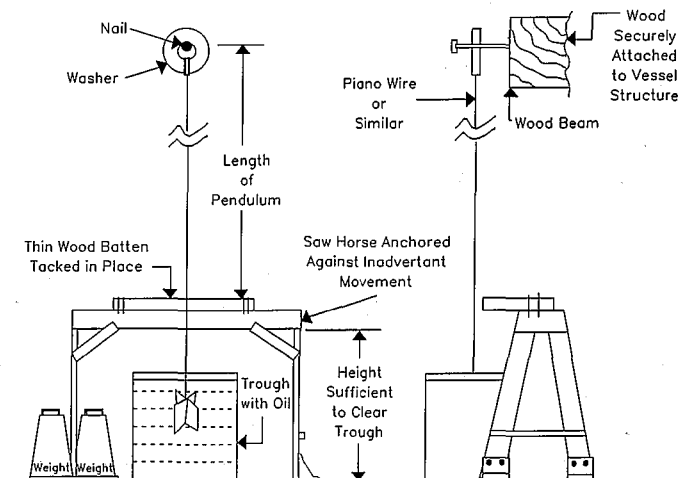**FIG. 15   Typical Satisfactory Pendulum Arrangement**

have available a copy of the following at the time of the stability test:

6.1.1 Lines plan,

6.1.2 Curves of form (hydrostatic curves) or hydrostatic data,

6.1.3 General arrangement plan of decks, holds, inner bottoms, etc.,

6.1.4 Outboard profile,

6.1.5 Inboard profile,

6.1.6 Midship section,

6.1.7 Capacity plan showing capacities and vertical and longitudinal centers of gravity of cargo spaces, tanks, etc.,

6.1.8 Tank sounding tables,

6.1.9 Draft mark locations, and

6.1.10 Docking drawing with keel profile and draft mark corrections (if available).

6.2 *Equipment*—Besides the physical equipment necessary such as the inclining weights, pendulums, small boat, etc., the following are necessary and should be provided by or made available to the person in charge of the inclining:

6.2.1 Three engineering scales for measuring pendulum deflections (rules should be subdivided into at least tenths of an inch),

6.2.2 Three sharp pencils for marking pendulum deflections,

6.2.3 Chalk for marking the various positions of the inclining weights,

6.2.4 A sufficiently long measuring tape for measuring the movement of the weights and locating different items on board,

6.2.5 A sufficiently long sounding tape for sounding tanks and taking freeboard readings,

6.2.6 One or more specific gravity hydrometers, either 60°F/15°C (ASTM 125) or other, with range sufficient to cover 0.999 to 1.030, to measure the specific gravity of the water in which the vessel is floating (a quality hydrometer for measuring specific gravity of less than 1.000 may be needed in some locations),

6.2.7 Other hydrometers as necessary to measure the specific gravity of any liquids on board,

6.2.8 Graph paper to plot inclining moments versus tangents,

6.2.9 A straight edge to draw the measured waterline on the lines drawing,

6.2.10 A pad of paper to record data,

6.2.11 An explosion proof testing device to check for sufficient oxygen and absence of lethal gases in tanks and other closed spaces such as voids and cofferdams,

6.2.12 A thermometer, and

6.2.13 Draft tubes (if necessary).

7. Procedure

7.1 The inclining experiment, the freeboard/draft readings, and the survey, may be conducted in any order and still achieve the same results. If the person conducting the stability test is confident that the survey will show that the vessel is in an acceptable condition and there is the possibility of the weather becoming unfavorable, then it is suggested that the inclining be performed first and the survey last. If the person conducting the test is doubtful that the vessel is complete enough for the test, it is recommended that

the survey be performed first since this could invalidate the entire test, regardless of the weather conditions. It is very important that all weights, the number of people on board, etc., remain constant throughout the test. Appendix X1 contains a stability test check list that can be used to make a quick check that the procedure is correctly followed.

7.1.1 *Initial Walk Through and Survey*—The person responsible for conducting the stability test should arrive on board the vessel well in advance of the scheduled time of the test to ensure that the vessel is properly prepared for the test. If the ship to be inclined is large, a preliminary walk through may need to be done the day preceding the actual incline. To ensure the safety of personnel conducting the walk through, and to improve the documentation of surveyed weights and deficiencies, at least two persons should make the initial walk through. Things to check include: all compartments are open, clean, and dry, tanks are well ventilated and gas free; movable or suspended items are secured and their position documented; pendulums are in place; weights are on board and in place; a crane or other method for moving weights is available; and the necessary plans and equipment are available. Before beginning the stability test, the person conducting the test should:

7.1.1.1 Consider the weather conditions. The combined adverse effect of wind, current, and sea may result in difficulties or even an invalid test due to the following:

(*a*) Inability to accurately record freeboards and drafts,

(*b*) Excessive or irregular oscillations of the pendulums, and

(*c*) Variations in unavoidable superimposed heeling moments.

In some instances, unless conditions can be sufficiently improved by moving the vessel to a better location, it may be necessary to delay or postpone the test. Any significant quantities of rain, snow, or ice must be removed from the vessel before the test.

7.1.1.2 Make a quick overall survey of the vessel to make sure the vessel is complete enough to conduct the test and to ensure that all equipment is in place.

7.1.1.3 Enter all empty tanks after it is determined that they are well ventilated and gas free to ensure that they are dry and free of debris. Ensure that any pressed up tanks are indeed full and free of air pockets.

7.1.1.4 Survey the entire vessel to identify all items which need to be added to the vessel, removed from the vessel, or relocated on the vessel to bring the vessel to the light ship condition. Each item must be clearly identified by weight and vertical and longitudinal location. If necessary, record also the transverse location. The inclining weights, the pendulums, any temporary equipment and dunnage, and the people on board during the stability test are all among the weights to be removed to obtain the light ship condition. The person calculating the light ship characteristics from the data gathered during the incline and survey or the person reviewing the stability test, or both, may not have been present during the test and must be able to determine the exact location of the items from the data recorded and the vessel's drawings. Any tanks containing liquids must be accurately sounded and the soundings recorded. Table 1 is an example of just a few typical entries from a survey.

(*a*) It is recognized that the weight of some items on board,

accurate by a keel survey while the vessel was in drydock.

7.1.2.7 A device, such as a draft tube, can be used to improve the accuracy of freeboard/draft readings by damping out wave action.

7.1.2.8 The dimensions given on a vessel's lines drawing are normally molded dimensions. In the case of depth (D), this means the distance from the inside of the bottom shell to the inside of the deck plate. In order to plot the vessel's waterline on the lines drawing, convert the freeboard readings to molded drafts (d). See Fig. 16. If the freeboard is measured from the main deck to the waterline:

$$d = D + t - f \qquad (5)$$

See Fig. 17. If the freeboard is measured from the top of the bulwark to the waterline:

$$d = D + t + b - f \qquad (6)$$

Similarly, correct the draft mark readings from extreme (bottom of keel) to molded (top of keel) before plotting. Resolve any discrepancy between the freeboard/draft readings.

7.1.2.9 Calculate the mean draft (average of port and starboard reading) for each of the locations where freeboard/draft readings are taken and plotted on the vessel's lines drawing or outboard profile to ensure that all readings are consistent and together define the correct waterline. The resulting plot should yield either a straight line or a waterline which is either hogged or sagged. If inconsistent readings are obtained, retake the freeboards/drafts.

7.1.3 *The Inclining Experiment:*

7.1.3.1 Prior to any weight movements, check the following:

(*a*) Check the mooring arrangement to ensure that the vessel is floating freely. (Do this just prior to each reading of the pendulums.)

(*b*) Measure the pendulums and record their lengths. The pendulums should be aligned so that when the vessel heels, the wire will be close enough to the batten to ensure an accu-
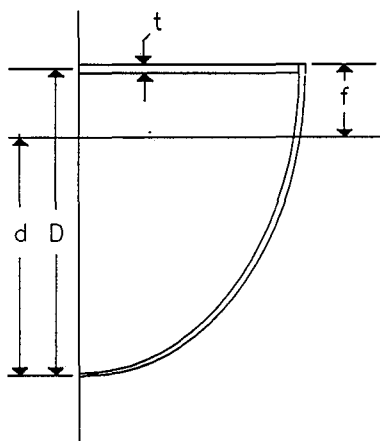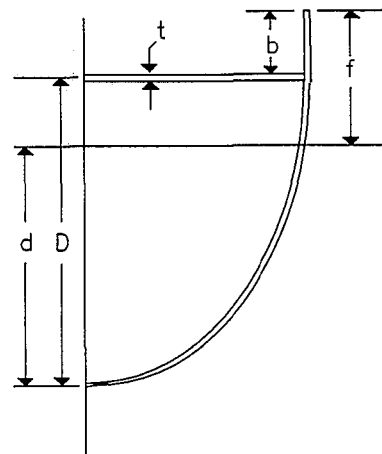
NOTE—where:
  D = molded depth
  d = molded draft
  f = freeboard reading
  t = deck thickness
  b = bulwark height

FIG. 17 Converting Freeboards (Measured to Top of Bulwark) into Molded Drafts

rate reading but will not come into contact with the batten. The typical satisfactory arrangement is shown in Fig. 15.

(*c*) Mark the initial position of the weights on the deck. This can be done by tracing the outline of the weights on the deck.

(*d*) The communications arrangement is adequate.

(*e*) All personnel are in place.

7.1.3.2 Run a plot during the test to ensure that acceptable data is being obtained. Typically, the abscissa of the plot will be heeling moment (weight times distance) and the ordinate will be the tangent of the heel angle (deflection of the pendulum divided by the length of the pendulum).

7.1.3.3 The standard test employs eight weight movements. Movement No. 8, a recheck of the zero point, may be omitted if a straight line plot is achieved after Movement No. 7.

7.1.3.4 The weight movements shown in Fig. 18 give a good spread of points on the test plot.

7.1.3.5 Once everything and everyone is in place, obtain the zero position and conduct the remainder of the experiment as quickly as possible, while maintaining accuracy and proper procedures, in order to minimize the possibility of a change in environmental conditions during the test.

7.1.3.6 Prior to each pendulum reading, each pendulum station should report to the control station when the pendulum has stopped swinging. Then, the control station will give a "standby" warning and then a "mark" command. When "mark" is given, the batten at each position must be marked at the location of the pendulum wire. If the wire was oscillating slightly, take the center of the oscillations as the mark. If any of the pendulum readers doesn't think the reading was a good one, the reader should advise the control station and the point should be retaken for all pendulum stations. Likewise, if the control station suspects the accuracy of a reading, it should be repeated for all the pendulum stations. Next to the mark on the batten should be written the number of the weight movement, such as zero for the

NOTE—where:
  D = molded depth
  d = molded draft
  f = freeboard reading
  t = deck thickness
  b = bulwark height

FIG. 16 Converting Freeboards (Measured to the Main Deck) into Molded Drafts
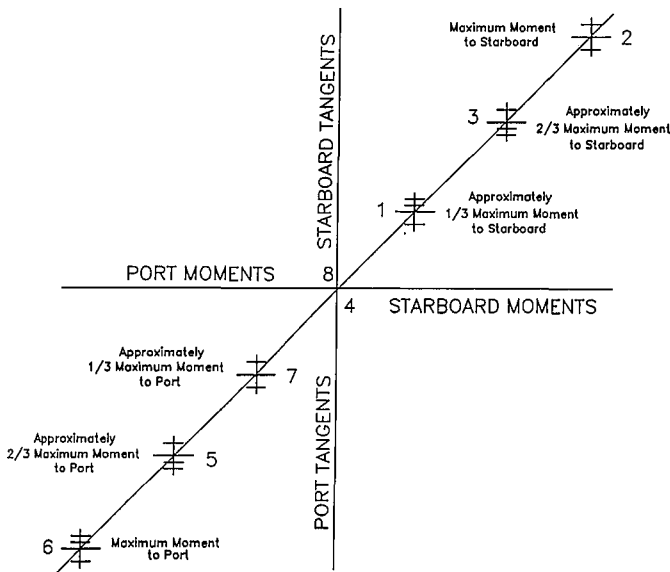
FIG. 18 Acceptable Spread of Test Points On Incline Plot

initial position and one through seven for the weight movements.

7.1.3.7 Make each weight movement in the same direction, normally transversely, so as not to change the trim of the vessel. After each weight movement, measure the distance the weight was moved (center to center) and calculate the heeling moment by multiplying the distance by the amount of weight moved. Calculate the tangent for each pendulum by dividing the deflection by the length of the pendulum. Plot the three resultant tangents on the graph. Provided there is good agreement among the pendulums with regard to the tan θ value, the average of the three pendulum readings may be graphed instead of plotting each of the readings.

7.1.3.8 If a straight line plot is achieved after the initial zero and six weight movements, the stability test is complete and the second check at zero may be omitted. If a straight line plot is not achieved, those weight movements that did

not yield acceptable plotted points must be repeated or explained.

8. Report

8.1 Appendix X2 contains sample data sheets to record data during stability tests. It is suggested that these sheets be used so that no data is forgotten and so that the data is clear, concise, and consistent in form and format.

8.2. Appendix X3 contains sample sheets to aid in calculating the results of the stability test.

8.3 Alternatively, all calculations performed during the inclining and in preparation of the report may be carried out by a suitable computer program. Output generated by such a program may be used for presentation of all or partial data and calculations included in the test report if it is clear, concise, well documented, and generally consistent in form and content with the forms in Appendixes X2 and X3.

8.4 Annex A3 contains conversion factors to be used in changing specific gravity of fuel oil and water to specific volume.

9. Precision and Bias

9.1 The accuracy of the stability test is directly related to the accuracy of the measuring conditions at the time of the test. Many factors can influence the reliability of the information gained. The weather, the vessel loading, the mooring arrangements, the state of completion of the vessel, etc., can all significantly affect the final results of the test. Conditions during the measurement period should be such that readings can be recorded and then repeated to give consistent data. Make the required measurements, attempting to reach the following precision:

Freeboards	nearest 1/8 in.
Draft marks	nearest 1/8 in.
Pendulum lengths and readings	nearest 1/16 in. (0.05 in. on a 1/10 in. scale)
Survey weights	1 % of the weight (5 % for small items)
Tank soundings	nearest 1/8 in.

The precision used to read measurements does not guarantee the resulting overall accuracy of the test. If all procedures in this guide are followed, the test results should have satisfactory accuracy.

ANNEXES

(Mandatory Information)

A1. TO RECEIVE UNITED STATES COAST GUARD APPROVAL OF THE STABILITY TEST ON COMMERCIAL VESSELS THE FOLLOWING ADDITIONAL REQUIREMENTS SHOULD BE FOLLOWED
(In Amplification of the Regulations)

A1.1 *Prior Notification To The Coast Guard Marine Safety Center*—Written notification of the test must be sent to the Coast Guard Marine Safety Center (MSC) at least two weeks prior to the test. The MSC will make arrangements for an acceptable representative to witness the test.

A1.1.1 *Details of Notification*—Written notification should provide the following information:

A1.1.1.1 Identification of the vessel by name and shipyard hull number, if applicable.

A1.1.1.2 Date, time, and location of the test.

A1.1.1.3 Inclining weight data.

(*a*) Type,

(*b*) Amount (number of units and weight of each),

(*c*) Certification,

(*d*) Method of handling (that is, sliding rail or crane), and

(*e*) Anticipated maximum angle of heel to each side.

A1.1.1.4 *Pendulums*—Approximate location and length. (If a shipyard/naval architect desires to substitute inclinometers or other measuring devices for one or two of the three required pendulums, prior approval must be obtained from the MSC. The MSC might require that the devices be used in addition to the pendulums on one or more inclinings to verify their accuracy before allowing actual substitution for a pendulum.)

A1.1.1.5 Approximate trim.

A1.1.1.6 Condition of tanks.

A1.1.1.7 Estimated weights to deduct, to complete, and to relocate in order to place the vessel in its true light ship condition.

A1.1.1.8 Detailed description of any computer software to be used to aid in calculations during the inclining.

A1.1.1.9 Name and phone number of the person responsible for conducting the test.

A1.2 Alternate mooring arrangements will be considered if submitted for review prior to the test. Such arrangements should ensure that the vessel will be free to list without restraint for a sufficient period of time to allow the pendulums to damp out motion so that the readings can be recorded.

A1.3 Each of the test weights must be certified by a weigh-master's document and a copy provided to the Coast Guard representative. For small vessels, capped drums, completely filled with water may be used. In such cases, the weight should be verified in the presence of the Coast Guard representative using a recently calibrated scale.

A1.4 If bad weather conditions are detected early enough and the weather forecast does not call for improving conditions, the Coast Guard representative should be advised prior to departure from the office and an alternate date scheduled.

A1.5 An estimate of work items which will be outstanding at the time of the stability test should be included as part of any test procedure submitted to the MSC. This is required so that the Coast Guard representative can advise the shipyard/ naval architect if in their opinion the vessel will not be sufficiently complete to conduct the stability test and that it should be rescheduled. If the condition of the vessel is not accurately depicted in the test procedure and at the time of the stability test the Coast Guard witness considers that the vessel is in such condition that an accurate stability test cannot be conducted, the witness may refuse to accept the test and require that a test be conducted at a later date.

A1.6 A certified marine chemist's certificate certifying that all fuel oil and chemical tanks are safe for human entry should be available, if necessary.

A1.7 If a computer program is used to perform calculations during the inclining, Coast Guard approval to use the program must be obtained prior to the test.

A1.8 Prior to departing the vessel, the person conducting the test and the Coast Guard representative should initial each sheet as an indication of their concurrence with the recorded data.

A1.9 A copy of the data should be forwarded to the MSC along with the stability test report.

A1.10 When completed, three copies of the stability test report should be submitted to the MSC for approval.

A1.11 The Coast Guard may alter or limit acceptance of any provision in this guide.

A1.12 When the American Bureau of Shipping is representing the Coast Guard during a stability test, the words, American Bureau of Shipping, should be substituted for the words, Coast Guard, and for the words, Marine Safety Center, in this annex.

A2. FOR STABILITY TESTS ON UNITED STATES NAVY (USN) VESSELS THE FOLLOWING ADDITIONAL REQUIREMENTS APPLY

A2.1 The inclining experiment shall be performed in accordance with the requirements set forth in Naval Ship's Technical Manual,[2] and as modified below. The stability test report shall be prepared on the forms described in the above technical manual.

A2.2 Photographs of topside arrangements including weather decks is required to document topside installations. Photographs of each draft mark reading are also required.

A2.3 A comprehensive survey of all compartments, tanks, and voids is required to determine the weight and center of

---

[2] *NAVSEA 59086-C6-STM-000*, Chapter 096, "Weights and Stability," available from Commanding Officer, Naval Ships Weapon System Engineering Station, Code 5700, Port Hueneme, CA 93043.

gravity (vertical, longitudinal, and transverse) of all consumable loads, including personnel, ammunition, provisions, general stores, and liquids.

A2.4 Draft readings are required. Amidships marks should be read to determine hog or sag of ship. Projection draft marks and freeboard readings can be used to verify accuracy of draft mark readings.

A2.5 Inclining weights are moved transversely to produce at least two inclinations to port and two to starboard.

A2.6 Significant items of weight which are considered part of the lightship displacement but are subject to change or are readily removable are listed, as part of the report, by weight and center of gravity. These items include boats, armament, ballast, salvage gear, and yellow gear.

A2.7 It is desirable under most circumstances to incline the vessel at design trim. If however, the area of the waterplane will change substantially as the ship is heeled from side to side, then the trim should be altered, to minimize the change in the waterplane area during the incline. This may require that functions of wedges be calculated to correct for the trimmed conditions. The hydrostatics must be verified or recalculated, or both, if the as-trimmed waterplane area differs from the waterplane area at the design trim.

A2.8 The freeboard/draft mark readings must be taken simultaneously on both sides of the vessel, to ensure that any heel is properly recorded at the time of the stability test.

A2.9 The transverse center of gravity (TCG) must be determined for all ships.

A2.10 In presentation of incline results, incline plots are to be arranged such that the slope of the incline plot can be directly substituted into the GM formula as shown below.

$$GM = \frac{slope}{(displ)}$$

where slope of the line from the incline plot equals the (rise/run). Heeling moments must be on the ordinate and tangents must be on the abscissa. Figure A2.1 gives an example of an acceptable plot.
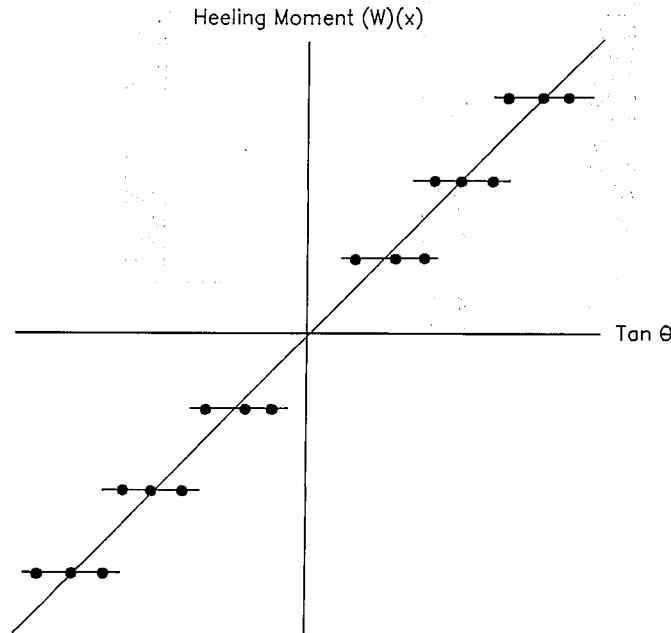
FIG. A2.1   Acceptable Orientation for Incline Plots on U.S. Navy Vessels

A3. CONVERSION TABLES FOR LIQUIDS

A3.1 Tables A3.1 and A3.2 are based on the weight of 1 gal of water in air against brass weights at 60°F and 30 in. mercury at 45° latitude at sea level and 50 % humidity. They were taken from the National Bureau of Standards Circular C-410.[3]

[3] Available from National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899.

TABLE A3.1 Fuel Oil[A]

Degrees API	Specifiction Gravity	bbl/ton	ft³/ton
10	1.0000	6.404	35.96
11	0.9930	6.449	36.21
12	0.9861	6.494	36.46
13	0.9792	6.540	36.72
14	0.9725	6.585	36.97
15	0.9659	6.630	37.22
16	0.9593	6.776	37.48
17	0.9529	6.720	37.73
18	0.9465	6.766	37.99
19	0.9402	6.811	38.24
20	0.9340	6.856	38.50
21	0.9279	6.901	38.75
22	0.9218	6.947	39.01
23	0.9159	6.992	39.26
24	0.9100	7.037	39.51
25	0.9042	7.082	39.76
26	0.8984	7.128	40.02
27	0.8927	7.174	40.28
28	0.8871	7.219	40.53
29	0.8816	7.264	40.78
30	0.8762	7.309	41.04

[A] Conversion Formula:

$$\text{Specific gravity} = \frac{141.5}{(131.5 + B)}$$

where B = degrees API.

TABLE A3.2 Water

Specific Gravity	ft³/ton
0.999	35.99
1.000	35.96
1.001	35.92
1.002	35.88
1.003	35.85
1.004	35.81
1.005	35.78
1.006	35.74
1.007	35.71
1.008	35.67
1.009	35.63
1.010	35.60
1.011	35.56
1.012	35.53
1.013	35.49
1.014	35.46
1.015	35.42
1.016	35.39
1.017	35.35
1.018	35.32
1.019	35.28
1.020	35.25
1.021	35.22
1.022	35.18
1.023	35.15
1.024	35.11
1.025	35.08
1.026	35.04
1.027	35.01
1.028	34.98

APPENDIXES

(Nonmandatory Information)

X1. STABILITY TEST CHECK LIST

X1.1 *Pre-Inclining:*

1. _____ Vessel is complete or nearly so.

(*a*) No major structural sections or major items of equipment to be added or removed.

(*b*) No tanks with liquids not shown in the inclining procedure.

(*c*) No extraneous gear and personnel on board the vessel.

2. _____ Weather conditions are satisfactory.

(*a*) No gusting winds. Steady light wind not causing motions is acceptable. Beam winds to be avoided. Wind speed normally acceptable if draft marks can be read.

(*b*) No strong currents.

(*c*) Not raining.

(*d*) No waves. Ripples acceptable if can read freeboards to ⅛ in.

3. _____ Depth of water is greater than draft of vessel.

4. _____ All empty tanks should be opened and checked for liquids. All tanks containing liquids should be sounded for liquid levels. All tank levels should be recorded.

5. _____ Weight certificates obtained or the weights used for the inclining actually weighed using certified scales.

6. _____ Initial angle of heel is less than 0.5° and the trim difference from design is less than 1 % of the *LBP*. If more trim is allowed, as-trimmed hydrostatics must be used in calculations.

NOTE X1.1—In some cases, if trim is different from design, as-trimmed hydrostatics must always be used (that is, Navy inclines).

X1.2 *Freeboard/Draft Readings:*

1. _____ At least five (5) freeboard readings on each side at approximately the same intervals along the length at readily identifiable locations (for example, ends of deck houses). A verified draft mark reading may be substituted for a freeboard reading.

(*a*) Each data point is to consist of:

1. Freeboard reading (*f*) taken from the top of the bulwark to the point where the plumb bob touches the water.

2. Bulwark height (*b*) reading at each location.

3. Deck plating thickness (*t*) from the structural plan.

4. Molded depth (*D*) at each location from the lines plan.

(*b*) Molded Draft = molded depth plus bulwark height plus deck plating thickness minus freeboard reading ($d = D + b + t - f$).

2. _____ Draft mark readings:

(*a*) Taken from a small boat.

(*b*) Port and starboard; forward, midship, and aft.

(*c*) Longitudinal locations from a known reference point.

3. _____ Plot of waterline (draft versus distance from forward perpendicular).

(*a*) Note that draft readings are extreme (bottom of keel)

while drafts from freeboard readings are molded (top of keel).

4. _____ Specific gravity of water (hydrometer reading) and water temperature readings.

X1.3 *Weight Movements:*

1. _____ Pendulums:

(*a*) At least three (3); can be located on different decks and do not have to be on centerline.

(*b*) Length of pendulums is measured from the pivot point to the top of the batten.

(*c*) Pendulums should be of different lengths; to get required angle of deflection, pendulums need to be at least 10 ft long. The longer the better if sheltered from the wind. Pendulum unrestricted through maximum angle expected.

(*d*) Thick oil in bucket to dampen movement of pendulums. Pendulums with dampers are recommended.

(*e*) Pendulum support is fixed so it cannot be accidentally moved during the inclining.

2. _____ Battens:

(*a*) Pencil marks placed on battens to record the position of the pendulum wires.

(*b*) Batten is fixed so it can not be accidentally moved during the inclining.

(*c*) Battens should never be reset once inclining begins and movements are being recorded.

3. _____ Weights:

(*a*) Record initial position (vertical, transverse, longitudinal distances from known reference points such as distance above the deck, distance from the end of a deckhouse and distance from the centerline).

4. _____ Weight Movements:

(*a*) At least three (3) to each side of the reference position.

(*b*) Deflection of the pendulums at maximum moment should be at least six (6) inches to each side of the initial position.

(*c*) Maximum angle of heel should not be greater than four (4) degrees; value of tangent must be less than 0.06993. Typical angle of heel should be between two (2) and three (3) degrees.

(*d*) Moment equals weight times distance moved; calculated and summed for all weights moved for each movement.

(*e*) Tangent equals pendulum deflection divided by pendulum length. When calculating the tangent, the deflection and the length must be in the same units (that is, inches or feet).

(*f*) During each movement, ensure that:

1. There are no taut mooring lines other than those attached to temporary pads on centerline;

2. Pendulum weight is not touching side of bucket; and

3. Pendulum is not touching batten.
(g) Plot of moment-tangent curve:
1. Plot each tangent value calculated for each weight movement. The average of the three pendulum readings may be graphed instead of plotting each of the readings only if the tan θ values measured among the pendulums are consistent.
2. Plot must be a straight line but it doesn't have to pass through the origin.
3. Curved line means unaccounted for free surface, gusting winds or the vessel is touching the bottom and should not be accepted.

X1.4 *Post Inclining:*
1. _____ Check drafts/freeboards to ensure consistency with first measurements.
   (a) Note that draft readings are extreme (bottom of keel) while drafts from freeboard readings are molded (top of keel).
2. _____ Survey tanks if drafts have changed.

X1.5 *Survey of Items to Be Added, Removed, or Relocated:*
1. _____ Record weight, vertical center of gravity, longitudinal center of gravity, and transverse center of gravity (if required) for each item. Weights become more critical as the size of the vessel becomes smaller.
2. _____ Typical weights to add:
   (a) Liferafts/lifesaving equipment;
   (b) Seating;
   (c) Liquids in engines and other machinery;

(d) Paneling;
(e) CO_2 bottles/firefighting equipment;
(f) Fenders;
(g) Deck coverings/tiles and underlayments;
(h) Cables for winches;
(i) Lines and hawsers;
(j) Engineroom insulation;
(k) Ventilation ducts;
(l) Galley equipment (stoves and refrigerators);
(m) Mattresses;
(n) Paint (on surfaces to be painted);
(o) Dampers;
(p) Electronic equipment in the pilothouse;
(q) Masts and navigation lights.
3. _____ Typical weights to deduct:
   (a) Inclining weights and pendulum set-up;
   (b) Personnel on board;
   (c) Liquids on board (in tanks and bilges but excluding liquids in engines and other machinery);
   (d) Workers equipment;
   (e) Scrap metal;
   (f) Scaffolding;
   (g) Dunnage.
4. _____ Typical weights to relocate:
   (a) Paneling;
   (b) Lifesaving equipment;
   (c) Fenders and mooring equipment;
   (d) Fire extinguishing equipment.

X2. SAMPLE DATA SHEETS

_____ Stability Test Rough Data _____

Description of Vessel:
Name _____
Type _____
Builder _____
Hull Number _____

Vessel inclined at _____

Date _____ Time _____
Test conducted by _____
Test witnessed by _____
Description of weather conditions _____

Specific gravity of water _____
Temperature of water _____
Weights certified by:
   Weigh master (certificate attached)   ☐
   Reviewing authority   ☐

FIG. X2.1 Stability Test Rough Data

F 1321

Items to Be Added

Description	Weight	Vertical Center	Longitudinal Center	Transverse Center (if needed)
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

TANKS:

Description	Location	Sounding or Ullage	Specific Gravity/Density
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

FIG. X2.2   Items to be Added

Items to Be Removed

Description	Weight	Vertical Center	Longitudinal Center	Transverse Center (if needed)
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

TANKS:

Description	Location	Sounding or Ullage	Specific Gravity/Density
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____
_____	_____	_____	_____

FIG. X2.3 Items to be Removed

Items to be Relocated

Description	Weight	From			To		
		Vertical Center	Longitudinal Center	Tranverse Center (if needed)	Vertical Center	Longitudinal Center	Tranverse Center (if needed)

FIG. X2.4 Items to be Relocated

Freeboard Readings

f = measured freeboard,
t = deck thickness,
D = molded depth from lines drawing,
b = measured bulwark height, and
d = calculated molded draft.

Without Bulwark or Side Shell Coaming
$$d = D + t - f$$
or

With Bulwark or Side Shell Coaming
$$d = D + t + b - f$$

Location		f	t	D	b	d
1.	P					
	S					
2.	P					
	S					
3.	P					
	S					
4.	P					
	S					
5.	P					
	S					
6.	P					
	S					
7.	P					
	S					
8.	P					
	S					

Draft Mark Readings

Location	Reading		Location	Reading
	P			P
	S			S
	P			P
	S			S
	P			P
	S			S

FIG. X2.5 Freeboard Readings

Ship at Time of Stability Test—Condition 0

Pendulums			Weight		Distance from Initial Positions		Moment	Total Inclining Moment		Pendulum Deflections			Tangents	
No. Location	Length to Batten		No.		Port	Star-board		Port	Star-board	No.	Port	Star-board	Port	Star-board
	Inches			Tons	Feet	Feet	Ft-Tons	Ft-Tons	Ft-Tons		Inches	Inches		
1st		1st Trial								1st 2d 3d				
2d		2d Trial								1st 2d 3d				
3d		3d Trial								1st 2d 3d				
Inclining Weights Location		4th Trial								1st 2d 3d				
Description		5th Trial								1st 2d 3d				
Weight Initial Position No. Port Starboard Tons Feet Feet		6th Trial								1st 2d 3d				
		7th Trial								1st 2d 3d				
		8th Trial								1st 2d 3d				

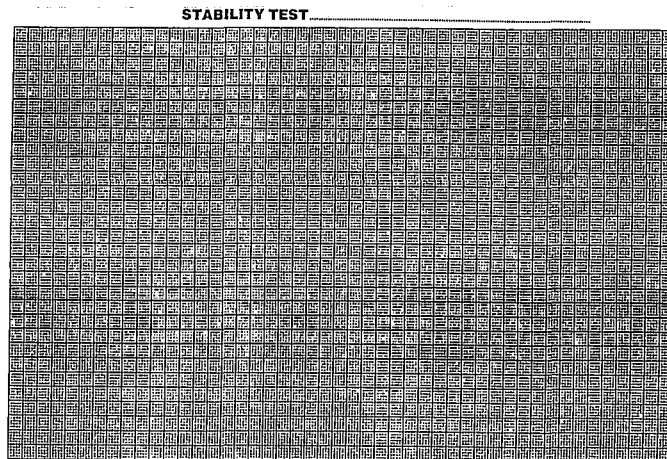**FIG. X2.6   Condition 0—Preliminary Report**

FIG. X2.7   Stability Test Graph—Preliminary Results

F 1321

X3. STABILITY TEST DATA

Stability Test Data

Official Number _____
Gross Tons _____

DESCRIPTION OF VESSEL _____

Type _____
Builder _____
Hull Number _____ Date Built _____
Hull _____
_____

Machinery _____
_____
_____

Classed By _____ Inspected ☐ Safety Certificate ☐ Load Line ☐
Route: Ocean ☐ Coastwise ☐ Great Lakes ☐ Bays ☐ Rivers ☐
Specify Route, If Limited _____

Owner _____
Owner's Address _____

Vessel Inclined At _____
Date _____ Time _____
Test Requested By _____

Plans Furnished By _____
Offsets Measured By _____
Curves of Form Computed By _____

Test Conducted By _____
Stability Calculations Made By _____
Sister Vessels _____

FIG. X3.1 Stability Test Data

Stability Test

Principal Dimensions

Length over all _____ ft _____ in. (_____ ft)
Length between perpendiculars which are at the extremities of _____ waterline _____ ft _____ in. (_____ ft)
Length between draft marks, _____ condition _____ ft _____ in. (_____ ft)
Breadth, extreme, at _____ feet above base _____ ft _____ in. (_____ ft)
Breadth, molded, amidships at _____ feet above base _____ ft _____ in. (_____ ft)
Breadth at load water line _____ ft _____ in. (_____ ft)
Depth amidships, from _____ to _____ ft _____ in. (_____ ft)

Apparent full-load mean draft for stability { molded base _____ ft _____ in. (_____ ft)

bottom of keel _____ ft _____ in. (_____ ft)
Displacement, sea water, tons (2240 lb), at above full-load draft _____ tons
Freeboard amidships at above full-load draft _____ ft _____ in. (_____ ft)
Freeboard at low point of sheer (_____ feet aft of amidships) _____ ft _____ in. (_____ ft)
Location of ports, in hull, which may affect stability _____

General Information

Names and duties of official observers _____
Designers represented by _____
Builders represented by _____
Owners represented by _____
Weather, tide, and mooring conditions _____
Condition of ship as to completeness and as
    to water in boilers, machinery, and bilges _____

FIG. X3.2 Stability Test—Principle Dimensions

Stability Test

All tons used in this calculation are of _____ lb

Ship at Time of Stability Test—Condition 0

Sketch Showing Hog, Sag, Trim, Drag, and Location of Draft Marks, Freeboards, and Perpendiculars

Draft from draft marks when inclined — Forward _____ ft _____ in. Aft _____ ft _____ in.

Amidships — Port _____ ft _____ in. Starboard _____ ft _____ in.

Distance between "curves of form" perpendiculars _____ ft

Bottom of keel below base line _____ in.

Molded Keel — drafts corrected to "curves of form" perpendiculars for use in calculations — Forward _____ ft Aft _____ ft Mean of amidships P and S _ ft

Mean of forward and after drafts _____ ft
Hog or sag _____ ft

Trim forward, aft _____ ft
Longitudinal center of floatation forward, aft _____ ft
Molded Keel   draft at center of flotation _____ ft

Molded Keel   draft at L.C.F. corrected for hog or sag _____ ft

Total displacement at above draft F.W., S. W. _____ tons

Specific gravity of water _____ equals _____ ft³/ton

Total displacement corrected for density _____ tons

FIG. X3.3 Stability Test Sketch—Condition 0

Ship at Time of Stability Test—Condition 0

Pendulums			Weight		Distance from Initial Positions		Moment	Total Inclining Moment		Pendulum Deflections			Tangents	
No. Location	Length to Batten		No.		Port	Star-board		Port	Star-board	No.	Port	Star-board	Port	Star-board
	in.			tons	ft	ft	ft-tons	ft-tons	ft-tons		in.	in.		
1st		1st Trial	—	___	___	___	___			1st 2d 3d	___	___	___	___
2d		2d Trial	—	___	___	___	___			1st 2d 3d	___	___	___	___
3d		3d Trial	—	___	___	___	___			1st 2d 3d	___	___	___	___
Inclining Weights Location		4th Trial	—	___	___	___	___			1st 2d 3d	___	___	___	___
Description		5th Trial	—	___	___	___	___			1st 2d 3d	___	___	___	___
Weight No. / Initial Position Port Starboard tons ft ft		6th Trial	—	___	___	___	___			1st 2d 3d	___	___	___	___
		7th Trial	—	___	___	___	___			1st 2d 3d	___	___	___	___
		8th Trial	—	___	___	___	___			1st 2d 3d	___	___	___	___

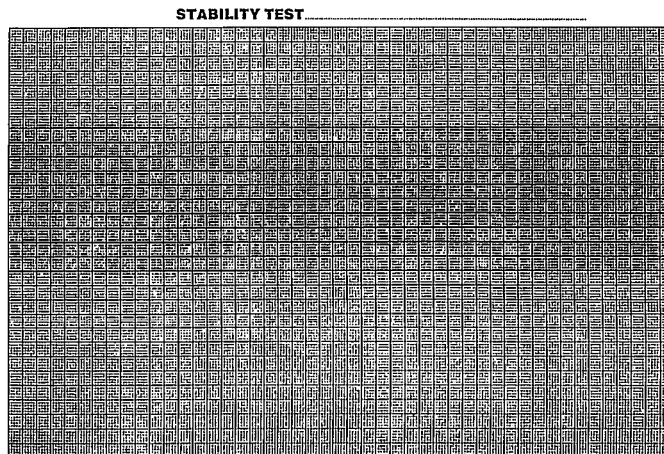**FIG. X3.4   Condition 0—Final Report**

STABILITY TEST

FIG. X3.5   Stability Test Graph—Final Results

Stability Test

Ship at Time of Stability Test—Condition 0

	From Hydrostatic Curves	From Independent Calculation
Corrected displacement	_____ tons	_____ tons
Mean virtual metacentric height obtained from plot of inclining moments versus tangents of angles of heel— $\dfrac{moment}{displacement \times tangent}$	_____ ft	_____ ft
Correction for free surface	_____ ft[A]	_____ ft
Mean metacentric height G. M. =	_____ ft	_____ ft
Transverse metacenter above the base line corresponding to draft at L. C. F. (corrected for hog or sag)	_____ ft[B]	
Transverse metacenter above the base line corrected (for trim, and hog or sag)	_____ ft	
C. G. above base line	_____ ft	_____ ft (from figure)
Longitudinal metacenter above C. G.	_____ ft	
Moment to alter trim 1 foot, $\dfrac{Longl.\ GM \times \Delta}{L}$	_____ ft-tons	
Trim by stern, bow	_____ ft[B]	
Trimming lever $= \dfrac{Trim \times moment\ to\ trim}{displacement}$	_____ ft	
L.C.B. forward, aft of amidships, which is ____ ft forward, aft of frame No.____	_____ ft	
C. G. forward, aft of amidships	_____ ft	_____ ft (from figure)
Period of complete roll _____ s		
Apparent radius of gyration of vessel—$k = \dfrac{T\sqrt{GM}}{1.108}$ _____ ft		
Rolling Constant—$C = \dfrac{T\sqrt{GM}}{B}$ _____		

[A] Water in bilges. The bilges should be entirely free of water; but should this be impossible, correction should be made in the derived GM. The details of this correction should form part of this report.

[B] If the trim is excessive, independent calculations should be made to obtain the positions of the center of buoyancy and transverse metacenter and the position of the center of gravity determined therefrom. These calculations should be incorporated in this booklet.

FIG. X3.6 Stability Test Results at Condition 0 from Hydrostatic Curves and Independent Calculation

Stability Test

Data for Tanks				Items	Weight, tons	C. G. Above base		C. G. Above from M. P.			
Liquid	Sounding	Net Inertia of Free Surface	Inertia, ft³-ton			Lever	Vertical Moments, ft-tons	Feet Aft	After Moments, ft-tons	Feet Forward	Forward Moments, ft-tons

FIG. X3.7   Stability Test—Data for Tanks

Ship Light—Condition I

Ship complete in every respect, with water in boilers at steaming level and liquids in machinery and piping,
but with all tanks and bunkers empty and no passengers, crew, cargo, stores, or baggage on board.

List of Major Equipment, etc., Included in Condition I as Shown Ballast, boats, rafts, cargo booms, anchors, guns, armor, etc.					Items	Displacement and Weight	C. G. Above Base		Feet Aft	C.G. Above from M. P.		
Items	Weight, tons	C.G. Above Base, ft	C.G. from M.P. Feet Forward	Feet Aft		tons	Lever	Vertical Moments, ft-tons	Feet Aft	After Moments, ft-tons	Feet Forward	Forward Moments, ft-tons
Fixed Ballast	_____	_____	_____	_____	Ship in Condition 0 Weight to Complete Weight to Relocate Weight to Remove Ship in Condition I	_____	_____	_____	_____	_____	_____	_____

Molded Keel—Draft at longitudinal center of flotation corresponding to above displacement for _____ water_____ ft
Transverse metacenter above base at L.C.F. draft, uncorrected for trim _____ ft
C.G. above base _____ ft
Metacentric height, uncorrected for trim, G.M. _____ ft
Metacentric height, corrected for G.M. _____ ft

Longitudinal metacenter above C.G. at L.C.F. draft   _____ ft   L.C.F. aft, forward of amidships   _____ ft

Moment to alter trim 1 foot at L.C.F. draft, $\dfrac{\text{longl GM} \times \Delta}{L}$ _____ ft-tons   Difference between L.C.F. and amidships draft   _____ ft

C.B. of ship on even keel at L.C.F. draft, aft, forward f ϕ _____ ft   Molded draft amidships   _____ ft

C.G. aft, forward of amidships   _____ ft   Draft on draft marks, forward   _____ ft

Trimming lever   _____ ft   Draft on draft marks, aft   _____ ft

Trim, aft, forward— $\dfrac{\text{displacement} \times \text{lever}}{\text{moment to trim}}$ _____ ft

FIG. X3.8   Ship Light—Condition I

802

F 1321

Stability Test

Ship in Condition _____

Description of Condition	Items	Displacement and Weight	C. G. Above Base		C. G. Above from M. P.			
		tons	Lever	Vertical Moments, ft-tons	Feet Aft	After Moments, ft-tons	Feet Forward	Forward Moments, ft-tons
_____ Ship in Condition _____								
_____ Total _____								

Molded Keel—Draft at longitudinal center of flotation corresponding
to above displacement for _____ water _____ ft

Transverse metacenter above base at L.C.F. draft, uncorrected for trim _____ ft

C.G. above base _____ ft

Metacentric height, uncorrected for free surface [corrected for trim / uncorrected for trim] G.M. _____ ft

Correction for free surface

Metacentric height, corrected for free surface [corrected for trim / uncorrected for trim] G.M. _____ ft

Longitudinal metacenter above C.G. at L.C.F. draft _____ ft

Moment to alter trim 1 foot at L.C.F. draft, $\dfrac{\text{longl GM} \times \Delta}{L}$ _____ ft-tons

C.B. of ship on even keel at L.C.F. draft, aft, forward of amidships _____ ft

C.G. aft, forward of amidships _____ ft

Trimming lever _____ ft

Trim, aft, forward—$\dfrac{\text{displacement} \times \text{lever}}{\text{moment to trim}}$ _____ ft

Longitudinal center of floatation, aft, forward of amidships _____ ft

Difference between L.C.F. and amidships draft _____ ft

Molded draft amidships _____ ft

Draft on draft marks, forward _____ ft

Draft on draft marks, aft _____ ft

FIG. X3.9 Stability Test—Condition Description

Stability Test
Conclusive Remarks

NOTE—This sheet should be used for any explanations that may be required other than those covered by the notes on the previous sheets. In case the results of the stability test show that under certain conditions caution in loading and handling the vessel is necessary, particularly in regard to the effect of deck loads or free surface, a detailed statement to this effect should be made here.

FIG. X3.10 Stability Test—Conclusive Remarks