REVIEW OF STABILITY TEST PROCEDURES

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Purpose:

This Plan Review Guideline (PRG) provides general guidance and information for conducting successful stability tests and submitting stability test procedures to the Marine Safety Center (MSC).

This PRG applies to vessels certificated under any subchapter of 46 CFR.

Contact Information:

If you have any questions or comments concerning this document, please contact the Marine Safety Center by e-mail or phone. Please refer to Procedure Number **GEN-05**.

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1.0 Applicability

This PRG is applicable to all deadweight survey and stability test procedures submitted to MSC for review. This PRG is applicable to both in-water and in-air (suspended) surveys and tests.

For towing vessels certificated under 46 CFR Subchapter M, the stability test procedures should be verified by the individual or entity who meets the requirements of 46 CFR 144.140.

2.0 Discussion

In order for the Coast Guard to issue a stability letter to a vessel with approved lightship characteristics, a stability test must be performed. 46 CFR 170.085 requires stability test procedures containing the information prescribed in 170.185(g) be submitted to the Coast Guard Marine Safety Center at least two weeks before the stability test. 46 CFR 170.180 requires Coast Guard approved stability test procedures be presented to the Coast Guard representative at the time of the stability test.

The American Society for Testing and Materials (ASTM) standard guide for conducting stability tests was developed by the Coast Guard, in cooperation with an industry task group, to ensure that the procedures followed during stability tests will produce an accurate determination of a vessel's light ship characteristics. The development of a test procedure following this widely used industry consensus standard is highly encouraged. It ensures that the test procedures provide witnesses and responsible parties with a good understanding of what factors influence the results of the test, and help them to recognize unacceptable conditions or procedures when they occur.

Coast Guard engineers must review, validate, and approve the lightship characteristics produced by the naval architect following the test. Should the test results provide insufficient detail or be flawed due to the use of inappropriate procedures preventing our approval, a new test may be necessary. The guidance provided herein highlights particularly pertinent portions of the ASTM standard practices and include guidance from the MSC based on our experience in reviewing and evaluating test results for vessels of all sizes and configurations. Therefore, in development of stability test procedures, it is recommended to incorporate the enclosed guidance to ensure a more timely approval of the submitted test procedures and ultimately more accurate test results.

3.0 References

a. 46 CFR Part 170, Subpart F: "Determination of Lightweight Displacement and Centers of Gravity"

b. Marine Safety Manual Vol. IV, Chapter 6

c. Navigation and Vessel Inspection Circular (NVIC) No. 17-91, "Guidelines for Conducting Stability Tests"

d. ASTM Standard Guide F1321 (Series) "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"

e. ASTM Standard Guide F3052 (Series) "Standard Guide for Conducting Small Boat Stability Test (Deadweight Survey and Air Inclining Experiment) to Determine Lightcraft Weight and Centers of Gravity of a Small Craft"

f. SNAME T&R Bulletin 9-1 "Standard Guide for Conducting Small Boat Air-Inclining Stability Test (Lightweight Survey and Air Inclining Test to Determine Lightweight and Centers of Gravity)"

4.0 Definitions

Deadweight Survey:
A survey in which a vessel's lightship weight, longitudinal center of gravity (LCG), and transverse center of gravity (TCG) are experimentally determined. As part of this survey, lightship weights that are to be added or relocated, and non-lightship weights that are to be removed from the vessel, are tabulated.

Downflooding:
The entry of seawater through any opening into the hull or superstructure of a vessel (or portion of a vessel) due to heel, trim, or submergence of the vessel.

Downflooding Point
Any opening in the hull or superstructure of the vessel that cannot be closed watertight and through which downflooding can occur. Common downflooding points include windows, compartment vents, and non-tight deck hatches. For the towline pull criterion of 46 CFR 173.095, a downflooding point is the first opening that does not close watertight automatically.

Inclining Experiment:
The part of a stability test where the vessel is intentionally heeled using inclining weights moved transversely onboard the vessel. The inclining moment and resulting heel angle data are used to experimentally determine the vessel's vertical center of gravity (VCG).

Inclining Weights:
Weights used during an inclining experiment to heel the vessel. Additional weights may also be onboard to reduce the vessel's trim.

Knife-Edge:
The pivot point created at the mutual contact point between the upper and lower lifting shackles, or an equivalent pivot point, during an in-air stability test.

Metacenter:
The intersection point between the upright condition buoyancy vector and the buoyancy vector for a very small angle of heel. For in-water stability tests, the vertical location of the metacenter is calculated from hydrostatics tables or software. For in-air stability tests, the vessel is constrained to pivot about the knife-edge, thus artificially defining the metacenter at the knife-edge while suspended.

Pick Points:
The forward and aft locations from which the vessel is suspended during an in-air stability test.

Stability Test:
A test that includes all steps of a deadweight survey to determine a vessel's lightship displacement, LCG, and TCG, as well as either an inclining experiment or an indisputably conservative estimate to determine the VCG.

5.0 General Review Guidance for both Deadweight Surveys & Inclining Experiments

5.1 Stability Test Procedure Submittal to MSC

a. Ensure the requirements of 46 CFR 170.185(g) are included in the procedures:

(1) Identification of the vessel to be tested.
(2) Date and location of the test.
(3) Approximate draft and trim of the vessel.
(4) Condition of each tank.
(5) Estimated items to be installed, removed, or relocated after the survey, including the weight and location of each item.
(6) Schedule of events.
(7) Person or persons responsible for conducting the survey

b. Deadweight Surveys and Inclining Experiments test results may be improved by conducting the test in accordance with an approved procedure incorporating the following guidance which expands upon the references (a) and (d). Procedures should clearly articulate and/or be developed based on the items below.

5.2 Vessel Floating Condition

a. The vessel should be moored and free floating as described in reference (d).

b. Trim should be less than 1% of the length between perpendiculars (LBP), unless the hydrostatic properties for the as-surveyed condition include the actual trimmed amount.

c. The vessel's initial heel should not exceed ½ degree.

d. A hydrometer of appropriate scale should be available to measure the specific gravity of the water at the time of the inclining, as well as any onboard liquid loads.

5.3 Freeboard Readings

A minimum of five separate and approximately equally spaced freeboard readings should be taken on each side of the vessel and plotted on a profile view of the vessel at the time of the survey.

5.4 Vessel Survey

a. A survey of the vessel should be conducted in the presence of the Coast Guard witness to ensure the vessel is at least 98% complete.

b. The list of weights to add/remove/relocate should be supplied to the Coast Guard witness prior to the survey.

c. Ensure on-board personnel are limited to individuals essential to conducting the stability test. Their combined weight should remain constant throughout the test and should be recorded for each individual rather than estimated.

d. All empty tanks and voids should be open, ready for inspection, and have a gas free certificate.

e. Ensure that the tankage specified in the procedure is acceptable per reference (d). The number of slack tanks should be minimized. No free surface correction will be allowed for loose water (in bilges and voids) or excessive slack tankage. Free surface correction for slack tanks may only be permitted if the slack tanks are of regular cross section and either:

(1) 20 to 80% full if they are deep tanks, or
(2) 40 to 60% full if they are double-bottom tanks.

f. The vessel's downflooding points should be identified and their locations clearly delineated in the stability test results submittal.

g. The Coast Guard witness should initial each page of the rough field notes after verifying the recorded data.

6.0 Specific Guidance for Inclining Experiments

6.1 Weight Movements

a. Ensure that a minimum of eight weight movements are planned, with at least three points on each side of the zero point. The zero point should be established with the inclining weights in their original starting locations prior to any weight movements; this constitutes weight movement number zero. After the first three weight movements, the fourth weight movement should return the weights to their original locations to verify the zero point. After weight movement numbers five through seven, the eighth weight movement should again return the weights to their original locations to again verify the zero point. These verifications of the zero point ensure that the angle measurement devices remain calibrated throughout the entirety of the inclining experiment.

b. The inclining weights should be clearly described and either be weighed on a certified scale in the presence of the Coast Guard witness or a valid weight certificate supplied to the witness before the test is conducted.

c. The weight movements should not heel the vessel more than four degrees to either side.

d. Ensure that weights onboard are sufficient to obtain a minimum pendulum deflection of six inches to each side at the maximum heeling moment.

e. When the use of solid weights to produce the inclining moment is impracticable, the movement of liquids may be considered as an alternate method. Specific approval is required as part of the test procedure. As a minimal prerequisite for acceptability, the following conditions should be required:

(1) Tank geometry should facilitate accurate calculation of the weight and center of gravity of the liquid in all three coordinate directions;
(2) Tanks should be sounded following each movement;
(3) Verification of the quantity of liquid shifted should be taken during and after the test;
(4) Specific gravity measurements should be taken during and after the test;
(5) Vertical, longitudinal, and transverse centers of the inclining liquid should be calculated for each movement;
(6) Free surface effects should be included in the calculations;
(7) Blanks should be inserted in transfer manifolds to prevent the possibility of liquids being "lost" during transfer.

6.2 Angle Measurement Devices

a. At least three angle measurement devices are required, of which at least one should be a pendulum. The locations and lengths of all pendulums should be detailed in the stability test procedure and results. With prior approval from MSC, the substitution of electronic devices or U-tubes for up to two of the three pendulums is permitted. The following guidance applies when making substitutions:

(1) U-tube manometers: When employed as a substitute for up to two of the three required pendulums, u-tube manometers should be readable to $1/16^{th}$ of an inch and a minimum of 6 inches of deflection should be attained above and below the zero point on each side of the vessel at the maximum heeling moment. Details of the u-tube test configuration including tube diameter and location/routing should be also be submitted.

(2) Digital Inclinometers: When employed as a substitute for up to two of the required three pendulums, digital inclinometers should have an angular precision equivalent to that attained by the required pendulum but no less than +/- 0.01 degrees with an accuracy of +/- 0.05 degrees. Manufacturer's data or certification for the inclinometers should also be submitted.

(3) Laser levels: When employed as a substitute for up to two of the three required pendulums, laser levels should be readable to $1/16^{th}$ of an inch and a minimum of six inches of deflection at the maximum heeling moment should be attained above and below the zero point. Details of the laser level test configuration should be submitted.

b. The pendulums should be long enough to achieve at least six inches of deflection when the maximum heeling moment is applied. A length of at least 87 inches may achieve the required minimum 6 inches of deflection to either side without exceeding the four degree

maximum heel. Note that most pendulums will need to be much longer than 87 inches. Pendulum length is measured from the rotation point at the top of the pendulum to the measurement batten, as shown in Figure 15 of reference (d).

c. Unless impracticable due to vessel size or arrangements, ensure that pendulum locations are widely separated (distributed transversely and longitudinally throughout the vessel) and varying in length (a minimum of at least two inch difference) to ensure independent readings, to guard against erroneous results, and to assess phenomena such as hull deflection (torsion).

7.0 Specific Guidance for In-Air Stability Tests

Deadweight surveys and inclining experiments performed with the vessel suspended in air should be conducted in accordance with references (a) and (e). Additional guidance may be found in reference (f).

It may be more appropriate or convenient for some small craft to be inclined in air rather than water. For example, craft which have significant features such as sponsons, collars, or chines at the waterline, such that the location of the metacenter varies with heel for small angles, may be more accurately assessed by an in-air stability test.

7.1 Personnel Safety

a. No personnel should be required to board the vessel once it is suspended. If personnel do board the vessel once suspended, appropriate safety measures should be implemented to prevent injury in case of a fall.

b. Personnel should not be under the suspended vessel during any portion of the test.

c. The lifting and test procedure, including all rigging, should be approved by the persons responsible for lifts and rigging at the facility where the test is performed.

7.2 Suspension System

a. The test should be administered indoors in an enclosed facility with no less than two lifting devices. However, if an enclosed facility cannot be provided, a test can be satisfactorily administered outdoors only in calm conditions.

b. The vessel should have structurally sufficient lifting points forward and aft, and the lift means should not shift in any respect during the test.

c. A calibrated scale with a rated capacity greater than that of the total estimated weight of the boat should be at each pick point. Load cells should be calibrated using a certified scale with a current calibration certificate, which should be copied and recorded on the test document.

d. The vessel should be suspended, as described in reference (e), such that it is capable of swinging freely during the course of the test.

e. The rigging should be vertical and connect the vessel to the knife-edge defining the metacenter, as shown in Figure 5 of reference (e). The mutual contact point between two lifting shackles, an upper and a lower lifting shackle, creates the knife-edge. The upper shackle is connected to the load cell, and the lower shackle is connected to the lifting straps suspending the boat. The knife-edge is the pivot point about which the vessel rotates during the test, and the vessel should be completely free to rotate through the full range of observed angles of inclination without any binding. The rigging system from the vessel to the pivot point should be effectively rigid in the transverse plane.

f. The rigging should be adjusted so that the craft baseline is level within one inch over the length of the craft and parallel with the forward and aft metacenters, or knife edges, which should also be level within one inch. The height at the forward and aft pick points should be within one inch and remain constant throughout the test. This requires that the height of the upper knife edges relative to the earth and the height of at least one end of the lower knife edges relative to the vessel baseline be adjustable. This typically is achieved by using adjustable chain falls connecting the vessel to the lower knife edge at one end of the vessel.

7.3 Inclining Weights

a. Inclining weights should be compact and easily movable by personnel or crane without requiring personnel to board the suspended vessel.

b. The inclining weight centers of gravity should be at the same vertical location relative to the vessel's baseplane in both the original and shifted positions.

c. For inclining experiments in air, it is often convenient to suspend the inclining weights over the side, either directly or in a basket. This makes moving the weights without going onto the boat more feasible. For suspended weights, their effective VCG is the point from which they are suspended. Ensure that suspended weights do not contact any other part of the boat when the boat heels.

7.4 Angle Measurement Devices

a. At least three angle measurement devices are required, of which at least one should be a pendulum. Up to 2 of the 3 required angle measuring devices may be u-tube manometers, digital inclinometers, or laser levels, as described in Section 6.2.

b. No pendulum or other means of measuring heel angle should require personnel aboard the suspended vessel.

c. Pendulums should be conveniently arranged on the vessel to allow test personnel to accurately read them without disturbing the vessel. Typically this requires the pendulums to be situated aft of the transom and/or forward of the bow.

8.0 Disclaimer

This guidance is not a substitute for applicable legal requirements, nor is it itself a rule. It is not intended to nor does it impose legally-binding requirements on any party. It represents the Coast Guard's current thinking on this topic and may assist industry, mariners, the general public, and the Coast Guard, as well as other federal and state regulators, in applying statutory and regulatory requirements. You can use an alternative approach for complying with these requirements if the approach satisfies the requirements of the applicable statutes and regulations. If you want to discuss an alternative, you may contact MSC, the unit responsible for implementing this guidance.