LIGHTWEIGHT DETERMINATION – SHIPS
(INCLINING TEST AND LIGHTWEIGHT SURVEY)

FEBRUARY 1990
Det norske Veritas is an independent Foundation with the objective of safeguarding life, property and the environment at sea and ashore.

Classification, certification and quality assurance of ships, offshore installations and industrial plants, as well as testing and certification of materials and components, are main activities.

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Classification Notes are publications which give practical information on classification of ships and other objects. Examples of design solutions, calculation methods, specifications of test procedures, quality assurance and quality control systems as well as acceptable repair methods for some components are given as interpretations of the more general rule requirements.

An updated list of Classification Notes available is given in the latest edition of the Introduction-booklets to the «Rules for Classification of Steel Ships» and the «Rules for Classification of Mobile Offshore Units».

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1. Introduction

1.1 General

1.1.1 The purpose of this Classification Note is to provide DnVC's clients with guidelines on lightweight determination of ships.

The purpose of the inclining test is to determine the vessel's lightweight and its centre of gravity.

1.1.2 The information in this Classification Note is made to suit various stability rules/regulations. Therefore one should refer to the rules/regulations in question to find out possible special requirements by the Flag Administration.

1.1.3 This Classification Note is not a substitute for the rules or regulations, but a means to help implementing them.

1.1.4 The inclining test is to be performed in accordance with the approved procedure. During the test, a copy of the approved procedure is to be available onboard for guidance. The test is to be carried out to the surveyor's satisfaction.

1.2 Procedure

1.2.1 At least one month in advance, a complete Procedure for Inclining Test or Lightweight Survey as described in Appendix A, is to be submitted in triplicate to DnVC for approval. After review, two copies will be returned with comments, if any.

1.2.2 DnVC may accept other procedure that provides at least the same level of accuracy and reliability of the result.

1.3 Reporting

1.3.1 Soonest possible after the inclining test or the lightweight survey, a report is to be submitted to DnVC for approval.

1.3.2 The reporting shall be legible and clear.

1.3.3 The report must be duly endorsed by the attending surveyor before forwarding for approval.

1.4 Approval

1.4.1 The approval of the inclining test report/ lightweight survey report means approval of the vessel's lightweight data which is needed for the purpose of stability approval and control. Consequently, it does not mean the approval of the vessel's deadweight which is not subject to approval.

1.4.2 Upon approval of the report, the final stability documentation is to be prepared based on the approved lightweight data. The lightweight data (weight and position of its centre of gravity) and definition (items included in/excluded from the lightweight) are to be included in the stability manual.

1.5 Sister vessels

1.5.1 In case of sister vessels in a series, Division Ship and Offshore (DSO) may grant a dispensation from the inclining test based on a satisfactory inclining test of the first vessel and satisfactory lightweight survey of the sister vessels. This is to be clarified by DSO beforehand. Such dispensation will depend on type of vessel, stability margin, records etc. Normally, this applies to tankers and bulk carriers.

1.5.2 The lightweight survey procedure is similar to the inclining test procedure but without inclining weights, pendulums or inclination.

1.5.3 If the yard/owner wishes to determine the lightweight data based on satisfactory lightweight survey and an inclining test of a sister vessel, a procedure for lightweight survey is to be submitted instead of the inclining test procedure. For a series of sister vessels, a lightweight survey may be accepted for the second and subsequent vessels. This will depend on:

- Type of vessel.
- Time span of building.
- Whether the vessels are built for the same owner.
- Dissimilarities between the vessels.
- Unaccounted difference in lightweight data between the estimate and the lightweight survey does not exceed 1%.
- Unaccounted difference in lightweight data between the inclining test and the lightweight survey does not exceed 1%.
- The inclining test of the first vessel.

1.5.4 For sister vessels, if the difference between lightweight data is sufficiently small and within the accuracy or tolerance of inclining tests/ lightweight surveys (difference in lightweight is less than 0.5% and difference in LCG is less than 0.5% LBP), the lightweight data of the first vessels may be used for the sister vessel, i.e. identical final stability documentation may be accepted for the sister vessel as for the first vessel.

2. Application

2.1 General

2.1.1 In connection with stability approval an inclining test or lightweight survey will be required by Det norske Veritas Classification A/S (DnVC) on behalf of the Flag Administration (or as a part of the classification engagement) upon:

- Completion of newbuilding.
- Alterations and/or conversions.

2.1.2 An inclining test or lightweight survey may also be required in other cases if deemed necessary.

2.1.3 The inclining test procedure described in Appendix A applies to vessels where the stability approval is required by the class rules, or when the Flag Administration has no inclining test procedure.

3. Reference

3.1 Recognized national procedures

3.1.1 Some Flag Administrations (eg. Norway, U.K.) have established their own inclining test procedure which is to be applied to vessels under their flag. The inclining test procedure of Norway and United Kingdom are accepted by DnVC for those vessels as alternative to the procedure described in Appendix A.

Copies of these procedures may be provided upon request.

3.2 Other national procedures

3.2.1 In case of other national inclining test procedures, DnVC should be consulted to decide if such procedures are equivalent to DnVC procedure (class engagement).
3.3 DnVC's procedure

3.3.1 Reference is also made to Appendix A on Inclining Test procedure.

4. Reporting

4.1 General

4.1.1 Upon completion of the inclining test or a lightweight survey, an Inclining Test Report/ Lightweigt Survey Report is to be prepared by the Yard/Owners and forwarded, in triplicate, to the attending surveyor. The report is to be duly endorsed by the surveyor, before forwarding for approval.

4.2 Contents

4.2.1 All records, measurements and calculations, as described in Appendix A, are to be included in the Report. The following information is to be included:

- • Location, time and environmental conditions.
- • Communication facilities.
- • Lightweight definition.
- • Vessel's general condition.
- • Vessel's loading condition (in case of lightweight survey procedure, it is important to specify the estimated lightweight data for comparison with the result of the lightweight survey).
- • Sounding of tanks.
- • Foreign weights (to be deducted).
- • Missing weights (to be added).
- • Mislocated weights (to be relocated).
- • Draught measurements.
- • Sea water density.
- • Inclining weights (only for inclining tests).
- • Inclining procedure/ weight shifting sequence (only for inclining tests).
- • Pendulum. Arrangement and measurements (only for inclining tests).
- • List of all items to be measured and recorded.

4.3 Calculations

4.3.1 The following calculations are to be shown:

- • Displacement, corrected for draught, trim, sagging/hogging and for actual sea water density.
- • Foreign, missing and mislocated weights and their position.
- • Inclining moments and the corresponding heeling angles (only for inclining tests). This is to be presented in form of a table and a diagram.
- • Calculation of GM based on least square method (only for inclining tests).
- • Calculation of lightweight data — weight, LCG and VCG (VCG only for inclining tests).
5. Appendix A: Inclining test procedure

The following is guidelines for the inclining test.

5.1 Environmental and general conditions

5.1.1 A sheltered location should be found for the test.

5.1.2 Sufficient time, say 12 hours, should be allowed for completion of the test.

5.1.3 Wind velocity during the test should not exceed 10 knots.

5.1.4 There should be no significant swell or current.

5.1.5 There should be no snow/ice which may influence the test.

5.1.6 The vessel must be free floating; i.e. mooring lines must be slack during draught and pendulum readings.

5.1.7 Water depth, location and time of the test are to be indicated.

5.1.8 Gangways, cranes etc. are to be in stowed position.

5.1.9 As few cables, hoses etc. as possible should be connected to the shore. Those that are connected should be slack.

5.1.10 The loading condition during the test is to be specified.

5.2 Communications

5.2.1 A sufficient number of walkie-talkies or other communication sets must be available for communication between the test leader, tugs (if used), crane operators, weight crew, pendulum crew, etc.

5.3 Draught measurements

5.3.1 Draught prior to the test should be determined, principally for unchanged waterplane area during inclining. There should be no heel. In cases where this is impractical, a heel up to 0.5 degrees may be accepted.

5.3.2 The trim should not exceed 1% of LBP, about 0.5 degree.

5.3.3 Position of draught marks should be checked prior to the test, by measuring against a known datum level.

5.3.4 Draught measurements should be performed on both sides astern, forward and midships.

5.3.5 Draught measurements should be performed using a throttled transparent plastic tube.

5.3.6 Draught measurements should be performed just before inclining starts, and should also be checked after the completion of the test.

5.4 Seawater density

5.4.1 Hydrometers for water sampling at approximately 25% and 75% of the draught are required to determine the specific gravity of seawater during test.

5.4.2 The hydrometers should be checked for accuracy prior to test. Seawater temperature is to be recorded.

5.5 Tanks

5.5.1 Tanks should in principle be either empty or full; i.e. as few tanks as possible shall be partly filled.

5.5.2 All empty tanks and void spaces should be visually inspected before and after the test.

5.5.3 Tanks not covered by 5.5.1 or 5.5.2 should be sounded manually using steel tapes with weight and paste. All sounding pipes are to be checked before the test to ensure free passage of the tape weight by comparing tape readings with the known length of sounding pipes.

5.5.4 Normally no production or consumption of fresh water will be allowed during the test.

5.5.5 When the soundings have been taken, no movement of liquid onboard is allowed until the test is completed.

5.5.6 Cross-flooding pipes should be closed to eliminate any possibility of cross flow between tanks.

5.5.7 Bilge and tank top water should be removed to the extent possible.

5.5.8 All system pipes and tanks are to be filled to normal operation condition.

5.6 Foreign weights

5.6.1 Minimum number of personnel is to be onboard during the test. Persons onboard are to remain in the same position during inclining and pendulum readings.

5.6.2 Deadweight is to be reduced to a minimum.

5.6.3 A detailed schedule of remaining items of stores etc. should be prepared; samples of multiple items should be weighed as a check, as should also large items which are difficult to estimate.

5.6.4 Loose weights (which may roll or slide) should be secured.

5.6.5 List of foreign weights (weights that are not part of the lightweight) including position of their centre of gravity is to be prepared.

5.6.6 Foreign weights include:
- Liquids in tanks.
- Stores, provisions, personnel etc.
- Temporary equipment and weights.
- Inclining weights.
- Any other variable weights.

5.7 Inclining weights

5.7.1 At least 4 solid weights shall be used to incline the vessel. Waterballast is generally not acceptable as inclining weight, however see 5.7.6.

5.7.2 The weights must be numbered and weighed with a calibrated instrument in the presence of the surveyor before the test.

5.7.3 The physical dimensions (L x B x H) of each weigh are to be given.

5.7.4 Sufficient weight must be provided to incline at least 2 degrees to each side but not more than 3 degrees.
However, for large ships (tankers, bulk carriers etc.) an inclination of 1.5 degrees to each side may be accepted.

5.7.5 The intended positioning of weights onboard must be checked for structural strength consideration, and planned so that only transverse moment is caused; i.e. only heel and no trim will take place.

5.7.6 Use of water ballast transfer to incline the vessel may be permitted in cases where it is absolutely impractical to incline 2 degrees using solid weights. If water ballast is to be used, the following must be observed:

- Inclining tanks are to be well sided and free of large stringers (air pockets) within the range of water transfer.
- Tanks are to be directly opposite to maintain vessel’s trim.
- Specific gravity of ballast water is to be measured and recorded.
- Pipe lines to inclining tanks are to be full.
- All ballast valves are to be closed prior to test. Strict valve control is to be maintained during the test.
- All inclining tanks are to be manually sounded after each shift.
- Calculations must account for the change of the VCG during test.
- Accurate sounding/ullage tables are to be provided.

5.8 Pendulums

5.8.1 Two pendulums, each at least 4 metre long, should be used to measure the inclination. Oil trays and measuring benches should be provided.

5.8.2 Protected positions should be provided for the pendulums and the measuring personnel. The positioning of the pendulums must be such that they swing freely.

5.8.3 The length of the pendulums shall be checked by the surveyor prior to the test.

5.8.4 The use of inclinometer and U-tube will be considered in each separate case.

5.9 Inclination

5.9.1 The inclining weights on port side should be shifted systematically from port to starboard and back again. The procedure is to be repeated for the starboard side weights.

5.9.2 Onboard cranes should be returned to their stowed position after each shift of weights, if used.

5.9.3 Exact location of moved weights and pendulum readings shall be recorded for each shift.

5.9.4 At least 8 shifts of weights and corresponding readings should be performed. Except for the upright positions (0-positions), the shifts should give even distribution of points on the inclining diagram (moment vs angle).

5.9.5 The vessel must be free floating and preferably positioned to have the wind in the longitudinal direction.

5.9.6 The shift of weights must take place transversely at the same height, or else a correction is to be made for the change in VCG.

5.9.7 The accumulated inclining moment and the corresponding inclining angle after each shift are to be plotted on a graph (Inclining Diagram). Any unexpected readings should be investigated immediately, before continuing the test.

5.10 Calculation of lightweight data

5.10.1 The following lists should be endorsed by the attending surveyor during the test before they are used in the Inclining Test Report:

- Weights to be deducted (foreign weights).
- Weights to be added (missing weights).
- Weights to be relocated.

5.10.2 The final GM value is to be calculated based on accumulated inclining moments and angles using the least square method (linear regression).

5.10.3 Final calculation of lightweight data and records from the inclining test are to be clearly presented in the Inclining Test Report.

5.10.4 The definition of lightweight should be clearly stated in the Inclining Test Report (items included/ not included in the lightweight).

5.10.5 The lightweight data and definition should be clearly stated in the Final Stability Manual. These data are to be used in the loading conditions calculation.

5.11 Miscellaneous

5.11.1 It is essential for good results that every part of the test is carried out with great care and accuracy under the control of a team experienced in performing such tests.

5.11.2 The surveyor shall verify that the inclining test or the lightweight survey is carried out in accordance with the approved procedure and witness all records taken in connection with the test or the survey.

5.11.3 Valid hydrostatic tables/curves should be available for the test condition.

5.12 Quantitative guidance

5.12.1 The values given hereunder are intended only as guidance. Deviations may be discussed with DnV.

5.12.2 Degree of lightweight completion at the test; minimum about 98% of the final lightweight.

5.12.3 Solid foreign weights; maximum about 2% of final lightweight.

5.12.4 Water ballast; maximum about 10% of the final lightweight. This may be increased to 20% when inclining by water ballast.

5.12.5 Wind speed during the test; maximum about 10 knots.

5.12.6 Inclining angle to each side; minimum 2 degrees and maximum 3 degrees. For larger vessels (tankers, bulk carriers), inclining angle of 1.5 degrees to each side may be accepted. In exceptional cases this may be reduced to 1.0 degree if it is not practically possible to achieve 1.5 degrees.

5.12.7 Pendulum length; minimum 4 metres.

5.12.8 Number of inclining weights; minimum 4.

5.12.9 Number of shifts; minimum 8.

5.12.10 Difference between any two successive shifts should not be less than 0.5 degrees.
5.12.11 Example for guidance: See the following table.

<table>
<thead>
<tr>
<th>Position</th>
<th>Inclining angle</th>
<th>Position</th>
<th>Inclining angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-position</td>
<td>0.0</td>
<td>5th shift</td>
<td>-1.3</td>
</tr>
<tr>
<td>1st shift</td>
<td>1.3</td>
<td>6th shift</td>
<td>-2.0</td>
</tr>
<tr>
<td>2nd shift</td>
<td>2.0</td>
<td>7th shift</td>
<td>-0.7</td>
</tr>
<tr>
<td>3rd shift</td>
<td>0.7</td>
<td>8th shift</td>
<td>-0.0</td>
</tr>
<tr>
<td>4th shift</td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>