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GUIDANCE FOR SHIPBOARD STABILITY MANAGEMENT

Guidelines on the management of ship's stability

Submitted by Germany

SUMMARY

Executive summary:	This document contains a revised draft proposal of an IMO document with the title "Guidelines on the Management of Ship's Stability"
Action to be taken:	Paragraph 6
Related documents:	SLF 42/10

1 The SLF Sub-Committee at its forty-second session has discussed a proposal on the guidance for shipboard stability management which had been submitted by Germany (SLF 42/10). The Sub-Committee recommended certain revisions to this document and Germany offered to present a revised proposal for SLF 43.

2 The Sub-Committee, in particular, proposed to delete all references to the ISM Code and to avoid the inclusion of provisions which could be interpreted as separate standards.

3 Several delegations offered to send written comments between sessions to support the revision. Comments were gratefully received by Germany from the United States.

4 During SLF 41 the Working Group on Intact Stability had undertaken a first listing of issues to be addressed to in such Guidance. The general view of the group was that the final document should be an aid to focus on problems of shipboard stability management rather than a comprehensive manual. Specific guidance may be provided in appendices to this document if deemed necessary.

5 Germany submits the revised draft proposal of this document which is presented in the annex to this submission.

Action requested of the Sub-Committee

6 The Sub-Committee is invited to take note of the above information and the attached annex and take action as appropriate.

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ANNEX

Guidelines on the Management of Ship's Stability

Contents **Page**

Guidelines on the Management of Ship's Stability

Introduction

1 These Guidelines on the Management of Ship's Stability have been developed to minimise accidents and losses caused by improper ship operation. The Guidelines are directed to Administrations, to shipping companies and to masters and officers.

2 It is recognised that the general stability characteristics of ships by design should be in accordance with relevant requirement of the 1974 SOLAS Convention and other IMO instruments, in particular with provisions specified in the Intact Stability Code.

3 There is, however, an urgent need for additional care for stability by the ship's master and officers during cargo operations, navigation and emergency procedures.

4 The stability of the ship is a vital element in any shipboard consideration of safety and environment protection. Proper management of ship's stability should therefore be addressed as a key shipboard operation.

5 As the operation of ships and thus the management of stability may differ considerably among ship types and trade patterns, specific guidance should be provided by the company as appropriate.

6 The following aspects are common to all ships and should therefore be addressed in the specific guidance provided by the company:

.1 care for and monitoring of the ship's water tight and weather tight integrity;

.2 control of KG_c in the course of cargo, ballast or bunker operations;

.3 avoidance of transverse shifting of masses, such as cargo or heavy items of equipment;

.4 avoidance of large liquid free surfaces;

.5 preparedness for corrective measures to mitigate detrimental effects on stability; and

.6 keeping of records for control and reference (e.g., light ship characteristics).

7 The Guidelines on the Management of Ship's Stability are intended as an aid to focus on problems of shipboard stability management rather than presenting a comprehensive manual. Specific guidance, however, on certain issues is provided in the appendices to these Guidelines.

8 When developing or revising the Safety Management System (SMS) Manual for a particular ship or group of ships these Guidelines and appendices may be used as references.

Section 1 - Definitions, documentation and recording

1.1 Definitions

1.1.1 *Stability parameters* are, as a minimum, the figures of KG_c and the draught of the vessel in the actual condition. The figure of GM_c and the righting levers for the positive range of stability are considered of additional value for assessing the stability.

1.1.2 *Stress condition parameters* are the curves of shear forces and bending moments or figures of shear forces and bending moments for selected frame positions of the vessel in the actual condition. Alternatively percentage figures of shear forces and bending moments with regard to harbour or sea going limits can be used as stress condition parameters.

1.1.3 *Limits of stability* are stability parameters presenting the minimum stability as defined by the IMO Intact Stability Code or by appropriate instruments of the Administration, or presenting the maximum stability as considered tolerable by the master or provided by company instructions.

1.1.4 *Assessment of stability* is any procedure or action taken by the master or cargo officer to identify the stability parameters of the actual or pre-planned condition of a ship.

1.2 Documentation

1.2.1 Each ship should be provided with a Loading and Stability Manual, approved by the Administration, which contains sufficient information to enable the master to operate the ship safely and in compliance with relevant statutory requirements.

1.2.2 The Loading and Stability Manual and associated plans should be in harmony with the IMO Model Loading and Stability Manual (MSC/Circ.920). It should be drawn up in the "working language" of the ship and any other language the Administration may require. If the working language is not English, French or Spanish, the text should include a translation into one of these languages.

1.2.3 For certain ships the information provided in the Loading and Stability Manual should include additional details related to specific requirements in those ships.

1.2.4 The arrangements for responsibility, authority and competence on board with regard to cargo operations and tank operations should be clearly laid down by the company.

1.3 Records

1.3.1 Records on ship's stability should be filed and kept in a suitable way and over a period according to the company's requirements.

1.3.2 Departure records should include:

.1 voyage number, port, date and time;

.2 cargo and tank status;

.3 actual stability parameters;

.4 result of ship's draught survey (if applicable);

.5 result of stability measurement (if applicable); and

.6 assessment of stability over the forthcoming voyage and applicable limits of stability.

1.3.3 During the voyage daily and at arrival, an update of tank status and actual stability parameters should be established and recorded.

1.3.4 The records may consist of appropriate printouts of the ship's loading and stability computer or tank monitoring system.

1.3.5 Records on actual longitudinal and torsional stress condition parameters should be included, if deemed appropriate.

Section 2 - Control of stability during loading and unloading

2.1 Minimum stability requirements in port

2.1.1 The stability criteria required by MARPOL regulation I/25A for oil tankers and as outlined in the IMO Intact Stability Code or in similar instruments of the Administration should be observed while the ship is at sea. In port, particularly during loading and unloading operations, a deviation from those criteria is generally acceptable provided the metacentric height GM_c is positive at all times and of sufficient magnitude.

2.1.2 It should be noted however that certain types of cargo operations like loading or unloading containers, ro-ro vehicles and any other heavy units may require a metacentric height exceeding the usual minimum values in order to avoid unsuitable heeling of the ship. The company should provide specific guidance regarding the minimum GM_c during cargo operations on such ships. Heeling restrictions of the ship with regard to the operation of ship's cranes should be observed.

2.2 Risks to stability during loading and unloading

2.2.1 Stability of a ship during cargo operations may suffer from inappropriate planning of the sequence of loading and unloading, particularly with both operations to be undertaken simultaneously. A close review of the operations plan should be carried out before the operation starts.

2.2.2 During cargo operations deviations from the agreed plan may occur due to delays or other unforeseeable circumstances. In order to avoid undue risks to stability the planned procedure should be divided into steps with check points or mile stones which provide for an effective control.

2.2.3 Incorrect figures of cargo unit masses in cargo documents may upset the operations plan and affect the final stability as well as the compliance with load line requirements. It is therefore recommended to take draught readings at suitable time intervals and check the cargo intake appropriately (see Appendix 1).

2.2.4 Lack of co-ordination between tank operations and cargo operations and short-comings in tank operations may adversely affect the stability of the ship. A proper management of bunker and ballast tanks in co-ordination with cargo operations is therefore of utmost importance.

2.2.5 The loading or unloading of heavy cargo units by lift-on/lift-off or roll-on/roll-off operation may require the movement of large quantities of ballast water for avoiding excessive heel or trim. This can be a threat to stability depending mainly on the vertical location of the ballast tanks. A properly calculated balance of heeling levers and righting levers should be made up for critical situations and evaluated using criteria accepted by the Administration.

2.2.6 A controlled list during heavy lift operations may cause other cargo units to shift if they are not adequately secured. This will increase the list, which may be dangerous. It may also cause accidents to persons. Cargo and any loose equipment should therefore be adequately secured before such heavy lift operations are started.

2.2.7 Free surfaces in ballast and/or cargo tanks reduce the stability margin. During loading or unloading operations, this may cause negative initial stability with unexpected list and loll behaviour of the ship. This may happen particularly to OBO-Carriers loading or unloading oil and to tankers of the "single tank across" design. The approved operations plan for loading or unloading those types of ships should be strictly observed.

2.3 Measures of control

2.3.1 The company should provide general instructions with regard to the control of stability during loading and unloading cargo, appropriate to the type of ship and her cargo, in particular covering:

- .1 the proper planning of cargo loading and unloading sequences including ballast and bunker operations;
- .2 adequate control of operations including suitable checks of cargo mass intake; and
- .3 specific advice as may be necessary for loading or unloading special cargoes like heavy lift units or liquid bulk cargoes.

2.3.2 The company's instructions should require a suitable recording of cargo loading and unloading operations.

2.3.3 Adequate communication should be maintained between the port facility and the master corresponding to the agreed responsibility for the operational control of loading.

Section 3 - Assessment of stability before departure

3.1 Defining stability limits for departure

3.1.1 Minimum stability requirements, as imposed by the Administration, should be well understood and identified with regard to:

.1 relevant information in the Loading and Stability Manual, i.e. limiting curves or tables of maximum KG_c or minimum GM_c; and

.2 additional criteria as may be applicable for certain cargoes or certain modes of operation (see chapters 4 and 5 of the Intact Stability Code).

3.1.2 Bearing in mind the season of the year, weather forecasts and the area of navigation, the master should also appraise and establish specific lower and upper limits of stability by his own experience to improve the behaviour of the ship at sea. Selected lower limits however must be kept within statutory minimum requirements.

3.1.3 The stability criteria contained in chapter 3 of the Intact Stability Code or appropriate requirements of Administrations generally specify limits of minimum stability but no limits of maximum stability. It is advisable however, to avoid excessive values of metacentric height and righting levers, since these might lead to acceleration forces at sea which may cause undue strain to the securing of cargo and thus endanger the ship's stability by the risk of cargo shifting.

3.1.4 Reduction of stability during the forthcoming voyage should be assessed and taken into account when defining limits of departure stability. This should include, if applicable:

.1 water absorption of deck cargo;

.2 icing;

.3 heaving a haul of fish on deck.;

.4 reduction/redistribution of consumables; and

.5 ballast water exchange.

3.2 Methods of assessment of stability

3.2.1 Stability should be assessed before departure or whenever deemed necessary by one or more of the following methods as appropriate:

.1 comparing the intended loading plan or the existing loading condition with similar conditions of known stability parameters;

.2 individual calculation of masses and moments of allocated or existing cargo distribution and tank fillings;

.3 measurement of stability by in-service inclining test or by evaluation of the observed natural period of roll (see Appendix 2 or Appendix 3).

3.2.2 The method under 3.2.1.1 should only be chosen if an ample margin of stability against minimum requirements is obviously existing.

3.2.3 An approved computer programme will facilitate the method under 3.2.1.2. The results will be accurate, provided that cargo masses, tank fillings and centres of gravity are available with sufficient accuracy and reliability.

3.2.4 The method under 3.2.1.3 generally provides results which take all uncertainties regarding masses and centres of gravity into account. However, it can only be used in a close to final state of loading and needs further adaptations to arrive at the result for departure condition or worst condition during the voyage (see Appendix 4).

3.3 Special considerations

3.3.1 Ships carrying grain cargo shall comply with the requirements of the International Code of the Safe Carriage of Grain in Bulk.

3.3.2 Ships loaded with timber on deck shall comply with the provisions of the Code of Safe Practice for Ships Carrying Timber Deck Cargoes.

3.3.3 Ships carrying certain solid bulk cargoes other than grain may require a defined effort of transverse cargo trimming before commencement of the voyage, according to the IMO Bulk Cargoes Code.

3.3.4 Oil tankers built after 1 February 1999 and of 500 dwt or more need to comply with the provisions of MARPOL regulation I/25A.

3.3.5 Before a voyage commences, care should be taken to ensure that the cargo and sizeable pieces of equipment have been properly stowed or lashed so as to minimise the possibility of both longitudinal and transverse shifting, while at sea, under the effect of accelerations caused by pitching and rolling.

Section 4 - Control of stability while at sea

4.1 Fuel consumption

4.1.1 The order by which bunkers from storage tanks are consumed during the voyage should be agreed between the master or cargo officer and the chief engineer with regard to consequential changes of stability.

4.1.2 Reduction of stability by consumed bunkers should be compensated by ballast in dedicated tanks, if necessary. This compensation should be done at pre-defined stages following an appropriate plan.

4.1.3 The number of partially filled or slack tanks should be kept to a minimum because of their adverse effect on stability. If a tank is kept slack deliberately in order to reduce a large metacentric height care should be taken to avoid dangerous sloshing of the tank contents in a seaway. Sloshing effects may be substantially reduced with filling above 90% or below 20% of the tank capacity.

4.2 Ballast exchange at sea

4.2.1 The exchange of ballast at sea may be required in certain trades as an option to avoid the transfer of unwanted aquatic species between geographical regions. For applicable vessels, the company should provide specific guidance in the form of a ballast water management plan on performing at-sea ballast water exchange (BWE).

4.2.2 Stability, strength, manoeuvrability, and bridge visibility are a concern during BWE evolutions. These safety attributes can be manageable through proper evaluation and timing of the BWE sequence. The above aspects are dependant on the tank exchange sequence selected, the amount and distribution of ballast to be exchanged, the margin between actual conditions and allowable limits and, to a lesser extent, the cargo and consumables loading arrangement.

4.2.3 Therefore, the ship's stability and strength may have to be analysed prior to each voyage to ensure that the ship does not violate its stability or strength limits during a BWE procedure. The use of stability and strength computers may facilitate performing these complex calculations.

4.2.4 When developing a ballast water management plan, the company should refer to IMO resolution A.868(20) on Guidelines for the Control and Management of Ship's Ballast Water to Minimise the Transfer of Harmful Aquatic Organisms and Pathogens.

4.3 Water absorption of deck cargo and icing

4.3.1 Certain deck cargoes like timber, open pipes, open barges, cork, coke and others may acquire added mass by heavy rain or overcoming sea water. Care should be taken to provide a good drainage in order to limit the reduction of stability to the anticipated value.

4.3.2 For any ship operating in areas where ice accretion is likely to occur, adversely affecting a ship's stability, icing allowances, as described in chapter 5 of the Code on Intact Stability, should be included in the analysis of conditions of loading.

4.3.3 The Recommendations for skippers of fishing vessels on ensuring a vessel's endurance in conditions of ice formation, as outlined in annex 2 of the IMO Code on Intact Stability, can be a useful guidance in case of ice accretion also on vessels other than fishing vessels.

4.4 Measures in case of negative GM_c

4.4.1 Although a proper allocation of departure stability would prevent a negative GM_c during the voyage in principle, experience has shown that a negative GM_c can develop due to extreme water soaking or icing or failures in tank management.

4.4.2 Depending on the existing sea conditions the decrease of GM_c may not be detected until a small overturning moment causes the ship to slightly list. This situation is critical in such a way that a first attempt may be to correct this list by re-arranging the transverse distribution of bunkers or ballast care must be taken as to the extent of re-distribution as it could exacerbate matters and the ship could loll to the opposite side and resume a list greater than before.

4.4.3 Although the observed list may be a combined result of negative GM_c and an eccentric centre of mass it is strongly recommended that with any corrective action the possible consequences of negative GM_c should be borne in mind. Emptying or filling of slack tanks, flooding of double bottom tanks, reducing weight on deck, or any other measure to increase the metacentric height should be given priority but with due regard for free surface effects at intermediate stages of filling/emptying tanks.

4.4.4 As flooding a double bottom tank will produce another liquid free surface until the tank is full, a narrow centre line tank should be chosen if possible. If a transverse pair of tanks has to be flooded the tank on the low side should be flooded first. This will temporarily increase the ship's list but avoids a possible loll to the opposite side.

Section 5 - Measures before and in heavy weather

5.1 Weathertight and watertight integrity of the ship

5.1.1 Weathertight and watertight hatches, doors, etc., should be kept closed during navigation, except when necessarily opened for the working of the ship, and should always be ready for immediate closure and be clearly marked to indicate that these fittings are to be kept closed except for access.

5.1.2 All doorways and other openings through which water can enter into the hull or deck-house, forecastle, etc., should be suitably closed in adverse weather conditions and accordingly all appliances for this purpose should be maintained on board and in good condition.

5.1.3 All small equipment and loose gear, such as hoses, electric lines, and dunnage, in spaces accessed by watertight doors, particularly remotely controlled sliding doors, should be secured to prevent blockage of the watertight door.

5.1.4 Any closing devices provided for vent pipes to fuel tanks should be secured in bad weather.

5.2 Stowage and securing of cargo and equipment

5.2.1 Before the ship commences a sea passage, all cargo should be properly stowed and secured in accordance with the Code of Safe Practice for Cargo Stowage and Securing. It is also advisable to reinspect all cargo in holds and on deck on a regular basis unless the nature of cargo or its stowage excludes any risk of shifting.

5.2.2 In doing such inspection it may be useful to observe the behaviour of critical cargo units or stowage blocks of cargo in the beginning of any major seas in order to detect possible deficiencies of the securing arrangement. This should be done timely however in order to upgrade the securing arrangement, if necessary, without undue risk for crew members.

5.2.3 Although any heavy items of equipment on board should be suitably stowed, locked or secured before the ship commences a sea passage there should be an inspection of this equipment before the ship enters a heavy weather area. This applies to the deck-, engine- and catering department.

5.3 Sailing in heavy weather

5.3.1 In severe weather, the speed of the ship should be reduced if excessive rolling, propeller emergence, shipping of water on deck or heavy slamming occurs. Six heavy slammings or 25 propeller emergencies during 100 pitching motions should be considered dangerous (refer to chapter 2.5 of the IMO Code of Intact Stability).

5.3.2 Water trapping in deck wells should be avoided. If freeing ports are not sufficient for the drainage of the well, the speed of the ship should be reduced or the course changed, or both. Freeing ports with closing appliances should always be capable of functioning, be routinely checked for paint closure, and are not to be locked.

5.3.3 Masters should be aware that steep breaking waves may occur in certain areas, or in certain wind and current combinations (river estuaries, shallow water areas, funnel-shaped bays, etc.). These waves are particularly dangerous, especially for small ships.

5.3.4 Special attention should be paid when a ship is sailing in following or stern quartering seas, because dangerous phenomena such as parametric resonance, broaching to, reduction of stability on the wave crest, and excessive rolling may occur singularly, in sequence or simultaneously in a multiple combination, creating a threat of capsize. Specific advice on how to navigate in such conditions is found in the IMO document "Guidance to the master for avoiding dangerous situations in following and quartering seas" (MSC/Circ.707).

5.3.5 Reliance on automatic steering in heavy weather may be dangerous as this prevents ready changes to course which may be needed in certain occasions.

5.4 Measures of control

5.4.1 The company's instructions should contain general advice on the issue "entering heavy weather" with regard to:

.1 watertight and weathertight integrity of the ship;

.2 re-assuring proper stowage and securing of cargo and equipment; and

.3 ship handling in heavy weather.

5.4.2 Before entering heavy weather the master should instruct crew members with regard to necessary safety measures and personal behaviour.

5.4.3 Fuel day tanks and settling tanks should be topped up appropriately in order to avoid loss of suction during heavy weather.

5.4.4 Dynamically supported craft should not be intentionally operated outside the worst intended conditions and limitations specified in relevant statutory documents.

Section 6 - Control of stability in small fishing vessels

6.1 General operating conditions

6.1.1 Fishing vessels should only be operated within the scope of approved loading conditions as specified under chapter 4.2.5 of the IMO Intact Stability Code.

6.1.2 On small fishing vessels, the master should be supplied with suitable information on minimum GM-values and appropriate maximum periods of roll for loading conditions as specified above.

6.1.3 The general precautions against capsizing as outlined in chapter 4.2.2 of the IMO Intact Stability Code should be observed.

6.1.4 A concise and comprehensive operating manual covering the applicable relevant aspects should be prepared and carried on board.

6.2 Operating in adverse weather and sea conditions

6.2.1 Hatch covers and flush deck scuttles should be kept properly secured when not in use during fishing operations. All portable deadlights should be maintained in good condition and securely closed in bad weather.

6.2.2 If icing is likely to occur, the provisions of annex 2 to the IMO Intact Stability Code ("Recommendations for skippers of fishing vessels on ensuring a vessel's endurance of ice formation") should be observed. All relevant particulars should be contained in the operating manual addressed to under 6.1.4 above.

6.2.3 The use of an approved automatic warning system which is designed to directly indicate the loss of stability due to fuel consumption, high deck loads of water, fish or ice or any other reason, is recommended, but should not be solely relied upon.

6.2.4 The development and use of simple information on the permissible co-relation of effective GM_c and wave height or any other suitable weather parameter is recommended.

Section 7 - Control of stability in damaged condition

7.1 Damage stability criteria

7.1.1 Certain ship types, in particular passenger ships and oil-, gas- and chemical tankers, have to be operated under the regime of damage stability criteria. Moreover, all cargo ships built after 1 February 1992, passenger ships, and ships assigned with reduced freeboard under the 1966 ICLL, need to be operated in accordance with stability limits based on a subdivision standard.

This may include separate information provided to the master in the form of diagrams, tables or suitable computer programmes prescribing the observation of a value of minimum GM_c or maximum KG_c related to the actual condition of loading. This value affords an acceptable level of protection against capsizing under specified conditions of damage while operating in a nominal environmental condition.

7.1.2 Generally damage stability criteria require a higher initial stability than the intact stability criteria. Damage stability criteria on tankers need not be observed by the master when the ship is in a pure ballast condition with cargo residues in normal quantities.

7.1.3 Compliance with damage stability criteria does not ensure immunity against capsizing in any damaged condition. Masters should therefore be aware of the necessity and benefit of proper contingency planning covering damage control.

7.2 Effects of damage on stability

7.2.1 Damages which affect ship's stability may result from collision, grounding, fire and explosion and any leak under or above the waterline through which progressive flooding may occur. Specified damages are found in various IMO instruments for the purpose of damage stability control based on ship design. The specified damages for the appropriate ship type may be taken as reference to judge the consequences of actual damage to an individual ship of that type. Damages are specified:

.1 for oil tankers in MARPOL, Annex I, regulation 25 and in regulation 13F (raking damage);

.2 for chemical tankers in the IBC Code, chapter 2.5 and in the BCH Code, chapter 2.2;

.3 for gas tankers in the IGC Code, chapter 2.5 and in the GC Code, chapter 2.3;

.4 for passenger ships in SOLAS, chapter II-1, regulation 8;

[.5 for cargo ships greater than 80 metres in length, probabilistic damage stability requirements in SOLAS, chapter II-1, part B-1;] and

.6 for offshore supply vessels in IMO resolution A.469(XII) on Guidelines for the Design and Construction of Offshore Supply Vessels.

7.2.2 Water entering a damaged ship will generally assemble in the lower parts of the hull and thus tends to lower the ship's centre of gravity. The amount of water able to enter the ship depends on the permeability of the flooded space, i.e. the volume percentage not occupied by other items like cargo, equipment, ballast or bunkers.

7.2.3 Water entering a damaged ship causes the draught to increase and thus changes relevant stability parameters like KM and cross-curve values. In fully loaded conditions KM is likely to increase slightly while cross-curve values for inclinations above 10° heel will decrease considerably with the draught. The latter bears the risk of capsizing, even with positive GM_c, in the case of asymmetrical flooding where heeling levers may exceed the reduced righting levers.

7.2.4 Asymmetrical flooding causes the immediate development of a list. This list is a most serious effect as it not only lowers the water inlet and increases the rate of flooding but also reduces the righting levers on the low side of the vessel.

7.2.5 If the flooded space has a large surface area the negative effect of liquid free surface will affect the stability seriously. Most commonly the initial ingress of water will heel the ship which will then fail to upright because of negative GM_c. Subsequently, the ship could capsize for the same reason as mentioned under sub-paragraph 7.2.3 above.

If however, during the process of flooding, the ship's waterplane area increases sufficiently and/or the amount of water taken in is sufficient to restore a positive GM_c, the ship could also potentially return to upright condition if there is no other heeling moment from asymmetrical flooding.

7.2.6 In most damage and flooding situations the effect of asymmetrical flooding combines with the effect of free liquid surfaces and reduces righting levers due to list and reduction of freeboard. The risk of capsizing in such a situation is higher on ships with low freeboard than on ships with ample freeboard.

7.3 Assessment and control of damage

7.3.1 Any actions undertaken to assess and control the damage and secure the stability and integrity of the ship should be made commensurate with preparations for safety and rescue actions for persons on board.

7.3.2 The assessment of damage should be undertaken with the aim to get a reasonably clear picture of the affected parts of the hull and an estimation of progress and final stage of flooding. For this purpose the following issues should be surveyed with due regard to damage control plans:

.1 location and extent of damage;

.2 estimated rate of flooding;

.3 size and permeability of flooded spaces;

.4 possible asymmetry of flooding and expected list; and

.5 neighbouring spaces liable to be affected by breaching of bulkheads or by leaks.

7.3.3 The information obtained should be used to control the flooding procedure in order to avoid capsizing of the ship. The following aspects should be taken into account:

.1 An intolerable list of the ship may be counteracted by deliberate counter-flooding, bearing in mind the additional risk from free liquid surfaces and the reduction of freeboard.

.2 Breaching of bulkheads to adjacent spaces may be prevented by shoring with timber or other suitable means. Small holes or cracks may be secured by wooden wedges or plugs.

.3 If the casualty has happened alongside or close to a jetty a good mooring of the damaged vessel may prevent capsizing. The support of tugs pressing the vessel to the jetty may be useful too.

.4 In the case of a collision bow to side with another vessel, it may be useful to secure the bow of the one vessel to the breached side of the other in order to prevent capsizing. This option however would not be feasible if motions from the seaway would cause further damage to the ships in contact or, if the nature of the cargo or the presence of passengers would impose a risk higher than currently exists.

.5 Using the ship's pumps and/or pumps supplied by other vessels may control the flooding, at least to an extent to save time for other useful measures.

.6 Deliberate beaching or stranding, although bearing the threat of reducing the longitudinal strength and/or the structural integrity with serious consequences, may save a damaged vessel from capsizing in the first place.

.7 The damage may have affected the longitudinal strength of the ship by weakening the structure. Additionally, there may be an increase of existing shear forces and bending moments by the effect of the incoming water. These aspects should be borne in mind when taking deliberate actions to secure the stability of the ship. As there is currently no simple comprehensive guidance available for assessing possible strength problems from damage, such decisions will have to be left to the discretion of the master, unless specific guidance is given in damage control plans.

7.3.4 A damaged vessel sitting on the ground should not be towed off or be allowed to re-float until sufficient structural integrity, stability and a close to upright floating condition is confirmed by thorough investigation.

Section 8 - Control of stability in special situations

8.1 Control of stability after a major shift of cargo

8.1.1 A major transverse shift of cargo will cause the ship to heel and reduces the righting levers at the immersed side (refer to the International Code for the Safe Carriage of Grain in Bulk). The stability of the ship is therefore at risk and action by the master may be required.

8.1.2 As the amount of shifted cargo and distance of shifting will be unknown until the cargo space has been inspected it may be useful to estimate the residual stability at the immersed side by the following method:

.1 Take the actual righting lever curve for the upright ship from the last record statement.

.2 Indicate the observed angle of heel after cargo shifting and draw a horizontal line through the intersection of the heeling angle ordinate with the righting lever curve (Fig. 1).

.3 The residual stability is presented by the shaded area that is bounded by the righting lever curve, the horizontal line established under 8.1.2.2, and the down-flooding angle (if applicable). The residual stability should be compared against usual minimum stability requirements and prevailing weather conditions in terms of range, area, and value of maximum lever.

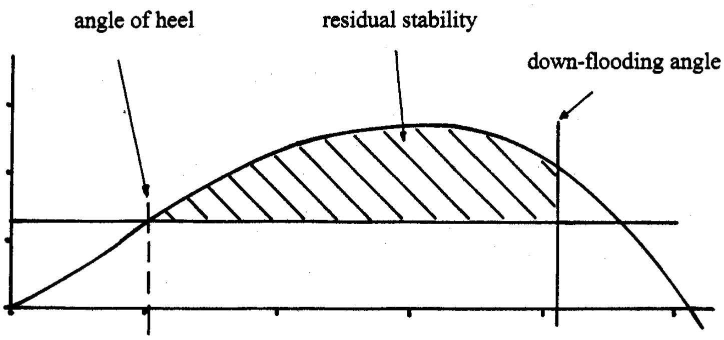

Fig. 1: Residual stability after cargo shifting

8.1.3 If remedial actions are deemed necessary to secure the stability of the ship the following aspects should be considered:

.1 Change of course and/or speed to reduce further rolling of the ship may be useful as a quick reaction.

.2 Securing of the shifted cargo to its new position may be advisable before righting the ship up by counter-flooding with ballast or by transfer of bunkers.

.3 As securing a shifted bulk cargo may be impractical any measures to upright the vessel should be restricted to a moderate reduction of the heel in order to avoid a re-shifting of cargo with a possibly larger heel to the other side.

8.1.4 A one-sided loss of deck cargo, e.g., containers, has the same effect to stability as a transverse shift of cargo notwithstanding the slight advantage of lowering the ship's centre of gravity by the loss of top mass. The method of assessing the residual stability and the measures of control are in principle the same as described under 8.1.2 and 8.1.3 above.

8.2 Towing operations

8.2.1 A ship, when engaged in towing operations, should possess an adequate reserve of stability to withstand the anticipated heeling moment arising from the tow line without endangering the towing ship (refer to MSC/Circ. 884 on Guidelines for Safe Ocean Towing).

8.2.2 In particular ships shifting berths within the port area may have a stability less than for seagoing condition. If a tugboat is used for this procedure the tug master should be warned accordingly to pull or push at reduced power.

8.3 Fire fighting

8.3.1 Fire fighting on board in port or at sea may involve the use of large quantities of water, in particular if access to the fire is restricted and an action of more or less flooding the space is the only way to control the fire. In such a case care should be taken not to endanger the ship by the risk of capsizing through the effect of liquid free surfaces from the water used for fire fighting.

8.3.2 Another threat to stability may arise if water from fire fighting becomes entrapped on upper decks, especially in unsymmetrical areas.

8.3.3 In particular with fire fighting alongside a jetty any developing list may not be noticed until the mooring ropes give way. Additionally shore fire brigades may not be fully aware of the risk of capsizing of a vessel due to the free surface effect.

8.3.4 In order to control the risk of capsizing the bilge pumps should be run to de-water the area as appropriate or drainage of spaces in upper decks should be effected.

8.4 Dry-docking

8.4.1 Ships being dry-docked have to go through a short period of reduced stability which is the time span between the first touching of the keel timbers and the settling on the full length of the keel whereupon lateral support booms or side propping devices can be put in place. For this reason ships being dry-docked should have ample stability and as little trim as possible.

8.4.2 During the docking period ballast tanks may have to be emptied and bunkers shifted depending on the work programme. Therefore, before the ship is re-floated again, a full survey of all tanks and a subsequent stability and trim calculation should be carried out to make sure that after re-floating:

.1 the ship has sufficient stability;

.2 the ship will float without list;

.3 the trim is within reasonable limits; and

.4 stress condition parameters are within acceptable limits.

Section 9 - Miscellaneous issues

9.1 Equipment for stability management

9.1.1 Equipment and instrumentation for stability management should, with due regard to the operating parameters of the ship, consist of:

.1 an approved computer and software supporting the documentation of cargo and tank operations, statical calculations with regard to stability, draught, trim and stress, and the evaluation of draught readings (shipboard draught survey);

.2 an approved system for carrying out a fast and reliable stability measurement;

.3 an approved remote draught gauging system; and

.4 an approved remote tank gauging system.

9.1.2 A simple and straightforward instruction manual, written in the working language of the ship and any other language the Administration may require, should be provided with this equipment (see MSC/Circ.891 on Guidelines for the On-Board Use and Application of Computers).

9.1.3 If computer based on-line evaluation of stability measurement, draught measurement or tank gauging is to be implemented, suitable means, like intermediate results and specific interrelations, should be provided for the user to check final results for plausibility.

9.1.4 It is desirable that the input/output form in the computer and screen presentation be similar to the one in the loading and stability manual so that operators will easily gain familiarity with the computer and the manual.

9.1.5 In order to validate the proper functioning of the equipment, test conditions should be run periodically at intervals specified in the company's instructions. Test results should be recorded and kept within the appropriate recording system.

9.2 Other considerations

9.2.1 The company should, when issuing instructions on the management of ship's stability, in particular in the context of the distribution of cargo, ballast and bunkers, provide attention also to other aspects of safe ship operation. This may include:

.1 longitudinal strength in terms of permissible bending moments and shear forces or torsional moments;

.2 vertical sequence of masses in container stacks on deck (refer to the ship's Cargo Securing Manual);

.3 observation of deck loading restrictions due to sight line requirements;

.4 suitable trim of the ship with regard to steering and handling in heavy weather; and

.5 load line requirements.

9.2.2 The above mentioned and other considerations related to the management of ship's stability should be appropriately reflected within records (see Section 1).

Section 10 - Training requirements

10.1 General education and training

10.1.1 General education and training of masters and mates with regard to the management of ship's stability is addressed to in the appropriate tables of Sections A-II/1, A-II/2 and A-II/3 of the Seafarers Training, Education and Watchkeeping (STCW) Code.

10.1.2 The instruction and education on the theoretical background of stability related issues and appropriate calculation procedures, generally carried out by Maritime Education and Training (MET) institutes, in complying with STCW requirements, should reflect the needs and provisions of stability management as lined out in these guidelines.

10.1.3 The practical training of future deck officers, as addressed to in Section B-II/1 of the STCW Code, should include appropriate familiarization with procedures of stability assessment and recording.

10.2 Specific shipboard training

10.2.1 The company should ensure that a deck officer, designated to assume the duties of a cargo officer, is given proper familiarization with the ship and the documentation and equipment regarding the management of ship's stability and related aspects.

10.2.2 The master should verify the appropriate ability of the particular deck officer and provide supervision if necessary.

10.2.3 Aspects of stability management within the contingency planning scheme should be appropriately addressed to within shipboard drills or paper exercises on damage control issues. This applies to all deck officers and engineers on board.

Appendix 1 - Simplified draught survey

1 Other than a full draught survey as described in detail in the IMO document BC 32/INF.9 and preferably used in bulk carriers, a simplified draught survey, as described in this appendix, may be carried out in any short break of cargo operations, even on a container ship. Its accuracy is sufficient to check the cargo intake, preferably by the differences of displacements between particular stages of loading.

2 The definitions and symbols used in this Appendix are consistent with the definitions and symbols presented in the MSC/Circ. 920. These are in particular:

L	length between perpendiculars	m		MTM	moment to change trim one metre	t·m/m
B	breadth moulded	m		TPC	tonnes per centimetre immersion	t/cm
DISV	displacement volume	m^3		KM	transverse metacentre above base	m
DISM	displacement mass	t		KG	centre of mass above base	m
ρ	density	t/m^3		KG_c	KG corrected for free surfaces	m
B.M.	stillwater bending moment at L/2	t·m		GM	metacentric height	m
d	deflection at L/2; $d = T_{KM} - T_K$	m		GM_c	GM corrected for free surfaces	m
t	trim; $t = T_{KF} - T_{KA}$	m		ZG	centre of partial mass above base	m
T_{KF}	keel draught at FP	m		XF	centre of flotation from AP	m
T_K	keel draught at MP	m		X_1	aft mark from AP	m
T_{KA}	keel draught at AP	m		X_2	mid mark from AP	m
T_{KC}	reference keel draught	m		X_3	fore mark from AP	m
T_{KFR}	reading at fore mark	m		FP	fore perpendicular	-
T_{KR}	reading at mid mark	m		MP	mid between perpendiculars	-
T_{KAR}	reading at aft mark	m		AP	aft perpendicular	-
T_{KM}	mean draught; $0.5 \cdot (T_{KF} + T_{KA})$	m		WL	actual waterline	-

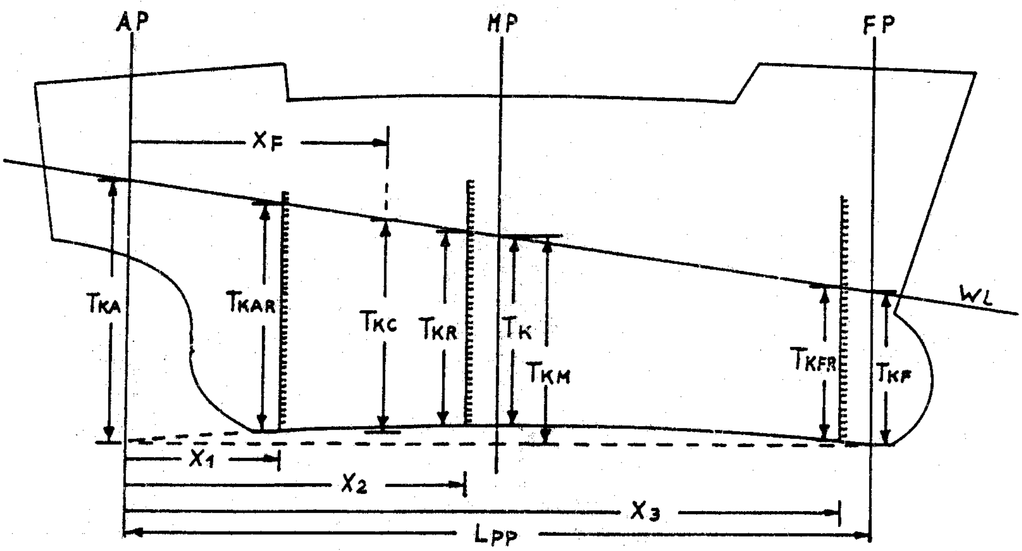

Fig. 2: Definition of draughts and mark positions

3 A ship in any given state of loading will be slightly listed, trimmed and longitudinally deflected. Draught readings are taken at marks which are generally close to but not exactly at the perpendiculars. Therefore a number of corrections must be applied to such readings to obtain a reference draught. This reference draught provides the immersed gross volume of the ship which, multiplied by the measured harbour water density, presents the actual mass-displacement (DISM) of the ship.

4 This slightly complex task is described below in a step by step procedure. Calculations should preferably be performed by a suitable routine within the ship's loading and stability computer.

.1 Remove any heel of the ship as far as practicable using the automatic anti-heel system or other suitable tanks.

.2 Take draught readings fore and aft as accurately as possible. Results are T_{KFR} and T_{KAR} .

.3 Measure the harbour water density by means of a hydrometer. Use a water sample from a depth of about half the ship's draught. The result is ρ.

.4 Estimate ship's deflection at L/2 using the formula:

$$d = \frac{L \cdot \text{actual B.M. at } L/2}{1000 \cdot \text{limit B.M. at } L/2} \quad [m]$$

(the sign of d equals the sign of actual B.M. at L/2)

.5 Apply corrections to draught readings for obtaining draughts at perpendiculars:

$$T_{KF} = T_{KFR} + (L - X_3) \cdot \left(\frac{T_{KFR} - T_{KAR}}{X_3 - X_1} + \frac{3.4 \cdot d}{L}\right) \quad [m]$$

$$T_{KA} = T_{KAR} - X_1 \cdot \left(\frac{T_{KFR} - T_{KAR}}{X_3 - X_1} - \frac{3.4 \cdot d}{L}\right) \quad [m]$$

.6 Calculate mean of draughts and the trim using the formulae:

$$T_{KM} = 0.5 \cdot (T_{KF} + T_{KA}) \quad [m]$$

$$t = T_{KF} - T_{KA} \quad [m]$$

.7 Calculate the reference draught using the formula:

$$T_{KC} = T_{KM} - 0.7 \cdot d + t \cdot \frac{XF - L/2}{L} + t^2 \cdot \frac{MTM_2 - MTM_1}{200 \cdot L \cdot TPC} \quad [m]$$

MTM_2: moment to change trim at (T_{KM} + 0.5 metres)

MTM_1: moment to change trim at (T_{KM} – 0.5 metres)

.8 Enter hydrostatic table using T_{KC} for obtaining gross volume DISV in m^3.

.9 Calculate mass displacement using the formula:

$$DISM = DISV \cdot \rho \quad [t]$$

5 An estimation of ship's deflection based on the actual bending moment at L/2 may be impaired by high temperature differences between deck and bottom of the ship or by a permanent deflection of the hull. It is recommended to check the estimated deflection on occasion by additional draught readings at the mid marks of the ship.

6 The accuracy of the result of a draught survey depends largely on the accuracy of draught readings, density measurement and estimation of deflection. For a ship of 100 m length, loaded close to her marks, the true displacement will be with 95% probability within ± 0.7% of the value found by this draught survey, provided the following margins are not exceeded with 95% probability:

draught readings:	± 0.020 m
estimation of deflection:	± 0.025 m
measurement of density:	± 0.004 t/m^3

For larger ships results are even more reliable.

7 The procedure described under paragraph 4 can be simplified and made more reliably by an equipment consisting of remote draught reading devices fore, mid and aft which are processed on-line and converted into a suitable display of the ship's displacement.

Appendix 2 - Measurement of stability by in-service inclining test

1 The purpose of an in-service inclining test is to measure the metacentric height GM_c and consider the result when deciding on further loading of deck cargo or on ballasting. The stability parameters obtained from an in-service inclining test include free surface effects and all masses and their vertical position in a realistic manner and should be preferred to parameters obtained from a mere calculation.

2 The accuracy required in shipboard practice can be sufficiently described by ± 10% with 95% probability. That is ± 5 cm with a GM_c of 0.5 m. This margin is easily met with reasonable effort in a test of less than 10 minutes duration. However care should be taken to observe the performance standards as outlined below.

3 The basic test procedure can be described by the following steps:

.1 Prepare the ship to heel freely.

.2 Eliminate interfering moments.

.3 Measure first angle of heel ϕ_1.

.4 Induce a defined heeling moment m·e.

.5 Measure second angle of heel ϕ_2.

.6 Remove the defined heeling moment and measure a third angle of heel ϕ_3 (cross-check).

.7 Carry out a simplified draught survey (see Appendix 1).

.8 Calculate the metacentric height GM_c using the formula:

$$GM_C = \frac{m \cdot e}{DISM \cdot \tan(\phi_2 - \phi_1)} \text{ [m]}$$

m = heeling mass [t]
e = heeling lever [m]
$(\phi_2 - \phi_1)$ = test angle of heel [°]

.9 Obtain KGc using the formula:

$KG_c = KM - GM_c$ [m]

Note: If the absolute trim of the ship is greater than 0.01 · L, then KM for trimmed condition should be used. KG_c is already increased for the effect of free surfaces in tanks.

Note: If the absolute difference of ϕ_3 and ϕ_1 (cross-check) exceeds 5% of the test angle of heel it should be considered to repeat the test and re-check any interfering moments.

Preparation of the ship to heel freely

4 The following principles should be observed when preparing the ship for the test with regard to slackening the mooring ropes:

.1 **Wind blowing off-shore:** Slack all mooring ropes until distance from fenders is about 0.5 metres. Steep ropes from fair leads on shore side of the ship should be slack.

.2 **Wind blowing on-shore:** Slack all mooring ropes until sag in the rope is about 10% of the free length. Steep ropes should be slackened a little more. Ship's contact to fenders is no hindrance to the test.

.3 **Wind blowing parallel to quay:** Keep one or two long mooring ropes taut and slacken the rest to 10% sag. Further contact of the ship to fenders is no hindrance to the test.

.4 Shut down automatic mooring winches and tighten breaks. Hoist up the gangway well clear from the quay unless its foot can roll readily and will not get stuck to any obstacle.

Elimination of interfering moments

5 It is important that in the short span of time between the first, second and third measurement of the heeling angle there is no change of heeling moments other than the test moment and free surface moments in slack tanks. For this reason the following task list should be worked through and arrangements made as appropriate:

.1 Stop all cargo loading, unloading or moving of cargo in the ship.

.2 Stop all moving of cargo gear (derricks, cranes, hatches, ramps) or other equipment and stop all tank operations in deck and engine department.

.3 Stop the automatic anti-heel system, if provided.

.4 Stop all tending of mooring ropes (automatic mooring winches disengaged).

.5 Limit the walk-around of persons on board (on ships below 100 m length only).

.6 Check wind conditions: With wind of 6 Bft or above there is an increased risk of squalls lasting several minutes, which may impair the test.

.7 Check current in the water and its effect to changes of heel (observe the heel indicator).

.8 Check swell in the harbour and decide whether movements of the ship are regular enough to use mean values of heel.

.9 Make sure there is no ship passing near by during the test.

.10 Check keel clearance to avoid touching the ground.

If one or more of the above conditions cannot be met or are considered unsuitable the test should be abandoned.

6 Free surfaces in bunkers and other tanks need not be considered. They are automatically accounted for in the test result GM_c. Care should however be taken that flat ballast tanks, which are to be nominally full, are really full and those, which are to be nominally empty, are really empty. Otherwise the tiny ullage of air or the bottom layer of liquid, which would practically not affect the stability, will lead to a reduction of the test-GM_c, pretending less stability than available.

Measuring of heeling angles

7 Preferably an advanced precision instrument should be used which provides a reading sufficiently smoothed and a print or a graphic record over the time.

8 The instrument should keep an accuracy of ± 0.05° with 95% probability. It should be robust against the usual shipboard environment (vibrations, humidity, accelerations). Equipment for easy re-check of calibration should be provided with the instrument. As the test angle of heel is the difference of two measurements a zero-calibration is not required. Classification societies are generally prepared to approve such instruments according to their specifications.

9 The absolute heel of the ship during an in-service inclining test should not be greater than 3.5° in order to keep the influence of additional form stability on the measured metacentric height within tolerable limits. It is therefore recommended to pre-heel the ship to one side before the test and convey the test heel back and beyond zero to the other side. The maximum obtainable test angle of heel would be 7° in that way providing for a higher relative accuracy of that test angle. The cross-check should be applied accordingly.

Providing a defined test moment

10 The test moment should be numerically between 2% and 7% of the ship's displacement, i.e. between 200 and 700 $t \cdot m$ for a ship of 10000 t displacement. The amount of the test moment should be known or determinable with a relative accuracy of ± 2% with 95% probability. The time for inducing the test moment should be less than 3 minutes, to keep within the desired overall duration of 10 minutes.

11 With these requirements there are three suitable choices available:

.1 One or two cargo units of known mass can be transversely shifted or loaded/unloaded on the side of the vessel. Preferably standard containers should be used. The mass should be determined by running the container over a weigh-bridge. The accuracy of weight control in container loading bridges is generally not sufficient. The lever of transverse shifting should be determined by using a tape-measure.

.2 Liquid of known density can be shifted between side tanks. Ballast tanks - although a preferred choice on large vessels (DISM > 25000 t) - are normally not suitable for this purpose because of low transfer capacity and inaccurate control of filling state. Special stability test tanks however with fast liquid transfer and accurate determination of test moments are available and successfully in use on cargo vessels and ro/ro-ferries with approval by the Administration.

.3 A heavy crane jib or heavy-lift derrick. can be given a defined transverse movement. The preferable method is to turn an empty crane jib or derrick to an extreme transverse position at a defined inclination. After taking the first measurement of heel the jib or derrick is turned to the opposite side at the same inclination. The test moment induced by this procedure should be suitably documented in the ship's Loading and Stability Manual.

12 It is recommended that the amount of the appropriate test moment is determined and approved by the Administration in the course of the ship yard inclining experiment or by a similar suitable test arrangement.

Overall accuracy of the test

13 Taken the required relative accuracy's with 95% probability as proposed above, i.e. average ± 2.5% with the test angle of heel, ± 2% with the test moment and a relative accuracy of the displacement by draught survey (see Appendix 1) of ± 0.7%, the probable relative error in GM_c is:

$$e_{GM\,c} = \pm \sqrt{(2.5^2 + 2^2 + 0.7^2)} = \pm 3.3\%$$

This error is well below the accepted error margin of ± 10% with 95% probability.

14 In order to achieve a reliable result of KG_c the value of KM should be carefully interpolated from ship's hydrostatic tables or curves using trimmed hydrostatics if the ship is trimmed more than 1% of L_{pp}.

Monitoring and recording the test

15 The in-service inclining test should be appropriately monitored and recorded in accordance with procedures provided by the company's Safety Management System. In particular the preparation of the ship and the task list for elimination of interfering moments should be filed together with measurements taken for the draught survey and the inclining test itself. If the test is carried out by on-line computer management the appropriate printed records should be kept with the documentation.

Abandon test conditions

16 The in-service inclining test should be abandoned if one of the following conditions are met:

.1 swell, ice or other circumstances which prevent a reasonable determination of the ship's displacement,

.2 lack of suitable means to produce a defined test moment of a magnitude sufficient for a test angle of heel of at least 1°,

.3 swell or other circumstances which prevent a precise measurement of heeling angles,

.4 inability to avoid interfering moments (see paragraph 5); this may be revealed by the cross-check heel procedure.

Advanced equipment for inclining tests

17 Such approved equipment may include a remote draught gauging system, a fast and precise inclining tank system and an inclinometer. The performance and evaluation of the test may be controlled by a computer programme. The use of advanced equipment for performing in-service inclining tests is recommended.

Appendix 3 - Measurement of stability by observing natural periods of roll

1 The so-called rolling test may be recommended as a useful means of approximately determining the initial stability of the ship. The advantage of the rolling period test against the in-service inclining test is its quick performance and the independence from a draught survey, although for a complete stability assessment the mass displacement of the ship should be determined as well. Disadvantageous however is its lesser accuracy compared with the in-service inclining test.

2 The result of a rolling test is the metacentric height GM_c which contains the effect of free surfaces in tanks holding liquids with usual viscosity. GM_c is obtained by the formula:

$$GM_c = \left(\frac{C_\phi \cdot B}{T_\phi} \right)^2$$

with
C_ϕ = rolling co-efficient
B = ship's breadth [m]
T_ϕ = natural rolling period [s]

3 The rolling period required is the time for one complete oscillation of the ship. The test should be conducted with the ship in harbour, in smooth water with the minimum interference from other disturbing influences. The effect of free surfaces in the ship is taken into account automatically.

4 The rolling co-efficient is a value ranging between 0.72 and 0.84 in general, although these figures have been exceeded in certain situations. It should be noted that the greater the distance of masses from the rolling axis, the greater the rolling coefficient will be. Therefore it can be expected that:

.1 the rolling coefficient for an unloaded ship, i.e. for a hollow body, will be higher than that for a loaded ship; and

.2 the rolling coefficient for a ship carrying a great amount of bunkers and ballast - both groups are usually located in the double bottom, i.e. far away from the rolling axis - will be higher than that of the same ship having an empty double bottom.

5 Although the preparation of the ship is similar to that for performing an in-service inclining test the sensitivity against interfering moments is much reduced. Thus the checklist given in Appendix 2 paragraph 5 may be restricted to the items 1, 3, 4, 8, 9 and 10 when applied to the rolling test. It is important however that the ship is prepared to roll freely by slackening the mooring ropes in accordance with paragraph 4 of the Appendix 2.

6 For the following reasons, it is not generally recommended that results be obtained from rolling oscillations taken in a seaway with the ship under way:

.1 coefficients for tests in open waters are not available,

.2 the rolling periods observed may not be free oscillations but forced oscillations due to seaway,

.3 frequently, oscillations are either irregular or only regular for too short an interval of time to allow accurate measurements to be observed; and

.4 specialised recording equipment is necessary.

Ships up to 70 m in length

7 For ships up to 70 m in length the IMO Intact Stability Code contains comprehensive guidance on the performance of the rolling test in Chapter 7.6 based on earlier studies on this issue.

Ships above 70 m length

8 A limited number of combined rolling and inclining tests with ships greater than 70 m length has indicated that there is in principle no difference to the behaviour of small ships. Ships over 70 m length should be prepared to roll freely in the same manner as described for small ships. A suitable way to initiate roll motions is to lift a heavy cargo unit, favourably a loaded container, with ship's gear from the quay and set it down again giving sufficient slack to the runner.

9 As the roll amplitude will be only small, i.e. in the range of 2 to 3 degrees in the beginning with a considerable rate of reduction due to damping, it has been found convenient to observe the roll motions on the quay by watching the rise and fall of the ship's side against the edge of fenders or similar reference. The average time of two complete roll motions, taken by a stop watch, will provide a sufficiently accurate period of roll. This procedure may be repeated without undue delay to cargo operations.

10 The rolling coefficient C_ϕ behaves on larger ships in the same manner as found with small ships below 70 metres length. Particularly in a situation where stability may become critical, i.e. a container vessel with full deck cargo and appropriately ballasted, the coefficient C_ϕ is found closing or even exceeding the value of 0.8. It is however recommended to evaluate the coefficient C_ϕ by a number of double tests (in-service inclining test and roll test) for such loading conditions.

Accuracy of rolling test

11 With reasonable assumptions the relative error margins of the rolling test can be found at $\pm$ 15% with 95% probability. This unfavourable result follows from the square expression in the rolling formula which indicates an increased sensitivity of GM_c against errors in C_ϕ and T_ϕ. The rolling test is therefore inferior to the in-service inclining test although there may be situations where a rolling test will be suitable to indicate whether a critical situation may be expected or not. The rolling test should however not be used to check the stability of a ship in a critical situation, i.e. close to stability limits.

12 Experiments have shown that the results of the rolling test method get increasingly less reliable the nearer they approach GM_c values of 0.20 m and below.

Monitoring and recording the test

13 The rolling test should be appropriately recorded in accordance with procedures provided by the company's Safety Management System. If the rolling test is carried out using a graphical heel recorder, the printed graphs should be appropriately identified and kept with the record.

Appendix 4 - Adaptation of test results for assessing final conditions

1 Preferably a measurement of stability should be carried out shortly before loading of cargo is completed in order to decide on the final intake without the commercial risk of unloading cargo already accepted for transport. As the condition of the ship at such an earlier test will generally deviate from the final departure condition and even more from the "worst condition" during the voyage, appropriate adaptations have to be made to the test result in order to compare it with limit values as set by the master or by statutory requirements.

2 These adaptations should regard all major changes or shifts of masses as:

.1 loading/unloading or shifting of cargo,

.2 lowering/hoisting of heavy cargo gear from working position into sea condition,

.3 returning hatch covers from the jetty to the ship,

.4 hoisting ramps or lowering bow visor,

.5 filling or emptying/consuming tanks including changes of free surface effects,

.6 increase of mass of deck cargo due to absorption of water,

.7 increase of top mass due to icing.

3 Results of a measurement of ship's stability are DISM and KG_c. The aim of any adaptation is to determine DISM and KG_c for the adapted condition. The two basic types of calculations, i.e. adding/removing a mass or mere vertical shift of a mass can be done within the same scheme. This is shown in the following example:

Calculated example

4 It is assumed the results of an in-service inclining test are DISM = 11425 t and KG_c=8.24m.

	mass [t]	ZG [m]	vert. Mom. [t·m]
Condition at time of test	**11425**	**8.24**	**94142**
Adaptations:			
Loading of 4 containers into tier 82	36	19.58	705
Lower crane boom No.2 from 80°	---	---	- 407
Hoist and stow stern ramp	---	---	784
Return hatch cover No.1 from shore	29	12.79	371
Consume fuel from DB tank No. 4	- 140	0.75	- 105
Cancel free surface moment in DB tank No. 4	---	---	- 560
Increase top mass due to icing	100	20.00	2000
Worst condition during the voyage	**11450**	**8.47**	**96930**

These results for the worst condition during the voyage should be compared with limit values of stability.

5 It is recommended that information on the adaptation of test results by moving cranes, ramps, hatch covers and similar heavy equipment into sea condition is contained in the loading and stability booklet in the form of suitable tables or diagrams.

6 Calculations for adapting stability test results to a departure condition or to a worst condition during the voyage should be kept with the record documents on stability management.

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