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# GUIDELINES FOR THE CONDUCT OF HIGH-SPEED CRAFT MODEL TESTS

1 The Maritime Safety Committee, at its seventy-third session, adopted, by resolution MSC.97(73), the International Code of Safety for High-Speed Craft, 2000 (the Code) which, following the entry into force of the 2000 SOLAS amendments, adopted by resolution MSC.98(73), became mandatory as from 1 July 2002.

2 While the provisions of paragraph 2.2.3.1 of the Code require the fitting of an inner bow door on ro-ro high-speed craft fitted with bow loading opening, the Code recognizes that exemption from this requirement may be granted in a number of cases which are stated in paragraph 2.2.3.2 of the Code. One of these alternatives is set out in paragraph 2.2.3.2.2 of the Code which states that, if it can be demonstrated that a craft complies with certain residual stability criteria, even if water accumulates on the vehicle deck as a result of failure of the bow shell door, it may qualify for such an exemption. Model testing is identified in the Code as one of the options for determining the quantity of water that the craft in question may accumulate.

3 The Committee, at its seventy-fifth session (15 to 24 May 2002), approved Interim Guidelines for the conduct of high-speed craft model tests (MSC/Circ.1029) which were intended to ensure that the aforementioned model tests would be sufficient and adequate so that requests for exemption are considered and granted in a consistent and safe manner without jeopardizing the safety of the craft and to enable the Administration to consult with each of the port States between which the craft may operate.

4 The Committee further agreed that:

.1 the Interim Guidelines should be applied with a view to verification and further development in the light of experience, and should be revisited after a period of time not exceeding four years following the date of entry into force of the Code;

.2 comparative model tests should be conducted and the results of such tests should be submitted to the Organization, so as to validate and further refine the Interim Guidelines; and

.3 Member Governments should undertake to seek the comments on, and evaluation of, the Interim Guidelines from the International Towing Tank Conference (ITTC) and, subsequently, collect information from the ITTC, in particular the results of their experience, and submit it to the Organization for consideration with a view to improving the Interim Guidelines.

5 The Committee, at its eighty-first session (10 to 19 May 2006), approved Guidelines for the conduct of high-speed craft model tests, prepared by the Sub-Committee on Ship Design and Equipment at its forty-ninth session, revising the Interim Guidelines, as set out in the annex.

6 Member Governments are invited to make use of the annexed Guidelines and bring them to the attention of craft designers, craft owners and other parties concerned, as appropriate, when considering the provisions of paragraph 2.2.3.2.2 of the Code.

7 This circular supersedes the Interim Guidelines for the conduct of high-speed craft model tests (MSC/Circ.1029).

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# ANNEX

# GUIDELINES FOR MODEL TESTING

## 1 INTRODUCTION

1.1 The exemption from the requirement to fit an inner bow door now incorporated in the 2000 HSC Code (paragraph 2.2.3.2.2) may be invoked if a craft can be shown to comply with certain residual stability criteria even if water accumulates on the vehicle deck(s) as a result of failure of the bow shell door. Model testing is one option for determining the quantity of water that accumulates.

1.2 These Guidelines are intended to ensure that such model tests would be sufficient and adequate so that the exemption would be applied safely and consistently, and so that the safety of the craft would not be endangered.

1.3 Terms used in these Guidelines are as defined in the 2000 HSC Code.

1.4 The aim of the model tests is to determine the answers to two questions:

.1 whether waves reach the bow loading door; and, if so,

.2 what volume of water would accumulate.

1.5 To meet these aims, the following is described in these Guidelines:

.1 the use of towed or self-propelled models;

.2 physical tests at heading increments of 45° relative to the waves at zero and at forward speed;

.3 tests to establish whether water reaches the bow openings, and if so tests to determine the amount of water that may accumulate; and

.4 direct measurement of the accumulated volume of water at the end of each test run, or determination of the volume by calculation from measurements of relative water level within the vehicle space.

## 2 MODEL DESIGN AND CONSTRUCTION

### 2.1 Type and size

#### 2.1.1 *Type of test facility*

2.1.1.1 The tests described by these Guidelines are intended to be undertaken in either a manoeuvring basin or in head and following waves in a conventional towing tank. The model may either be:

.1 towed from a carriage (preferably equipped with the capability for free-to-surge under constant towing force), with freedom to heave, pitch and roll; or

.2 self-propelled and remotely controlled, either by radio or by a lightweight umbilical attachment.

2.1.1.2 The wave making facility should be capable of generating the requisite specific wave spectra with accuracy within + 2.5% on significant height, ±2.5% on $T_P$, and ± 5% on $T_Z$.

### 2.1.2 *Scale*

The model scale should be as large as practicable with respect to the test facility employed, but the model should not be less than 1.5 m in length, and be:

.1 appropriate to enable the requisite full scale significant wave height to be generated; and

.2 capable of providing the equivalent of at least 1 min duration of operation at full scale per tank run at the maximum speed to be tested.

## 2.2 Construction

### 2.2.1 *General*

The model should comply with the following:

.1 be capable of operating in both displacement mode and where appropriate in the non-displacement mode at a running attitude (trim and sinkage) appropriate to the full scale craft;

.2 any lift devices (e.g., fans, foils, flaps, flexible seals, wings, etc.) should generate forces, pressures and volumetric flows resulting in the same running attitude in calm water, as specified above, ensuring a bow height accuracy within 5%. Actively controlled stabilizing or ride-control devices should be assumed to be in a fixed pre-set or passive mode;

.3 the hull should be suitably thin ($0.01L_{model}$ with a minimum of 2 mm is recommended) in floodable spaces;

.4 be equipped with all main design features such as watertight bulkheads, air escapes, freeing ports, access trunks, etc corresponding to the full scale vehicle spaces, and modelled properly to represent the real situation as far as practicable;

.5 be constructed with superstructures to the extent needed to ensure a realistic response in waves;

.6 be suitably constructed to permit monitoring of the interior of the floodable spaces, using video cameras;

.7 be equipped with external appendages such as bilge keels, spray rails, lift devices or fendering as may reasonably be expected to influence the results of the tests;

.8 be provided with a bow aperture to accurately model the full scale craft after the bow loading door(s) may have been lost, special attention being paid to the freeboard at the lowest point;

.9 be equipped with fast-closing watertight shutters to the bow aperture(s) and any drainage openings that can be remotely opened and closed at the beginning and end of the test period during each run;

.10 prior to ballasting, the model should be equipped with all the necessary instrumentation; and

.11 freeing ports and other means of drainage should be closed at all times during the tests.

**2.2.2** ***Permeability of vehicle spaces***

The reduction of permeability of the vehicle spaces due to the presence of cargo should not be represented.

**2.2.3** ***Accuracy***

2.2.3.1 The mass of the model after ballasting to the directly scaled design waterline should be within ±1% of that representing the full scale craft.

2.2.3.2 The longitudinal centre-of-gravity after ballasting to the directly scaled design waterline should result in a static trim attitude within 0.2° of that representing the full scale craft.

2.2.3.3 The volume of the vehicle spaces to the first downflooding opening derived when the craft is at the designed trim attitude should be within ±2% of that representing the full scale craft. Where open vehicle spaces are modelled, the volume should be measured up to the level at which water might first begin to spill out, or alternatively the deck area should be within ± 2% of that representing the full scale craft (commensurate with hull thickness as specified in 2.2.1.3).

2.2.3.4 The freeboard from the directly scaled design waterline (at zero speed) to the lowest point of the bow loading opening should be within +0 to -1% of that representing the full scale craft.

**2.3 Model loading**

2.3.1 Ballasting particulars should be developed for one loading condition prior to testing, viz: maximum operational weight (as defined in the 2000 HSC Code), combined with the most onerous bow down running trim or the condition with the bow aperture closest to the water in the running trim.

2.3.2 The ballasting particulars should be such as to achieve:

.1 a mass corresponding to the loading conditions defined above;

.2 a vertical centre-of-gravity position corresponding to the maximum allowable in service (limiting KG) for the respective operational weight, or alternatively the maximum predicted operational KG plus a margin of 10%;

.3 longitudinal centre-of-gravity positions corresponding to the nominal and most forward and most aft positions envisaged by the loading restrictions contained in the craft operating manual;

.4 a longitudinal radius of gyration equivalent to that calculated for the full-scale craft ±8%, or (where this information is not available) within the range 0.23 to 0.27L, where L is as defined in the 2000 HSC Code; and

.5 a roll radius of gyration equivalent to that calculated for the full-scale craft ±8%, or (where this information is not available) within the range 0.35 to 0.4 B, where B is as defined in the 2000 HSC Code,

after ballasting for each condition:

.6 the total model mass should be verified by weighing;

.7 the actual vertical centre-of-gravity and longitudinal trim should be verified by physical inclining in air and/or water;

.8 the longitudinal and roll radii of gyration should be verified in air; and

.9 the natural roll period should be measured by a roll decrement test with the model at rest in calm water.

## 3 ENVIRONMENTAL CONDITIONS

### 3.1 Waves

3.1.1 Two sea states should be used. The model should be tested in a long-crested irregular seaway at maximum significant wave steepness of $H_s/(gTp^2/(2\pi))=0.05$. In the absence of information on specific spectrum data, JONSWAP type spectra should be used with a peak enhancement factor $\gamma=3.3$. In the first sea state, $H_s$ should be the maximum significant wave height for the area of operation, which is not exceeded by a probability of more than 10% on a yearly basis, but limited to a maximum of 4 m. In the second sea state $H_s$ should represent the significant wave height corresponding to the most onerous relative bow motion (worst intended conditions).

3.1.2 Generation of the waves should be such that each wave realization results in a non-repeating wave train during the model test.

### 3.2 Wind

Wind should not be represented during the tests.

## 4 INSTRUMENTATION, CALIBRATION AND DATA RECORDING

### 4.1 Model instrumentation

4.1.1 The following model instrumentation should be provided as a minimum: one relative water level sensor located in front of the opening at the port and starboard extremities of the opening (i.e. 2 sensors).

4.1.2 If the water volume is to be estimated using water height measurements, 15 water level sensors should be used at the following locations (where $l$ = the length of the floodable vehicle space):

.1 at 10% of $l$ from the bow loading opening, at the watertight boundary on the port and starboard sides and centreline ($h_{FP}$, $h_{FS}$ and $h_{FC}$ respectively);

.2 at 30% of $l$ from the bow loading opening, at the watertight boundary on the port and starboard sides and centreline ($h_{FMP}$, $h_{FMS}$ and $h_{FMC}$ respectively);

.3 at 50% of $l$ from the bow loading opening, at the watertight boundary on the port and starboard sides and centreline ($h_{MP}$, $h_{MS}$ and $h_{MC}$ respectively);

.4 at 30% of $l$ from the aft limit of the vehicle space, at the watertight boundary on the port and starboard sides and centreline ($h_{AMP}$, $h_{AMS}$ and $h_{AMC}$ respectively); and

.5 at 10% of $l$ from the aft limit of the vehicle space, at the watertight boundary on the port and starboard sides and centreline ($h_{AP}$, $h_{AS}$ and $h_{AC}$ respectively).

4.1.3 A drawing of the positions of the water height sensors should be provided.

4.1.4 Instrumentation to measure roll and pitch angles and heave motion is recommended.

4.1.5 If the testing is conducted solely to demonstrate that water does not reach the bow loading opening, then all items except 4.1.1 may be omitted.

4.1.6 As an alternative to the use of water level sensors described in 4.1.2 above, the volume of water accumulated during a test run may be determined by direct collection and weighing of the water inside the model.

**4.2 Facility instrumentation**

The following instrumentation should be provided in the model basin:

.1 one static wave height probe located clear of tank end effects;

.2 one moving wave height probe mounted so that it approximately matches the mean model position;

.3 mean forward speed of the model;

.4 video camera(s) to monitor the interior of the vehicle spaces; and

.5 video camera(s) to monitor the exterior of the model, especially the bow aperture.

### 4.3 Data recording

Continuous records should be obtained for all the media required by 4.1 and 4.2 for each test run, with a sampling rate at model scale of not less than 25 Hz.

## 5 TEST PROCEDURE

### 5.1 Preparation

5.1.1 The model should be prepared in accordance with 2.2, 2.3 and 4.1 above, and all verification checks required by 2.1 to 2.3 should be completed before testing commences.

5.1.2 The wave spectra should be run and verified for compliance with the requirements in 2.1.1.

### 5.2 Craft speed and operating mode

5.2.1 Where a craft normally operates in a non-displacement mode, tests should be conducted in both zero speed (displacement mode) and maximum operating forward speed (non-displacement mode). Where a non-displacement mode is tested, any lift devices should be employed as specified in 2.2.1.1.

5.2.2 Prior to the testing, an estimate should be made by the owner and/or builder as to the maximum speed of the full scale craft into head seas ($V_W$) that would be practically attainable in the specific loading condition (powering considerations) or be structurally permissible (e.g.: by the classification society). Where a craft may be operated in both displacement and non-displacement modes, separate values of $V_W$ should be derived for the two modes.

5.2.3 In head seas the speed of the model should not exceed $V_W$, but may be reduced to not less than 65% of $V_W$, provided that if a reduced speed is necessary to satisfy the terms of the exemption, the maximum permissible speed in the relevant wave height is incorporated in the Permit to Operate and in the craft operating manual.

### 5.3 Test run procedure

5.3.1 Once the craft has reached the required test speed during a tank run, the watertight bow aperture(s) are to be rapidly opened and are to remain open until the point at which the model is decelerated at the end of the run. At that point the watertight shutters are to be rapidly closed to trap the water collected inside the model. This water is to be measured directly after the tank run (5.5.3 refers) and the water is to be removed from the model after each run.

5.3.2 A weight made of high density material, such as lead or steel, equal to the mass of water collected at the end of each tank run is then to be placed on the vehicle deck, on the centreline of the craft and at the longitudinal mid point of the vehicle deck. This weight should be cuboid in shape, with length and beam selected to fit the available deck space, aiming not to restrict the water flow on the vehicle deck. This may allow for more water to accumulate on the ro-ro deck than what would be the case in one continuous run but this error is likely to be small and on the side of safety.

5.3.3 This process is to be repeated for each run of a test case.

## 5.4 Test programme

### 5.4.1 *General*

5.4.1.1 The test programme should be witnessed by an Administration (whenever known, this should be the flag Administration), surveyors nominated by them for the purpose or by organizations recognized by them.

5.4.1.2 The test programme should be conducted for the craft operating in each of the sea states stipulated in 3.1 above through direct physical testing at zero and forward speed on five headings relative to the wave direction, between head and following seas in 45 degrees increments.

### 5.4.2 *Duration and repetition of test runs*

5.4.2.1 For test runs at zero speed, each run should have a duration of 10 min (full scale). Each test case at each heading should consist of a set of three tank runs with different wave realizations.

5.4.2.2 Each tank run at forward speed should be of the maximum practical duration, in any case not less than the equivalent of 1 min at full scale, with the bow opening shutter being opened and closed at the beginning and end of the test period of each run. Each test run should comprise successive tank runs to represent not less than 10 min of continuous full scale operation in one wave realization at a given heading angle.

5.4.2.3 Each test case per heading angle (at forward speed) should consist of an ensemble of test runs with different wave realizations. The number of associated wave realizations should depend on the heading angle as follows:

.1 three wave realization trains in head and bow quartering seas;

.2 four wave realization trains in beam seas; and

.3 five separate wave realization trains in following and stern quartering seas.

5.4.2.4 Each wave realization train will be of at least 10 min full scale total duration, each such wave train being taken from the required wave spectrum.

### 5.4.3 *Tests in waves at all heading angles*

5.4.3.1 As a minimum the following tests should be conducted: at a speed of $V_W$ and design LCG, tests in waves specified in 3.1.

5.4.3.2 If the craft does not comply with the water volume required to meet the exemption, then the tests can be repeated at lower speed to a minimum of 65% $V_w$.

## 5.5 Test results

### 5.5.1 *General*

The tests are required to determine the answers to two questions:

.1 whether the bow loading door is reached by the waves; and, if so,

.2 what volume of water would accumulate.

**5.5.2 *Determination of whether water reaches the bow opening***

If, during the constant speed portion of ANY of the test runs required by these guidelines, water is observed or measured as having exceeded the lower edge of the bow opening, then the requirement of the 2000 HSC Code, paragraph 2.2.3.2.2.1 (objective 5.5.1.1) should be deemed NOT to have been satisfied. In the event this is not satisfied, then an exemption may still be possible by further tests to demonstrate compliance with the 2000 HSC Code, paragraph 2.2.3.2.2.2 (objective 5.5.1.2).

**5.5.3 *Determination of volume of water***

From the model tests the accumulated volume of water for each heading angle may be determined by:

.1 direct measurement of the accumulated volume of water by collecting the trapped water on the vehicle deck in a measurement receptacle (preferred method). The water volume collected during each (10 min) test run should be based on the sum of volumes recorded for each successive tank run. For each test case at a given heading angle the volume should be averaged over the volumes of the different test runs (wave realizations) to give a collected volume for a 10 min (full scale) time period; or

.2 determination of the volume by calculation from measurements of water level within the vehicle space, using the method of 5.5.4 below. The position of the solid weight after each run should be positioned to minimize interference with the water height measurement probes.

**5.5.4 *Calculation of volume of water accumulating on the vehicle deck***

5.5.4.1 When the volume of water accumulated on the vehicle deck is estimated from water height sensors, it should be calculated as follows. The mean volume of water during each successive tank run should be determined from the fifteen sensors as defined in 4.1.2.1 to 4.1.2.2. The mean heights of water measured at these locations should be scaled to full scale before calculating the volume of water as follows (where the symbol *h'* denotes the water height scaled as described above).

5.5.4.2 Volume of water during tank run i:

$$\mathrm{Vol}_i = A_{VD}\,(h'_{FS} + 2h'_{FC} + h'_{FP} + h'_{FMS} + 2h'_{FMC} + h'_{FMP} + h'_{MS} + 2h'_{MC} + h'_{MP} + h'_{AMS} + 2h'_{AMC} + h'_{AMP} + h'_{AS} + 2h'_{AC} + h'_{AP}) / 20 \qquad (m^3)$$

Where: $A_{VD}$ = plan area of vehicle deck capable of being flooded ($m^2$ at full scale).

5.5.4.3 The volume of water accumulated during a test run is given by the sum of $\mathrm{Vol}_i$ for each successive tank run.

### 5.5.5 *Volume of water to be used in calculating residual stability*

The volume of water resulting from the most onerous condition (i.e., heading angle) obtained from 5.5.3.1 or .2 is to be used for calculating the stability properties for demonstrating compliance with the 2000 HSC Code, paragraph 2.2.3.2.2.2.

## 5.6 Test report

The test report should include the following information as a minimum:

.1 general arrangement drawing of the craft, showing the spaces that might be flooded as a result of failure of the bow loading door;

.2 general arrangement drawing of the model, showing the scale ratio and details of the construction and instrumentation;

.3 calculations to show the derivation of the maximum operational and minimum operational weights and corresponding limiting KG positions;

.4 tests conducted to verify the mass, centre-of-gravity position and radii of gyration;

.5 where appropriate, calculations to show that the elements necessary to achieve the non-displacement mode have been appropriately scaled;

.6 the nominal and measured wave spectra (at the fixed wave probe location); and

.7 records for each test case:

.7.1 wave elevation at model position;

.7.2 relative wave height at the opening; and

.7.3 internal water volume measurements.

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