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INTERIM 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), will become 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 the Interim Guidelines for the conduct of high-speed craft model tests, as set out in the annex, which are 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 Member Governments are invited to make use of the annexed Interim 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.

5 The Committee further agreed that:

.1 the annexed Interim Guidelines should be applied with a view to verification and further development in the light of experience, and these 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.

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ANNEX

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

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 Interim Guidelines for the conduct of high-speed craft model tests 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 Interim Guidelines are as defined in the 2000 HSC Code.

1.4 A number of options are available within the scope of these Interim Guidelines:

.1 the use of towed *OR* self-propelled models;

.2 physical tests at heading increments of 30° or 45° relative to the waves, *OR* physical tests in head and following seas complemented by stationary tests at other headings and numerical simulations;

.3 tests solely to establish whether water reaches the bow openings, *OR* tests to determine the steady state volume of water that may accumulate;

.4 tests to demonstrate compliance with one test run of long duration, *OR* successive test runs to achieve the required duration for each test case, during which the bow and other apertures are only opened when at test speed;

.5 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

The tests described by these Interim 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.

The wave making facility should be capable of generating the requisite specific wave spectra with a repeatability of not more than ± 5% on significant height, ± 10% on spectral density at peak frequency, ± 0.3 s (at model scale) on modal period, and ± 5% on zero crossing period.

2.1.2 Scale

The model scale should be as large as practicable with respect to the test facility employed, but:

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

.2 capable of providing the equivalent of at least one minute 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 the height and attitude appropriate to the full scale craft;

.2 any lift devices (e.g. fans, foils, flaps, flexible seals, wings) should generate the Froude scaled forces, pressures and volumetric flows corresponding to the full scale craft within ± 10%. Actively controlled stabilising or ride-control devices should be assumed to be in a fixed pre-set or passive mode;

.3 the hull should be suitably thin in those areas where this feature may influence the results;

.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 should be modelled properly to represent, as far as practicable, the real situation;

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

.6 be constructed using sufficient transparent panels to permit monitoring of the interior of the vehicle spaces from above, using video cameras;

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

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

.9 be equipped with 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; and

.10 be equipped with all the necessary instrumentation prior to ballasting.

2.2.2 Drainage and downflooding

Particular care should be taken to represent all means of drainage or potential downflooding from the vehicle space as faithfully as practicable, consistent with the objective of the tests.

2.2.3 Permeability of vehicle spaces

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

2.2.4 Accuracy

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

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.

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.

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

When using towed models, the fittings used to link the towed model to the carriage should be such as to minimize the interferences of the fittings on the free movements of the model and to have the least possible influences on the measured values.

2.3 Model loading

Ballasting particulars should be developed for two loading conditions prior to testing, viz: maximum operational weight (as defined in the 2000 HSC Code), and minimum operational weight (comprising 10% payload, 10% fluids and stores, full crew and effects, and fluids in systems at normal working levels).

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 0.40 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 determined in calm water by a roll decrement test at rest in calm water.

3 ENVIRONMENTAL CONDITIONS

3.1 Waves

The model should be tested in waves with not less than two significant heights (H_S), corresponding to 100% and 70% of the worst intended conditions (as defined in the 2000 HSC Code).

Tests should be conducted in three narrow band Jonswap spectra corresponding to spectral peak periods T_P = 3.5, 4 and 5 times $(H_S)^{0.5}$ with a peak enhancement factor γ = 3.3, the zero crossing period not being greater than $\{T_P / (1.20 \text{ to } 1.28)\}$.

Where repeat runs are required, several different wave realization trains should be employed, not less than three in head and bow quartering seas, four in beam seas and five in following and stern quartering seas.

3.2 Wind

Wind should not be represented during the tests.

4 INSTRUMENTATION, CALIBRATION AND DATA RECORDING

4.1 Model instrumentation

The following model instrumentation should be provided as a minimum:

.1 one relative water level sensor on the stem of each hull;

.2 one relative water level sensor on each side and close to the centreline of each vehicle space close to the forward limit of that space (i.e. 3 sensors);

.3 one relative water level sensor on each side and close to the centreline of each vehicle space close to the aft limit of that space (i.e. 3 sensors); and

.4 relative water level sensors on each side and close to the centreline of each vehicle space at three intermediate locations between those described in .2 and .3 above (i.e. 9 sensors).

See also 5.4.4 for the positioning of these sensors.

Instrumentation to measure roll and pitch angles, and heave position may be deemed helpful.

If the testing is being conducted solely to demonstrate that water does not reach the bow loading opening, then all items except .1 above may be omitted.

As an alternative to the use of relative water level sensors described in .2 to .4 above, the volume of water accumulated during each test run (as part of testing for one test case) may be determined by direct weighing, provided that this water is restored to the vehicle space on the model before commencing the next test run.

4.2 Environmental instrumentation

The following instrumentation should be provided on the towing tank:

.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 (to be measured within ± 5%);

.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(s).

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 15 Hz.

Channels for the instrumentation listed in 4.1.1 to 4.1.4 and 4.2.1 to 4.2.3 should also be analysed to provide maximum, minimum, mean and RMS values of each parameter.

5 TEST PROCEDURE

5.1 Preparation

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.

The wave spectra should be run and verified for compliance with the repeatability limits required in 2.1.1.

5.2 Craft speed and operating mode

Where a craft normally operates in a non-displacement mode, tests should be conducted in both displacement and non-displacement modes. Where a non-displacement mode is tested, only the maximum designed amount of lift should be employed.

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.

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 programme

5.3.1 General

The test programme should be witnessed by a Contracting Government to the Convention (whenever known, this should be the Administration), surveyors nominated by them for the purpose or organizations recognized by them.

The following test programme should be conducted for each operating mode (i.e. displacement and non-displacement) and for each of the significant wave heights stipulated in 3.1 above.

Either of two approaches may be adopted to the test programme:

.1 direct physical testing on five headings relative to the wave direction, with 45° increments in heading, or seven headings relative to the wave direction, with 30° increments in heading; or

.2 direct physical testing at speed in head and following seas, and stationary in beam and bow and stern quartering seas, complemented by numerical simulations on five headings relative to the wave direction, with 45° increments in heading.

Where the latter approach is adopted, the numerical simulations should predict accumulated volumes of water at least 10% more than those determined from the equivalent physical model test cases.

5.3.2 Duration and repetition of test runs

Each tank run should be of the maximum practical duration, in any case not less than the equivalent of one minute at full scale. Each test case should comprise sufficient tank runs to represent not less than ten minutes of full scale operation, the bow opening shutter being opened and closed at the beginning and end of the test period of each run, in order that the maximum opportunity is given to establish a steady state volume of water on the vehicle deck(s).

Tank runs for each test case should be conducted in at least three separate wave realisation trains in head and bow quartering seas, four in beam seas and five separate wave realisation trains in following and stern quartering seas, each such train being taken from the required wave spectrum.

Numerical simulations should replicate the equivalent of the required physical test cases, and in addition model the roll decrement tests (both stationary and at speed) for verification against the model tests.

5.3.3 Head seas

As a minimum the following tests should be conducted:

.1 at a speed of approximately 65% of V_W and nominal LCG, tests in waves with three spectral peak periods to determine which period is the most critical;

.2 at a speed of approximately 65% of V_W and in the most critical wave spectrum, tests at the forward and aft LCGs to determine which is most critical;

.3 at the most critical LCG, tests at progressively increasing speed up to but not exceeding V_W; and

.4 tests in .3 to be repeated at the minimum operating weight.

5.3.4 Following seas

As a minimum the following tests should be conducted:

.1 at a speed of approximately V_W and nominal LCG, tests in waves with three spectral peak periods to determine which period is the most critical;

.2 at a speed of V_W and in the most critical wave spectrum, tests at the forward and aft LCGs to determine which is most critical;

.3 at the most critical LCG, tests at progressively decreasing speed down to but not less than 65% of V_W; and

.4 tests in .3 to be repeated at the minimum operating weight.

5.3.5 Other headings

Tests at other headings should be conducted similar to those described above except that:

.1 bow quartering sea tests according to 5.3.3.3 and 5.3.3.4 above should use the wave period and LCG deduced from 5.3.3.1 and 5.3.3.2;

.2 stern quartering sea tests according to 5.3.4.3 and 5.3.4.4 above should use the wave period and LCG deduced from 5.3.4.1 and 5.3.4.2; and

.3 beam sea tests according to 5.3.3.3 and 5.3.3.4 above should use an intermediate wave period and LCG deduced from 5.3.3.1 and 5.3.3.2 and 5.3.4.1 and 5.3.4.2.

5.4 Test results

5.4.1 General

These tests are required to determine the answers to three questions:

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

.2 whether the volume of water entering the vehicle decks reaches a steady state; and if so

.3 what volume of water would accumulate in that steady state.

5.4.2 Determination of whether water reaches the bow opening(s)

If, during the constant speed portion of ANY of the test runs required by these Interim Guidelines, water is observed or measured as having exceeded the lower edge of the bow opening(s), then the requirement of paragraph 2.2.3.2.2.1 of the 2000 HSC Code (objective 5.4.1.1) 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 HSC Code paragraph 2.2.3.2.2.2 (objectives 5.4.1.2 and 5.4.1.3).

5.4.3 Determination of whether water reaches a steady state volume

From physical model tests, the accumulated volume of water at the end of each test run may be determined by:

.1 direct measurement of the accumulated volume of water by collection into a recording receptacle, *OR*

.2 determination of the volume by calculation from measurements of relative water level within the vehicle space, using the method of 5.4.4 below.

If the method indicated in .1 above is adopted, the water measured should be returned to the model vehicle space before the commencement of the next test run for that test case.

A steady state volume should be deemed to have been reached if the volumes determined over the last four minutes (at full scale) of testing for each test case do not show a continuous increase and in addition do not vary by more than ± 5% from the mean value over that period.

In cases of doubt, a steady state volume should be assumed NOT to have been reached.

5.4.4 Calculation of volume of water accumulating on the vehicle deck(s)

Where the volume of water accumulated on the vehicle deck is determined from relative water height sensors, it should be calculated as follows. The mean height of water in any period of one minute (at full-scale) should be determined for the following fifteen sensor 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);

.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).

The mean heights of water measured at these locations should be scaled to full scale before calculating the steady state volume of water as follows (where the symbol h' denotes the water heights scaled as described above):

steady state volume of water (m^3)

$$= A_{VD}\,(h'_{FS} + h'_{FC} + h'_{FP} + 2h'_{FMS} + 2h'_{FMC} + 2h'_{FMP} + 2h'_{MS} + 2h'_{MC} + 2h'_{MP} + 2h'_{AMS} + 2h'_{AMC} + 2h'_{AMP} + h'_{AS} + h'_{AM} + h'_{AP}) / 24$$

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

5.4.5 Volume of water to be used in calculating residual stability

The volume of water to be used in calculating the stability properties for demonstrating compliance with paragraph 2.2.3.2.2.2 of the 2000 HSC Code should be that determined in accordance with 5.4.3.1 or 5.4.3.2 increased by the following amount to allow for modelling and/or measurement errors:

.1 for physical model tests: percentage increase = 0.3 λ%
where λ = the model scaling factor,
e.g. 30 for 1:30 scale;

.2 for numerical simulations: no additional margin, since 10% is already required by 5.3.1.

5.5 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 the rationale for the fore and aft limits for the position of the longitudinal centre of gravity;

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

.6 roll decrement tests;

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

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

.9 records for each run against a base of time (commencing from achieving model test speed) of encountered significant wave height and internal water volume measurements (where appropriate); and

.10 the determination of steady state accumulated water volume, without and with the necessary margin.
