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GUIDELINES FOR UNIFORM OPERATING LIMITATIONS OF HIGH-SPEED CRAFT

1 The Maritime Safety Committee, at its eighty-sixth session (27 May to 5 June 2009), recognizing that unrestricted operation is not suitable for high-speed craft and that, therefore, operating limitations are necessary, approved the Guidelines for uniform operating limitations of high-speed craft, prepared by the Sub-Committee on Ship Design and Equipment at its fifty-second session, as set out in the annex.

2 Member Governments are invited to utilize the annexed Guidelines when applying the Permit to Operate High-Speed Craft provisions of the 2000 HSC Code and to bring them to the attention of all parties concerned.

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ANNEX

GUIDELINES FOR UNIFORM OPERATING LIMITATIONS OF HIGH-SPEED CRAFT

1 INTRODUCTION

1.1 An explicit element of the Code of Safety for High-Speed Craft, 2000 (2000 HSC Code – “the Code”) is that unrestricted operation is not suitable for high-speed craft and that operating limitations are necessary. In this regard, attention is drawn to paragraphs 1.2, 1.3.4 and 1.4.61 of the Code.

1.2 These Guidelines for uniform operating limitations of high-speed craft have been prepared to assist in the uniform implementation of the Code as amended in 2007, in particular paragraph 1.9.7 and annex 12, and to provide information on the rationale underpinning such operating limitations.

1.3 It should be noted that the factors listed in annex 12 of the Code are prefaced by the words “as a minimum” and may, where appropriate, be supplemented by other factors where the flag and/or port State Administrations are of the view that those additional factors are applicable to the satisfactory operations of the craft under the Permit to Operate.

1.4 Matters determining the operating limitations set out in the craft’s Permit to Operate, as outlined in these Guidelines, may relate to one or more of the following three sectors:

.1 those affecting the safety of the craft as a whole;

.2 those specifically affecting the safety of the passengers and crew as individuals; and

.3 those affecting the safety of persons outside the craft.

1.5 The operating limitations established under these Guidelines should relate to the craft’s normal operations. For example, if an automatic ride control system is normally used in conditions approaching the *worst operating conditions*, then that system should be assumed operational for the establishment of the operating limitations but should also be included in the FMEA analysis specified in the Code.

1.6 Any operating limitations resulting from consideration of all the relevant factors outlined in the following sections of these Guidelines should define the permitted operational envelope for the craft. Those limitations should be described in clear but succinct terms on the Permit to Operate and the Craft Operating Manual and clearly communicated to the craft’s operating personnel.

2 MAXIMUM DISTANCE FROM REFUGE

2.1 Paragraph 1.3.4 of the Code gives time limits for passenger craft (4 hours) and cargo craft (8 hours) for the passage to a *place of refuge* (defined in paragraph 1.4.48 of the Code) when proceeding at 90% of *maximum speed* (as defined in paragraph 1.4.38 of the Code). This is to allow the craft to operate solely in areas where the necessary shore-based support is available and to safely retire to shelter in the event of changes in the weather and sea state.

2.2 This limitation is generally set by the referenced provisions of the Code, but should be clearly stated in the craft's documentation and shown on the Permit to Operate unless covered indirectly (e.g., by coordinates of boundaries of the operational area).

2.3 The maximum distance from base port or place of refuge should be established in accordance with paragraph 18.1.4 of the Code, taking account of the relevant limits specified in paragraph 1.3.4 of the Code.

3 AVAILABLE RESCUE AND OPERATIONAL SUPPORT RESOURCES

3.1 In some cases, the operating limitations are functions of the resources available on the route, rather than the craft's limitations. Specifically, the Code is predicated on adequate communications facilities, weather forecasts and maintenance facilities being available within the area of craft operation. Taken in conjunction with the requirement for proximity to place of refuge, the weather forecast requirement is intended to facilitate timely decision-making with regard to seeking refuge.

3.2 In setting the operating limitations, Administrations should consider whether the wave height corresponding to the w*orst intended conditions* should be such as to permit the craft to complete its passage without relying on a drastic reduction in speed, thus increasing the exposure of the passengers and crew to progressively more severe conditions. Such consideration relates to the craft being considered its own best survival craft in deteriorating conditions.

3.3 Paragraph 1.2.7 of the Code states: "*in the intended area of operation, suitable rescue facilities will be readily available*". Further, paragraph 1.4.12.1 states that a category A high-speed craft is one "*operating on a route where it has been demonstrated to the satisfaction of the flag and port States that there is a high probability that in the event of an evacuation at any point of the route all passengers and crew can be rescued safely within the least of:*

- *the time to prevent persons in survival craft from exposure causing hypothermia in the worst intended conditions,*

- *the time appropriate with respect to environmental conditions and geographical features of the route, or*

- *4 hours*".

3.4 The words "a high probability" in this text should be taken to mean that the probability of an evacuation **not** being successful is "remote" as defined in annex 3 of the Code.

3.5 Although the Code gives no guidance on what constitutes "suitable rescue facilities", the Permit to Operate should only be issued where the flag and relevant coastal State Administrations are satisfied that appropriate measures have been implemented and an appropriate assessment made that demonstrates to their satisfaction that the Code's requirements are met across the operational area in accordance with paragraph 18.2.2.4 of the Code. For this purpose Administrations may require the application for the Permit to Operate to be accompanied by an analysis of shipping traffic and other resources likely to be available in the operating area in the event that the craft evacuates and rescue is required. Assessment of suitable rescue facilities through trial evacuation or rescue exercise may be highly beneficial in identifying gaps and weaknesses and in improving overall performance in preparation for an actual rescue, but should not normally be required.

3.6 Appropriate consideration should be given to the seasonal availability of resources. For example, presence of ice due to seasonal variation may render a specified place of refuge unusable due to navigational safety considerations.

4 WIND FORCE, MINIMUM AIR TEMPERATURE, VISIBILITY AND DEPTH OF WATER

4.1 Paragraph 1.4.61 of the Code, in defining the *worst intended conditions*, makes specific reference to the following parameters, which should therefore appear on the Permit to Operate, when appropriate:

.1 significant wave height (refer to section 5 of these Guidelines);

.2 wind force (refer to chapter 2, paragraph 1.1.4 of annex 6, paragraphs 1.3 and 2.2 of annex 7 and paragraphs 1.1 and 2.1.4.3 of annex 8 of the Code. For example, in worst intended conditions the maximum wind pressure should not exceed that used in the craft's stability calculations, nor should it create aerodynamic lift beyond that associated with the craft's normal operating attitude);

.3 minimum air temperature (reference for example brittle fracture properties of materials, susceptibility to icing and resulting effect on stability, etc.);

.4 visibility (e.g., conditions of impaired vision and night navigation may necessitate improved navigation equipment or night vision equipment); and

.5 minimum safe water depth (e.g., safe navigation, bottom scouring, adverse effects on seabed flora and fauna, wash waves (see paragraph 7.2 below).

4.2 The matters outlined in the preceding paragraph are intended to only comprise an illustrative and non-exhaustive list. They may be supplemented by Administrations to include, for example, the effect of sea ice on the craft's structure, propellers, rudders and sea intakes and its ability to navigate safely and reach a place of refuge.

5 SEA STATE LIMITATIONS – SIGNIFICANT WAVE HEIGHT

5.1 General

5.1.1 The *worst intended* sea *conditions* are usually set in terms of a *significant wave height* value as defined in paragraph 1.4.54 of the Code. These Guidelines have been prepared on the assumption that this parameter is used but the underlying principles are still applicable if another parameter is used. In applying the Guidelines, it should be noted that craft motions are dependent upon wave period as well as significant wave height.

5.1.2 For operational purposes, significant wave height is most reliably measured either by satellite or by a system providing real-time monitoring of the height between the sea surface and a point on the craft in conjunction with gyroscopic measurement of accelerations at that point. Alternatively, significant wave height readings could be provided by transmitting-type wave measurement buoys located along the route. In the absence of such systems, visual observations of significant wave height will be necessary, for which the guidance provided in appendix 1 may be used.

5.1.3 Sea state limitations applicable to a craft may vary according to the craft's course relative to waves, but for each course should not be greater than the lowest sea state derived from taking account of the factors listed in the remainder of this section.

5.2 Damage stability

In paragraph 2.6.11 of the Code, the required minimum residual freeboard to downflooding is a function of the significant wave height corresponding to the w*orst intended conditions.*

5.3 Structural safety

5.3.1 It is clearly vital to the structural integrity of a high-speed craft that the craft is not operated outside the limitations to which the structure has been designed.

5.3.2 In this regard, and bearing in mind the equivalence of safety standards of craft covered by the Code with those of SOLAS in accordance with SOLAS chapter X, it should be noted that SOLAS regulation II-1/3-1 requires that:

> "*… ships shall be designed, constructed and maintained in compliance with the structural, mechanical and electrical requirements of a classification society which is recognized by the Administration in accordance with the provisions of regulation XI-1/1, or with applicable national standards of the Administration which provide an equivalent level of safety*".

5.3.3 Some classification society rules base their structural loadings on a limiting vertical acceleration at the longitudinal centre of gravity. In order to avoid exceeding this structural limitation, the societies may issue the craft with a diagram developed from this assumption, which relates the maximum permitted speed of the craft to the prevailing significant wave height. Refer to paragraph 8.2 of these Guidelines in relation to presentation of the resulting operating limitations, which may be determined by other factors in accordance with paragraph 1.6.

5.3.4 Sometimes speed reduction in waves may be involuntary, due to increased resistance. But deliberate speed reduction is generally necessary in order to stay within safe limits in high sea states.

5.4 Dynamic stability

5.4.1 Safe operation of most high-speed craft is significantly affected by the sea state. Safe seakeeping limitations may be as a result of some of the examples listed in paragraphs 2.1.5 and 17.5.4.1 of the Code, including most particularly: propensity to deck diving or broaching; incidence of hull or wet-deck slamming; plough-in, yawing and turning. Refer to the guidance information in appendix 2 in relation to operations in following and quartering seas.

5.4.2 Implied but not explicit these limitations should also include excessively violent motions affecting the passengers and crew (see also section 5.6 of these Guidelines).

5.4.3 Paragraph 18.1.3.2 of the Code requires that the Administration be satisfied that the operating conditions on the intended route are within the capabilities of the craft. This should be verified during the trials conducted in accordance with annex 9 and invoked by paragraph 17.2.1 of the Code.

5.4.4 Administrations should note that paragraph 3.1.2 of annex 9 of the Code explicitly states that "*worst intended conditions, referred to in 1.4.57 of this Code, are those in which it shall be possible to maintain safe cruise without exceptional piloting skill. However, operations at all headings relative to the wind and sea may not be possible*". This provision should be taken into account when setting operating limitations in relation to dynamic stability.

5.5 Safe deployment of evacuation systems and survival craft

5.5.1 The Code places great emphasis on the ability to evacuate a high-speed craft quickly and safely, the maximum evacuation time being linked (in paragraph 4.8.1) to the structural fire protection time. To this end, paragraph 8.6.5 of the Code requires that: "*Survival craft shall be capable of being launched and then boarded ... in all operational conditions and also in all conditions of flooding ...*".

5.5.2 "All operational conditions" includes all intact loading conditions without reference to environmental conditions. "All conditions of flooding" was included to take account of the need to provide for evacuation of the craft under the damage conditions defined in chapter 2 of the Code.

5.5.3 Where the craft is to be evacuated by MES complying with the requirements of the Code, the Code assumes that the environmental conditions required for the heavy weather sea trial (in accordance with paragraph 12.6 of the Revised recommendation on testing of life-saving appliances (resolution MSC.81(70) as amended) provide an assurance of operability of the MES in heavy weather. Experience has shown that heavy weather sea trials in more severe conditions than those specified for type approval of MES involve substantial physical danger for the personnel involved.

5.5.4 Where the craft is to be evacuated directly into survival craft in accordance with paragraph 8.7.5 of the Code without the use of MES, Administrations may require evacuation trials on the craft or an identical sister high-speed craft to be conducted in weather and sea conditions up to the *worst intended conditions* specified in the Permit to Operate, in order to assure itself that such evacuation can be carried out safely in such conditions.

5.6 Safe handling limitations

5.6.1 The Code makes reference to three safety levels (see table 1 in annex 3) and prescribes the acceptable probability that each safety level may occur. Level 1 is expected to have a probability of occurrence of greater than 10^{-5}, i.e. frequent or reasonably probable. Table 1 in annex 3 reveals that for Safety Level 1 (minor effect) it only prescribes that horizontal accelerations should not exceed 0.2 g.

5.6.2 In applying these standards it should be noted that paragraph 4.3.1 of the Code advises that superimposed vertical accelerations exceeding 1 g at the longitudinal centre of gravity should be avoided "unless special precautions are taken with respect to passenger safety". For vertical accelerations exceeding 1 g then hazards for safe seating of passengers and crew will ensue.

5.6.3 Similarly, table 1 in annex 3 of the Code stipulates acceptable maximum horizontal accelerations for severe and extreme operating conditions.

5.6.4 Table 2 in annex 3 of the Code makes it clear that Safety Level 2 relates to conditions when emergency procedures are required and passengers may be injured, and Level 3 to conditions when there is a large reduction in safety margins, and serious injury to a small number of occupants may occur.

5.6.5 The upper limit of Level 2 corresponds to the *worst intended conditions* – see paragraph 3.3.2 of annex 9 of the Code. Passengers must be seated before the onset of Level 2 in accordance with the Code provisions in paragraph 4.2.4 and annex 9, paragraph 3.3.2.

5.6.6 Many forms of high-speed craft may have safe handling limitations as suggested in paragraph 17.5.4.1 of the Code, for example:

.1 Amphibious hovercraft may have to avoid certain speed and drift angle combinations in order that plough-in or skirt tuck-under and possible capsizing do not occur.

.2 Many forms of high-speed craft may have to avoid excessive bow-down trim in order to preserve safe manoeuvring behaviour, such as avoidance of bow-diving or broaching (see paragraph 17.2.1 of the Code).

.3 Guidance in this safe handling may be obtained from appendix 2 and the Revised Guidance to the master for avoiding dangerous situations in adverse weather and sea conditions (MSC.1/Circ.1228), as appropriate, bearing in mind that the latter document is largely addressed to conventional ships.

5.6.7 Chapter 17 of the Code requires full-scale testing to determine operating limitations and procedures for operation of the craft within limitations. Annex 9 defines the test procedures needed to develop these operational limits. In particular section 3 of annex 9 and table 1 of annex 3 define the horizontal and vertical acceleration levels which must not be exceeded to ensure passenger safety. Under normal operation conditions, craft must not exceed Safety Level 1 (0.2 g in horizontal plane) at maximum operating speed as per paragraph 3.3 of annex 9 of the Code. In worst intended conditions, craft should not exceed Safety Level 2 (0.35 g in horizontal plane). Vertical acceleration measurements are also required by annex 9, and these limits are driven by structural limitations for which craft must not exceed the limiting vertical acceleration at the longitudinal centre of gravity as per paragraph 4.3.1 of the Code and paragraph 5.3.3 of these Guidelines. The above limits, trial results, and the significant wave height to speed table inform the process of defining operational limits. It should be noted that paragraph 17.4 of the Code requires the trials conducted under annex 9 to include verification of the effects of failure(s) identified as being critical.

5.6.8 Although paragraph 17.1 of the Code makes provision for use of data from model tests where appropriate, wherever practicable use of such data should be confirmed by suitable trials of the craft or an identical craft. Model tests should be used to evaluate safe limits in situations that would be hazardous to investigate during sea trials. For these purposes, model tests should be taken to include mathematical modelling as well as testing of a physical model.

5.6.9 The references to vertical accelerations in paragraph 4.3.1 and table 1 of annex 3 of the Code should be interpreted as referring to the mean of the $1/100^{th}$ highest accelerations (not RMS), which should be measured using the criteria of footnote 1 to table 1 of annex 3.

6 TRIALS DEMONSTRATING PERFORMANCE IN RELATION TO OPERATING LIMITATIONS

6.1 The *worst intended conditions* of wind and sea may not be available for the conduct of the verification trials required by chapter 17 of the Code, in which case some extrapolation of satisfactory trial results may be necessary. Any extrapolation should take account of the non-linear nature of seakeeping behaviour and of variation in wave period (frequency) and height (amplitude). In such cases, the *worst intended conditions* specified on the craft's Permit to Operate should not be more than 130% of the significant wave height in which the verification trials were conducted. Extrapolation of wave period should be conducted separately from wave height. Where satisfactory trials have been completed on a craft, those trials are not required on subsequent identical sister craft, provided the operational envelope of wave height and wave period is not significantly changed. Any extrapolation based on trial results of another closely similar design of similar size (length and breadth both within 5% of that of the craft in question) should be verified through trials of the new craft. Extrapolation is not applicable to trials conducted under section 5.5 of these Guidelines.

6.2 In order that extrapolation of wave height may be conducted in a consistent manner, a minimum wave period should be associated with each significant wave height used to establish the *worst intended conditions*.

7 NAVIGATIONAL MATTERS

7.1 Casualties to high-speed craft have illustrated that there are number of navigational circumstances that need to be taken into account when establishing the operating limitations under the Permit to Operate. These include:

.1 adequacy of fixed aids to navigation on the route;

.2 night vision with regard to unlit obstacles; and

.3 other restricted visibility.

7.2 Administrations should note that paragraph 3.1.2 of annex 9 of the Code explicitly states that "*worst intended conditions, referred to in 1.4.57 of this Code, are those in which it shall be possible to maintain safe cruise without exceptional piloting skill. However, operations at all headings relative to the wind and sea may not be possible*". This provision can be taken into account by Administrations when setting operating limitations in relation to the craft's course-keeping and ability to follow alternative courses in worsening weather and sea conditions.

7.3 Minimum safe water depth may relate to local environmental regulations or hazards to other craft, persons and property in the operational area in addition to navigational safety. For example, Administrations may require investigation of wash waves generated by the craft that are hazardous to nearby small craft and persons on the shoreline, investigation of environmental hazards due to erosion, and any restrictions on craft speed on the specific route in relation to water depth[*] in order to avoid these hazards should be stipulated in the Permit to Operate.

[*] For wake wash waves this is based on depth Froude Number but is also dependent on the depth profile adjacent to the shore.

7.4 Where a route is considered to be especially vulnerable to grounding or stranding, Administrations may require a risk assessment of these hazards, considering the applicability of, for example:

.1 minimum safety margins around particular hazards on the route;

.2 reduced speed during critical sections of the route; or

.3 requiring two navigators in the operating compartment during critical sections of the route.

8 PRESENTATION OF OPERATING LIMITATIONS

8.1 All operating limitations shown on the Permit to Operate, irrespective of whether they relate, for example, to geographical boundaries or limits of wind, weather and sea conditions, should be presented in a manner that provides simple and clear direction to the craft's personnel and should be immediately available to the operator in the operating compartment. Wherever practicable, the information should be posted in a prominent position in the operating compartment readily visible from the operator's position(s). Supplementary and more detailed information may be provided in the Craft Operating Manual or Route Operational Manual, as appropriate.

8.2 The presented information should not extend beyond the limits of permitted operations unless clearly labelled with the purpose of the extended information. Where additional information is provided, for example to place the boundaries of the operating area in geographic context, the presentation should be such as to clearly indicate that operations outside those boundaries are not permitted.

8.3 Limitations with regard to significant wave height, if varied according to heading, may be presented in a number of forms, including:

.1 polar diagram showing safely attainable speed versus wave height and relative heading, since the safe speed in head seas will often be less than that attainable on other headings (see figure 1); or

.2 graph(s) having different lines for heading angles from head through to stern at intervals of not more than 15º (see figure 2).

8.4 Permanently installed instruments may be provided to guide the craft's personnel in maintaining safe operating conditions, particularly in respect of structural safety, through direct onboard monitoring of vertical and lateral accelerations and/or measurement of wave height. Where the operational limitations include limiting sea conditions covering hazards other than those covered by the instrumentation, the specified limiting sea conditions should not be exceeded irrespective of the guidance information provided by the instrumentation system. The instrumentation should:

.1 be calibrated and verified by, or on behalf of, the flag Administration as providing clear, accurate and reliable information to operating personnel for the safe operation of the craft in accordance with paragraph 4.2.4 of the Code;

.2 meet the requirements of paragraph 17.1 of the Code for the conduct of verification trials;

.3 be supplemented by sea state limitations that are to be adhered to in the event of failure of the instrumentation; and

.4 trials required by annex 9 of the Code in relation to areas monitored by the instrumentation should be limited to those necessary under subparagraph .1 above for verification of the instrumentation system.

8.5 Where the information provided in accordance with paragraph 8.1 is not consolidated so as to cover all hazard areas in a single display or document, its presentation should unambiguously facilitate simultaneous compliance with **all** operational limitations listed on the Permit to Operate, addressing as appropriate all the hazards associated with the safe operation of the craft such as those covered in all the preceding sections of these Guidelines.

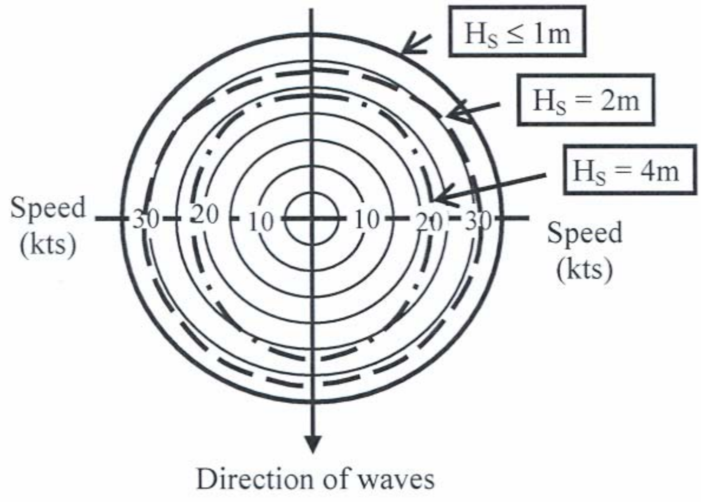

Figure 1

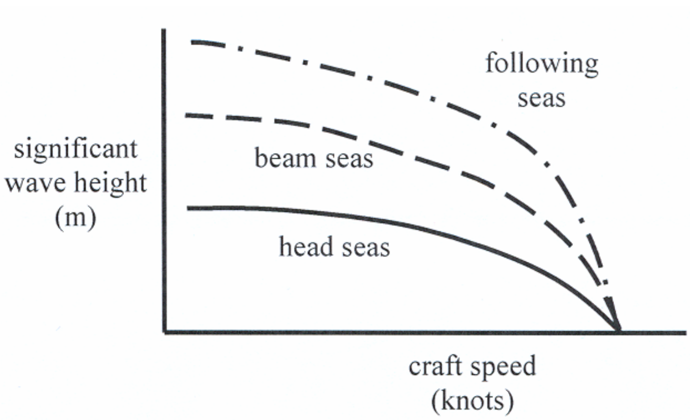

Figure 2

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APPENDIX 1

VISUAL ESTIMATION OF SIGNIFICANT WAVE HEIGHT*

1 A typical record of wave traces is shown in figure 1 below.

2 The record is, in general, complex and shows immediately all the difficulties inherent in eye observation. For example, are all the waves to be considered on an equal footing or are only the big waves to be counted? Since the wave characteristics vary so much, what average values shall be taken? It is obvious that if comparable results are to be obtained the observer must follow a definite procedure. The flat and badly formed waves ("A" in figure 1) between the wave groups cannot be observed accurately by eye and different observers would undoubtedly get different results if an attempt were made to include them in the record. The method to be adopted, therefore, is to observe only the well-formed waves in the centre of the wave groups. The observation of waves entails the measurement or estimation of the following characteristics:

Direction Period Height

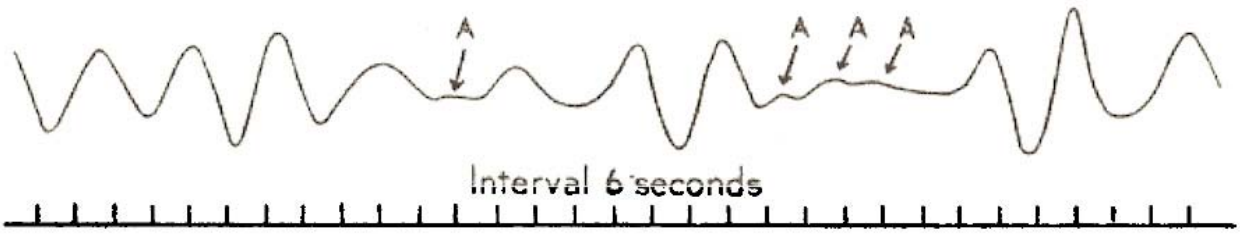

Figure 1 – Wave form of the sea surface

3 Reliable average values of period and height can only be obtained by observing at least twenty waves. Of course, these cannot be consecutive; a few should be selected from each succeeding wave group until the required number has been obtained. Only measurements or quite good estimates are required. Rough guesses have little value and should not be recorded. It will often be found that there are waves coming from more than one direction. For example, there may be a sea caused by the wind then blowing and a swell caused by a wind that has either passed over or is blowing in a distant area. Or there may be two swells (i.e. cross swells) caused by winds blowing from different directions in distant areas. In such cases, the observer should distinguish between sea and swell, and report them separately, giving two groups for swell when appropriate. The direction, height and period of the sea wave may be quite different from that of the swell wave. It will, however, often happen – particularly with winds of Beaufort force 8 and above – that the sea and swell waves are both coming from the same direction. In that case, it is virtually impossible to differentiate between sea and swell, and the best answer is to look upon the combined wave as being a sea wave and log it accordingly.

* Reproduced from Meteorological Office (UK), *The Marine Observers Handbook*, Her Majesty's Stationery Office, London, 1969.

Observing waves from a moving ship

4 Care should be taken to ensure that the observations, especially those of period, are not influenced by the waves generated by the motion of the ship.

4.1 DIRECTION FROM WHICH THE WAVES COME. This is easily obtained either by sighting directly across the wave front or by sighting along the crests of the waves and remembering that the required direction differs from this by 90º. Direction is always recorded true, not magnetic.

4.2 PERIOD*. For measurements of period, a stopwatch is desirable. If this is not available, an ordinary watch with a seconds hand may be used or, alternatively, a practised observer may count seconds. The observer selects a distinctive patch of foam or a small object floating on the water at some distance from the ship, and notes the time at which it is on the crest of each successive wave. The procedure is repeated for the larger waves of each successive group until at least twenty observations are available. The period is then taken as the average time for a complete oscillation from crest to crest. In a fast ship it will be found that the "patch of foam" method will rarely last for more than one complete oscillation and that many waves should be observed separately. With practice, suitable waves can easily be picked out and the timing from crest to crest becomes quite simple. When it is desired to use an object (an empty beer can is usually conspicuous against the sea and will remain afloat long enough to serve its purpose) it should be thrown as far forward as possible. Another method available to the observer with a stopwatch is to observe two or more consecutive "central" waves of a wave group while the watch is running continuously, then to stop the watch until the central waves of the next wave group appear, the watch being then restarted. This procedure is repeated until at least twenty complete oscillations have been observed. The period is then obtained by dividing the total time by the number of oscillations. It is important to note that the periods between times of crests passing a point on the ship are not the ones required.

4.3 HEIGHT. Although wave-recorders are fitted to a few research ships, there is at present no method of measuring the height of waves suitable for general use on merchant ships, but a practised observer can make useful estimates. The procedure to be adopted depends on the length of the waves relative to the length of the ship. If the length of the waves is short in comparison with the ship's length, i.e. if the ship spans two or more wave crests, the height should be estimated from the appearance of the waves at or on the side of the ship, at times when the pitching and rolling of the ship is least. For the best result, the observer should take up a position as low down the ship as possible, preferably amidships where the effect of pitching is least, and on the side of the ship towards which the waves are coming.

4.3.1 This method fails when the length of the waves exceeds the length of the ship, for then the ship rises bodily with the passage of each wave crest. The observer should then take up a position in the ship so that his eye is just in line with the advancing wave crest and the horizon, when the ship is vertical in the trough. The height of eye above the ship's waterline is then the height of the wave. The nearer the observer is to an amidships position, the less chance will there be of the measurement being vitiated by pitching. If the ship rolls heavily, it is particularly important to make the observation at the moment when she is upright in the trough.

* There are several different definitions of wave period, such as modal period, zero up-crossing period, etc. The visual observation of wave period does not necessarily represent the necessary wave periods required for numerical processing, and corrections should be made as appropriate.

Exaggeration of estimates of wave height is mostly due to errors caused by rolling (see figures 2.1 and 2.2). When the ship is rolling (figure 2.2), the observer at "0" should take up a higher position to get a line on the horizon than when she is upright (figure 2.1).

Figure 2.1

Figure 2.2

4.3.2 The observation of height of waves is most difficult when the length of the waves exceeds the length of the ship and their height is small. The best estimate of height can be obtained by going as near the water as possible, but even then the observation can only be rough. In making height estimates an attempt should be made to fix a standard of height in terms of the height of a man or the height of a bulwark, forecastle or well-known dimension in the ship. There is generally a tendency to overestimate the height of short waves and underestimate the height of long waves.

4.3.3 Estimating the height of a wave from a high bridge in a fast ship is a difficult job and much will depend on the skill and ingenuity of the observer; in many cases all one can hope for is a very rough estimate. All estimates of wave height should be made preferably with the ship on an even keel so that the observer's height of eye is consistent. The inherent difficulties already mentioned, together with the practical difficulties of estimation, make it essential that the recorded height be the average value of about twenty distinct observations. These observations should be made on the central waves of the more prominent wave groups.

Wave observations at night or in low visibility

5 Under these conditions, the most that the observer can normally hope to record is direction and an estimate of height, or perhaps direction only, which would at least indicate the presence of waves. Such observations might be of considerable value in tropical waters in the hurricane season. It is only on very bright nights that the observation of period would be practicable.

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APPENDIX 2

GUIDANCE FOR OPERATION OF HIGH-SPEED CRAFT IN FOLLOWING AND STERN-QUARTERING SEAS

1 GENERAL

1.1 This note has, as its primary aim, the provision of advice to mariners on what to expect and how to handle a high-speed craft in severe following and stern-quartering seas. The guidance offered here is based, not only on the recent research, but also on the accumulated experience of practising mariners.

1.2 The principal hazards likely to be experienced by a high-speed craft in severe following or stern-quartering seas are surfing, bow-diving and broaching.

1.3 The master will be in a better position to avoid dynamic problems if he has instruments that inform of the behaviour of his vessel and information on the sea states he is likely to encounter on the voyage. These parameters include vessel speed, heading, vertical acceleration, longitudinal acceleration, wave forecasts and current sea state.

1.4 Following seas refer to seas which are dead astern while stern-quartering seas refer to wave directions between dead astern and 45^{o} from dead astern.

1.5 Bar crossings may involve behaviours similar to a number of those outlined in this appendix. As this guidance is of a general nature, it does not include specific information on bar crossing for which the hazards and behaviours are highly variable according to the individual circumstances. Specific information in this regard in relation to the craft and its route should be provided in the Route Operational Manual.

1.6 It should be noted that the advice given in this note is for guidance only and should augment and not replace the skill and judgement of the mariner, or the tenets of good seamanship.

2 CRITICAL BEHAVIOUR IN FOLLOWING AND STERN-QUARTERING SEAS

2.1 Trapping

2.1.1 Trapping can occur when the craft is moving directly down-wave in waves whose length is roughly equal to the waterline length of the vessel. When cresting one wave, the craft will experience a reduction in resistance, which will cause it to accelerate into the trough ahead and immerse its fore-body in the next wave. If this does not result in a bow dive, the craft will experience a significant increase in resistance that will slow it down to the speed of the waves. It can be the precursor to a bow-dive.

2.1.2 ***Warning signs:***

.1 moving at the speed of the wave, see table 1; **and**
.2 one wave crest at the stern and another at the bow; **and**
.3 wave height greater than 4% craft waterline length;
.4 craft becomes trapped between two successive crests.

2.1.3 ***Corrective action:***

.1 slow down and allow the waves to draw ahead.

2.2 Surging and surfing

2.2.1 When a high-speed craft is moving in following seas which are directly astern and where the wave length is about the same as or greater than the vessel length, it may accelerate and decelerate in surge as the crests pass. Such surge velocities may differ by as much as 50% of the average speed and are caused by significant changes in resistance and propulsive efficiency as the waves pass. Without warning the craft may accelerate rapidly to the speed of the wave and surf. Surfing is best avoided if at all possible because of the almost total loss of control that occurs while it is in progress. Surfing can be the precursor to a bow-dive, or a broach.

2.2.2 ***Warning signs:***

.1 large variations in craft speed at constant throttle;
.2 craft is moving at wave speed plus or minus 10% ($^1/_{10}$th), see table 1; **and**
.3 the wave length is between 1 to 2.5 times craft waterline length; **and**
.4 the craft has a slight bow-down pitch attitude, with a wave crest abaft amidships;
.5 response to steering controls is poor;
.6 breaking waves increase the tendency to surf.

2.2.3 ***Corrective action:***

.1 avoid running at wave speed (see table 1) in waves of dangerous length;
.2 if caught in a surf wait until the critical wave has passed without attempting any major helm action;
.3 afterwards, slow down.

2.3 Bow-diving

2.3.1 Bow-diving occurs when a high-speed craft buries its bow into a wave in following or stern-quartering seas. This causes all way to be lost, the vessel experiences a severe bow-down pitch and the bow becomes submerged, sometimes resulting in structural damage and injury to personnel. It is particularly severe for vessels such as catamarans with a cross deck and limited residual buoyancy forward. It is different to bow immersion in head seas as the wave behind lifts the stern and worsens the situation.

Bow-diving may have a slow onset if moving at wave speed, but may be dramatic without warning if craft is moving substantially faster than the waves.

2.3.2 ***Warning signs:***

.1 If preceded by trapping (see 2.1 above):

  .1 as for trapping; **and**
  .2 wave height greater than about 75% ($^3/_4$) of bow freeboard when stopped; **and**
  .3 waves from between directly astern and the quarter;
  .4 bow almost immersed to the deck or top of cross-structure.

.2 If craft is moving faster than the waves and:

.1 waves from between directly astern and the stern quarter; **and**
.2 wave height greater than 25% ($^1/_4$) of bow freeboard when stopped; **and**
.3 wave length 100% to 150% of the waterline length of the craft.

2.3.3 ***Corrective action:***

.1 avoidance by attention to the warning signs;
.2 avoiding any trim by the bow;
.3 slow down to less than about 70% of wave speed;
.4 alternatively, if practicable, change course, even to head seas.

2.4 Broaching

2.4.1 Broaching is a severe, and often uncontrollable, yawing movement in following seas which turns the vessel beam on to the waves resulting in a dangerously heavy roll, and a sideways sliding motion down-sea. In monohulls with insufficient stability it can result in capsize. It may be preceded by surfing.

2.4.2 ***Warning signs:***

.1 desired course slightly or appreciably across the waves, up to 45° from directly down-sea;
.2 wave length similar to craft waterline length, or slightly shorter in quartering seas; **and**

.3 craft speed similar to wave speed plus or minus 15% ($^1/_7$th), see table 1; **and**
.4 wave height greater than 4% craft waterline length; **and**
.5 bow-down attitude and bow burying into wave ahead;
.6 up-sea waterjets or propellers beginning to ventilate;
.7 severe yaw motions either side of intended course;
.8 surfing.

2.4.3 ***Corrective action:***

.1 avoid a diagonal course across the waves, i.e. up to 45° from directly down-sea;
.2 avoid running close to wave speed (see table 1) in waves of dangerous length;
.3 reduce speed to less than about 70% of wave speed;
.4 after a broach, directional control is best reasserted by reducing speed.

3 OTHER BEHAVIOUR WHICH MAY OCCUR

Masters should also be aware of the other types of behaviour that may occur, *viz*:

.1 loss of transverse stability due to loss of waterplane area when poised on a wave;
.2 slamming, which can occur with high-speed craft in following seas if their speed is at least twice the speed of the waves;
.3 synchronous rolling, which occurs in stern-quartering seas when the period of the transverse components of the waves coincides with the natural roll period of the craft;

.4 parametric rolling, which can occur in following seas if the length of time each wave takes to pass the craft is approximately equal to half the natural roll period;

.5 combinations of behaviour, such as surfing which can lead to a broach or a bow-dive; both of which can lead to further severe events such as fore-deck immersion or capsize.

4 SUMMARY

4.1 Craft speed

4.1.1 It is important that speed should be appropriate for the sea conditions. In a following or stern-quartering seas, it is comparatively easy to determine whether the craft is moving faster or slower than the dominant waves in daylight. At night-time, however, such assessments are not so easy.

4.1.2 Craft speed, it is assumed, will be known with some accuracy. If not, then, when moving at or near the dominant wave speed (and possibly trapped or in danger of surfing), pitch and heave motions will be considerably reduced, but surge motions will be significantly increased.

4.1.3 A rough idea of the speed of the dominant waves in a given sea state can be obtained from table 1, according to the type of waters in which the craft is operating.

Table 1 – Tabulated typical wave speeds (knots)

Significant wave height (m)	**1**	**2**	**3**	**4**	**5**	**6**
Coastal waves (knots)	15 - 18	17 - 23	19 - 27	20 - 30	21 - 33	23 - 35
Ocean waves (knots)	19 - 29	21 - 31	25 - 35	29 - 39	32 - 42	36 - 46

4.2 Wave length

It can be seen from the advice given above that wave length in relation to the waterline length of the craft is also important in assessing the vulnerability to adverse behaviour. It is therefore important to monitor the length of the waves in which the craft is being operated.

4.3 Tabular summary

Table 2 summarizes the guidance given in this note.

Table 2 – Summary of guidance in following and quartering seas

Behaviour	Critical craft speed		Critical wave length		Critical wave heights
Trapping	≈ V_W	and	≈ L_S	and	> 4% L_S
Surfing	≈ V_W ±10%	and	≈ 1→2.5 L_S	and	> 4% L_S
Bow-diving (slow)	≈ V_W	and	≈ L_S	and	>75% F
Bow-diving (sudden)	> V_W	and	≈ 1→1.5 L_S	and	> 25% F
Broaching	≈ V_W ±15%	and	≈ L_S	and	> 4% L_S

***Key*:**
≈ is approximately equal
± is plus or minus
> is greater than
V_W is wave speed
L_S is ship length
F is bow freeboard when stopped

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