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GUIDANCE TO THE MASTER FOR AVOIDING DANGEROUS SITUATIONS IN FOLLOWING AND QUARTERING SEAS

1 The Maritime Safety Committee, at its sixty-fifth session (9 to 17 May 1995), approved the annexed Guidance to the master for avoiding dangerous situations in following and quartering seas, with a view to providing masters with a basis for decision making on ship handling in following and quartering seas, thus assisting them to avoid dangerous phenomena that they may encounter in such circumstances.

2 Member Governments are invited to bring the Guidance to the attention of shipmasters and other interested parties of the shipping industry as they deem appropriate.

3 The Maritime Safety Committee has decided to review the Guidance in the future with a view to improving it, in particular with respect to large ships, on the basis of new technical developments and in the light of experience gained from its application.

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ANNEX

GUIDANCE TO THE MASTER FOR AVOIDING DANGEROUS SITUATIONS IN FOLLOWING AND QUARTERING SEAS

1 GENERAL

1.1 When sailing in severe following or quartering seas, a ship is likely to encounter various kinds of dangerous phenomena, which may lead to capsizing. Although the dynamic behaviour in following and quartering seas is not yet covered in present stability standards, much progress has been made in recent years towards understanding the physics of capsize mechanisms and identifying potentially critical conditions.

1.2 The sensitivity of a ship to dangerous phenomena will depend on the actual stability parameters, hull geometry, ship size and ship speed. This implies that the vulnerability to capsizing and its probability of occurrence in a particular sea state may differ for each ship.

1.3 The guidance aims at giving seafarers caution on dangerous phenomena that they may encounter during navigation in following and quartering seas, and providing the basis for a decision on ship handling in order to avoid such dangerous situations. It provides advice on safe and unsafe combinations of ship speed and course relative to waves, in a simplified form of a polar diagram. The diagram does not take into account the actual stability and the dynamic characteristics of an individual ship, but provides a general unified boundary of safe and unsafe combination of the operational parameters for all types of conventional ships covered by IMO instruments.

1.4 For the ships which are equipped with an on-board computer, the Administrations are encouraged to use a specially developed software which would take into account the main particulars, actual stability and dynamic characteristics of the individual ship in the real voyage conditions. Such software should be approved by the Administration.

2 PRECAUTIONS

It should be noted that the operation guidance is not the criteria to guarantee the safety absolutely. A ship could be unsafe even outside the dangerous zone defined in this guidance if the stability of the ship is insufficient and several dangerous phenomena characteristic for following and quartering seas happen simultaneously. Therefore, the ship master should pay attention that the ship maintains a good state of stability and do not carelessly navigate in severe following and quartering seas.

3 DANGEROUS PHENOMENA FOR SHIPS IN FOLLOWING AND QUARTERING SEAS

3.1 Dangerous ship responses in following and quartering seas

The period with which a ship travelling in following and quartering waves encounters the waves becomes longer than in head or bow waves, and principal dangers caused in such situations are as follows:

.1 Surf-riding and broaching-to

When a ship is situated on a steep forefront of high wave in following and quartering sea condition, the ship can be accelerated to ride on the wave; this is known as surf-riding. When a ship is surf-ridden, the so-called broaching-to phenomenon may occur, which endangers the ship to capsize as the result of sudden change of ship's heading and unexpected large heeling.

.2 Reduction of intact stability caused by riding on the wave crest at midship

When a ship is riding on the wave crest, the intact stability will be decreased substantially according to the ship form. The amount of stability reduction is nearly proportional to the wave height and the ship may lose the stability when the wave length is one to two times of ship length and wave height is large. This situation is especially dangerous in following and quartering seas, because the duration of riding on wave crest, i.e. the time of inferior stability, becomes longer.

.3 Synchronous rolling motion

Large rolling motions may be excited when the natural rolling period of a ship coincides with the encounter wave period. In case of navigation in following and quartering seas this may happen when the transverse stability of the ship is marginal and therefore the natural roll period becomes longer.

.4 Parametric rolling motion

Unstable and large amplitude roll motion will take place if the encounter wave period is approximately equal to half of the natural roll period of the ship. This type of rolling can occur in head and bow seas where the encounter wave period becomes short. In following and quartering seas, this can occur particularly when the initial metacentric height is small and the natural roll period is very long.

.5 Combination of various dangerous phenomena

The dynamic behaviour of a ship in following and quartering seas is very complex. Ship motion is three-dimensional and various detrimental factors or dangerous phenomena such as additional heeling moment due to deck in water, water shipping and trapped on deck or cargo shift due to large roll motions, may occur in combination with the above-mentioned phenomena simultaneously or in a sequence. This could create extremely dangerous combination which may cause ship capsize.

3.2 Dangerous navigation conditions in following and quartering seas

There exist two kinds of critical conditions of encounter waves under which the dangerous phenomena as above-mentioned are excited:

.1 When the ship speed approaches to the phase velocity of wave

When the ship speed is so high that its component in the wave direction approaches to the phase velocity of wave, the ship will be accelerated to reach surf-riding and broaching-to (paragraph 3.1.1). The critical speed for the occurrence of surf-riding is considered to be $1.8\sqrt{L}$ (knots), where L is ship length. It should be noted that there is a marginal zone ($1.4\sqrt{L} \sim 1.8\sqrt{L}$) below the critical speed, where a large surging motion may occur, which is almost equivalent to surf-riding in danger. In these situations, a significant reduction of intact stability (paragraph 3.1.2) may also be induced with longer duration; and

.2 When the ship speed is nearly equal to the group velocity of wave

When the ship speed component in the wave direction is nearly equal to the wave group velocity, that is a half of the phase velocity of the dominant wave components, the ship will be attacked successively by high waves. The expectable maximum wave height of the successive waves can reach almost twice of the observed wave height of the sea state concerned.

In this situation, the reduction of intact stability (paragraph 3.1.2), synchronous rolling motions (paragraph 3.1.3), parametric rolling motions (paragraph 3.1.4) or combination of various dangerous phenomena (paragraph 3.1.5) may occur and create the danger of capsize .

4 OPERATION GUIDANCE

The shipmaster is recommended to take the following procedures of ship handling to avoid the dangerous situations when navigating in severe following and quartering seas.

4.1 Ship condition

This guidance is applicable to all types of conventional ships navigating in rough seas, provided the stability criteria specified in resolutions A.167(ES.IV) and A.562(14) for merchant ships, and resolutions A.168(ES.IV) and A.685(17) for fishing vessels or an equivalent are satisfied.*

4.2 Wave condition

The following and quartering seas mean here that the wave direction relative to the ship course is within 0º to 45º from the ship's stern, as shown in figure 1.

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* Refer to the Code on Intact Stability for All Types of Ships covered by IMO Instruments, adopted by the Organization by resolution A.749(18).

4.3 How to avoid dangerous conditions

.1 For surf-riding and broaching-to.

The master should reduce ship speed to less than $1.8\sqrt{L}$ (knots) to prevent surf-riding, referring to figure 2.

It should be noted that even in lower ship speed than that specified above the dangerous large surging can occur as shown in figure 2. Since a remarkable surging acceleration with long period is a sign of the dangerous large surge motion, the master should reduce the speed in such case, too.

.2 For successive high wave attack

When the average wave length is larger than 0.8 x ship length and the significant wave height is larger than 0.04 x ship length, and at the same time some indices of dangerous behaviour of the ship can be clearly seen, the master should pay attention not to enter in the dangerous zone as indicated in figure 3. When the ship is situated in this dangerous zone, the ship speed should be reduced to prevent successive attack of high waves.

The course change is also possible in order to escape this zone. However, large course change is undesirable, because it may induce an adverse effect by approaching to the beam sea condition which is also dangerous for stability. The combination of appropriate speed reduction with a slight change of course will be another possible choice of ship handling according to figure 3.

When the encounter wave period is nearly equal to double (i.e. about 1.5-2.8 times) of the observed wave period, the ship is considered to be situated in this dangerous zone. This relation is indicated in figure 3.

.3 For synchronous rolling and parametric rolling motions

The master should prevent a synchronous rolling motion which will occur when the encounter wave period T_E is nearly equal to the natural rolling period of ship T_R. Large rolling motions which occur under the condition of $T_E \approx T_R/2$, that is the parametric rolling should be also prevented. The encounter wave period T_E is a function of V/T as shown in figure 3. By using this relation, the master can know whether his ship will encounter the synchronous and parametric rolling or not.

When reducing speed in order to avoid any of above critical conditions, the master should take into consideration the minimum speed required for maintaining course control in waves and wind. The procedures to execute the operation guidance is represented by the "Operation diagram for the master", which is shown in the appendix.

5 EXPLANATION OF OPERATION GUIDANCE

5.1 Definition of symbols used

L	length between perpendiculars of the ship (metre)
B	breadth of the ship hull (metre)
d	draught of the ship hull (metre)
V	actual ship speed (knot)
T	mean wave period (second)
T_E	encounter wave period (second)
T_R	natural rolling period (second)
GM	metacentric height of ship (metre)
λ	average length of the wave (metre)
χ	encounter angle of the ship to wave (degree), as shown in figure 1
$H_{1/3}$	significant wave height (metre)

5.2 Method of obtaining data necessary to use operation guidance

.1 V: Estimate the actual ship speed in an appropriate way.

.2 χ: Obtain by visual observation. The wind direction can be referred as the same as the wave direction. If the sea condition is not visible, the radar image can show wave crest trains and wave direction.

.3 T: Measure the period of heaving motion of foam on the sea surface generated by breaking wave with the use of a stop watch. The time duration of N cycles is to be measured and divided by N to get the average wave period. When the wave length λ is determined either by visual observation in comparison with the ship length or by reading the mean distance between successive wave crests on the radar image of waves, T can be calculated by the following equation:

$$T = 0.8 \sqrt{\lambda}.$$

.4 T_E: Measure the period of such a ship motion as pitching by using a stop watch.

.5 T_R: Measure the period of rolling motions preferably when the ship is in calm sea; alternatively, this value is roughly estimated by the following equation:

$$T_R = 2CB/\sqrt{GM}$$

where:

$C = 0.373+0.023(B/d)-0.043(L/100)$, or by equivalent determination of coefficient C.

6 NECESSARY TRAINING ITEMS AND CAUTIONS TO EXECUTE THE GUIDANCE

6.1 Understanding of stability of ship

The ship should satisfy the stability standard specified in resolutions A.167(ES.IV) and A.562(14) for merchant ships and resolutions A.168(ES.IV) and A.685(17) for fishing vessels or equivalent.* Therefore, the master should have knowledge on the stability of his ship for every possible loading conditions whether it satisfies the above standards of stability, or equivalent standards.

6.2 Measurement or estimation of natural rolling period

The natural rolling period of a ship depends on the loading condition of the ship. Therefore, it is desirable to measure the natural rolling period in calm sea on every occasion of departure after cargo loading or unloading. A stop watch can be used for the measurement.

6.3 Measurement of wave period and observation of wave direction

The wave period is measured by a stop watch, and the wave direction is estimated by visual observation or by watching radar image. The practice of wave and wind observation is common for the shipmasters of selected ships (World Meteorological Organization (WMO)).

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* Refer to the Code on Intact Stability for All Types of Ships covered by IMO Instruments, adopted by the Organization by resolution A.749(18).

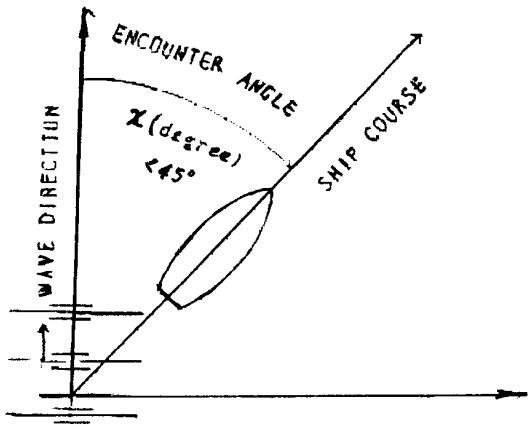

Figure 1-Definition of encounter angle χ

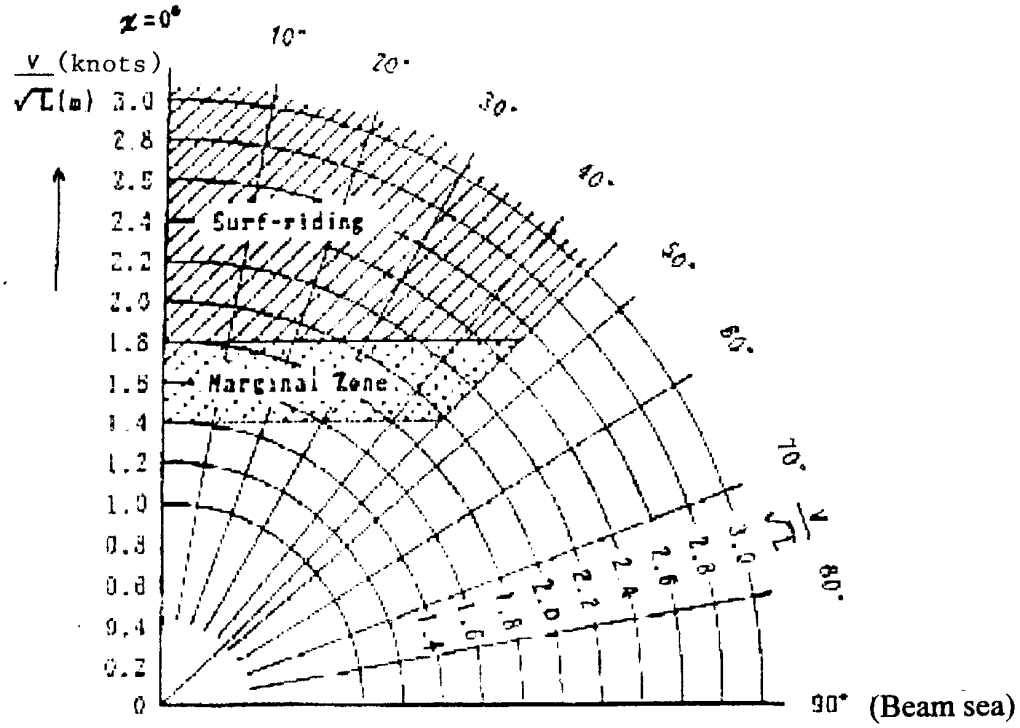

Figure 2-Diagram indicating dangerous zone due to surf-riding

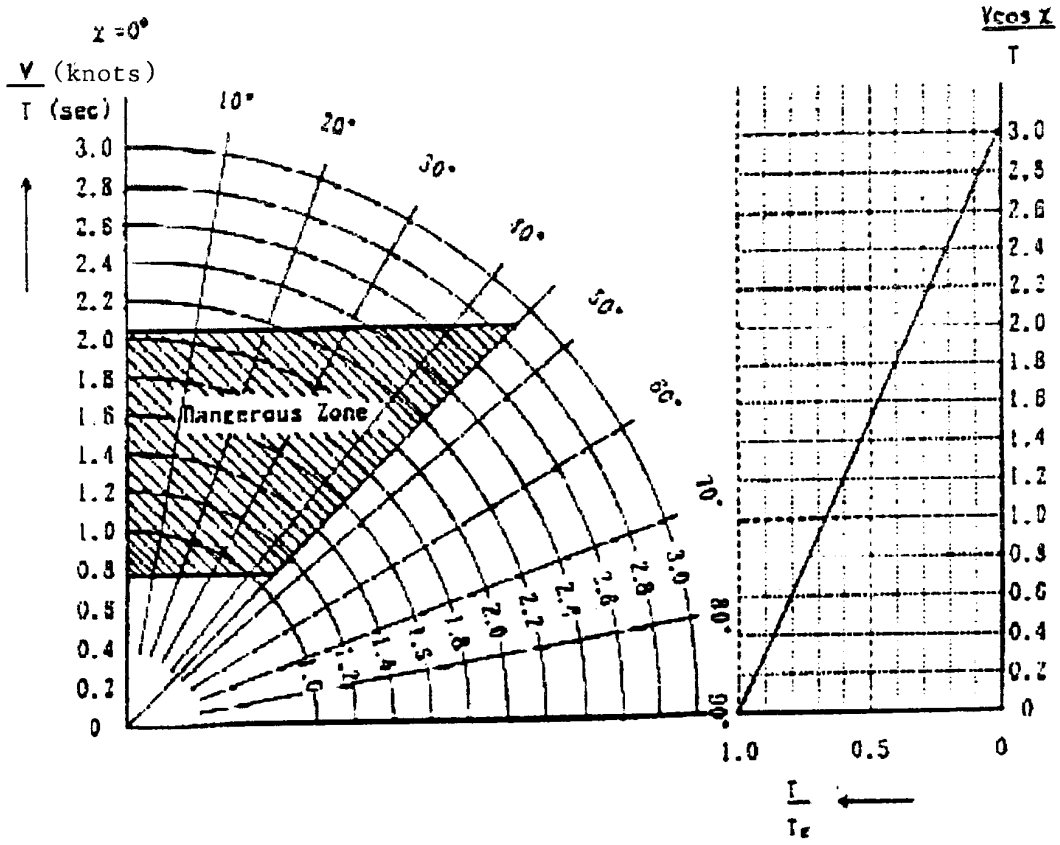

Figure 3 - Diagram indicating dangerous zone of encountering to high wave group and relation between mean wave period and encounter wave period in following and quartering seas

APPENDIX

OPERATION DIAGRAM FOR THE MASTER

Ship: Satisfaction to IMO stability criteria or equivalent

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Wave: Wave length > 0.8 × ship length, $H_{1/3} > 0.04 \times$ ship length
Estimate λ, T, and χ, where $T = 0.8\sqrt{\lambda}$.

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Ship course: Wave direction is 0° to 45° from the stem.

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Encounter wave period, T_E

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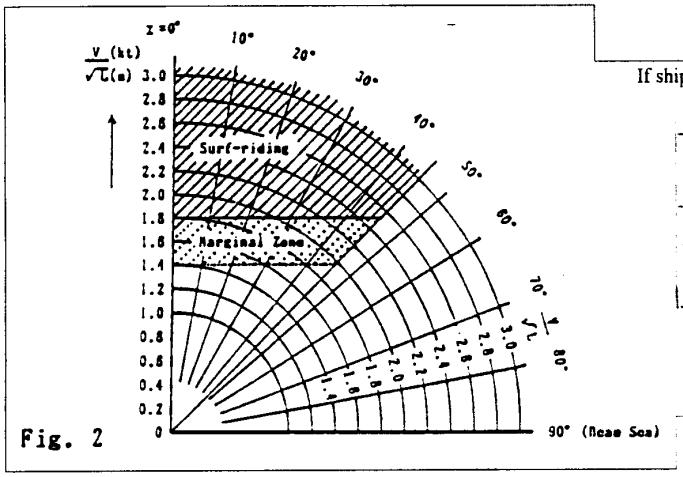

Fig. 2

If ship's speed:

→ (1) in Surf-riding zone
Reduce to speed zone (2),

→ (2) in marginal zone
Reduce to speed zone (3),
when felt large surging.

→ (3) beyond the zones

↓

Next step

↓

Plot V(knot)/T(s) versus χ on Figure 3.

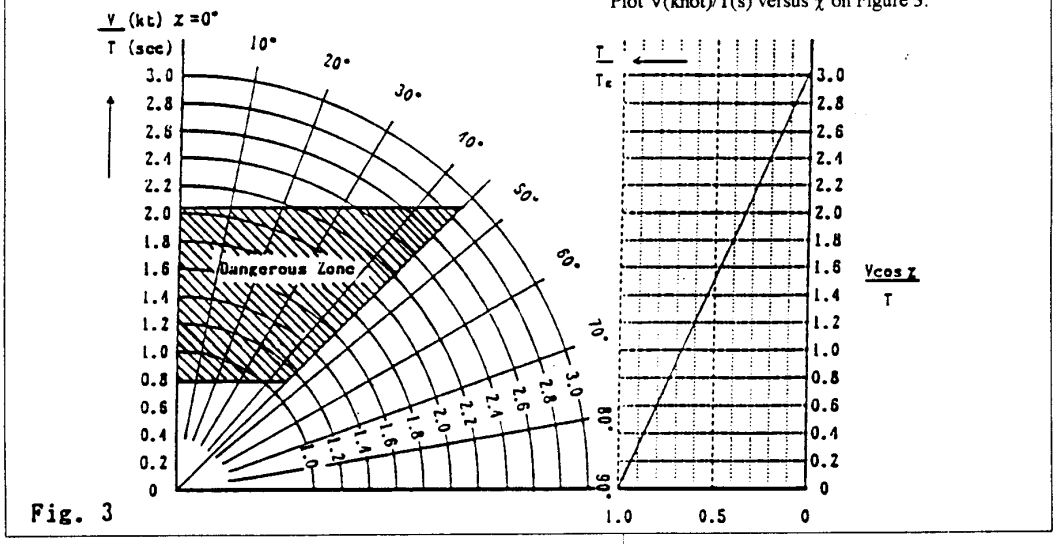

Fig. 3

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If V/T (χ) is in the dangerous zone, reduce the speed to come out of the zone.

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If V/T (χ) is beyond the dangerous zone, keep speed and course.

Judge T_E

↓

If T_E is nearly equal to T_R or T_R /2, reduce the speed further.*

* Take into consideration the minimum speed for maintaining course control of the ship.