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ADVICE ON THE DANGERS OF FLOODING OF FORWARD COMPARTMENTS

1 The Maritime Safety Committee, at its seventy-fourth session (30 May to 8 June 2001), considered the recommendations of the Re-opened Formal Investigation into the loss of the motor vessel **Derbyshire**, carried out by the United Kingdom, in particular that masters of bulk carriers should be made fully aware of the possible dangerous consequences of water entry into forward spaces and consequent reduction of freeboard, and approved the Advice on the dangers of flooding of forward compartments, set out in the annex.

2 Member Governments are invited to bring the annexed Advice to the attention of all those involved in the operation of bulk carriers and other similar types of ships flying their flags, in particular of all owners, operators and masters of such ships.

ANNEX

ADVICE ON THE DANGERS OF FLOODING OF FORWARD COMPARTMENTS

The capesize Oil Bulk Ore Carrier **mv Derbyshire** sank off Okinawa in Typhoon ORCHID in September 1980 with the loss of 44 lives. The cause of her sinking remained a mystery until 1994 when, using modern deep-sea underwater techniques an expedition located the wreck. This preliminary expedition led to a detailed survey of the wreck in 1997 which revealed aspects of the sinking that showed - after subsequent research using testing tank models – that the initial cause of sinking was progressive flooding of forward spaces.

The **Derbyshire** initially suffered damage to the air pipes serving the fore peak tank and the forward bosun's store. The damage was attributed to the impact of heavy seas on air pipes and, possibly, the displacement of the starboard windlass, which then caused further damage.

The research that was commissioned subsequent to the findings at the wreck site showed that large volumes of water can be taken in through damaged air pipes of the size and type typically fitted to bulk carriers and tankers to serve forward tanks. Flooding rates in excess of 400 cubic metres per hour through a single 300 mm air pipe were found to be possible in relatively heavy but by no means extreme seas.

Flooding of the fore peak and the forward ballast tank through air pipes caused the ship to trim by the head and reduce the effective bow height. Statistical analysis of tank test results indicated that, although there was a low probability of the ship meeting a hatch-breaking wave in her intact condition, a reduction in bow height of as little as 1.1m could lead to a 70% probability of encountering a hatch-breaking wave (depending on speed, etc). The hatch covers of Nos.1 and 2 cargo holds subsequently failed allowing rapid flooding of those spaces. The ship was then in a condition beyond its survival capability.

The evidence considered by the investigation indicated that these events took place rapidly. There was no evidence that any attempt to abandon ship had been possible. The events took place almost certainly at night and it was concluded that in such circumstances the ship's crew would have been unlikely to have detected the impending disastrous circumstances until the ship was already doomed.

Masters - particularly those who sail on large ships where the bridge is remote from the forward spaces - need to be especially vigilant that the weathertight integrity of their ship is fully maintained. After initial battening down, regular checks should be made to detect any reduction in the integrity of the closing arrangements. In particular:

- Spaces that are entered on routine basis should be subject to a careful check after their use to ensure that watertight integrity is fully restored.
- Rope and other hatches should have their fixing arrangements checked to compensate for any slackening of toggles or other fixing devices.
- Bilges and tanks should be regularly sounded and any ingress of water investigated.

- Where bilge alarms are fitted, they should be regularly tested.
- Pumping arrangements in forward spaces should be regularly checked for operational effectiveness.

Owners of ships without bilge alarms in remote forward spaces should consider fitting such devices with audible and visual indication on the bridge.

Masters should consider early evasive action in the event that severe weather systems approach the region in which the ship is navigating. Due regard should be had to the handling characteristics of the ship and any limitations of control that may lead to the ship being dangerously exposed to the forces of such extreme weather.

Masters should keep owners or managers advised when weather conditions deteriorate necessitating evasive action. Such advice should include position, course and speed and should be given more frequently in proportion to the severity of the weather and the limitations imposed on the ship's progress.



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**REVISED GUIDANCE TO THE MASTER FOR AVOIDING DANGEROUS
SITUATIONS IN ADVERSE WEATHER AND SEA CONDITIONS**

1 The Maritime Safety Committee, at its eighty-second session (29 November to 8 December 2006), approved the Revised Guidance to the master for avoiding dangerous situations in adverse weather and sea conditions, set out in the annex, with a view to providing masters with a basis for decision making on ship handling in adverse weather and sea conditions, thus assisting them to avoid dangerous phenomena that they may encounter in such circumstances.

2 Member Governments are invited to bring the annexed Revised Guidance to the attention of interested parties as they deem appropriate.

3 This Revised Guidance supersedes the Guidance to the master for avoiding dangerous situations in following and quartering seas (MSC/Circ.707).

ANNEX

REVISED GUIDANCE TO THE MASTER FOR AVOIDING DANGEROUS SITUATIONS IN ADVERSE WEATHER AND SEA CONDITIONS

1 GENERAL

1.1 Adverse weather conditions, for the purpose of the following guidelines, include wind induced waves or heavy swell. Some combinations of wave length and wave height under certain operation conditions may lead to dangerous situations for ships complying with the IS Code. However, description of adverse weather conditions below shall not preclude a ship master from taking reasonable action in less severe conditions if it appears necessary.

1.2 When sailing in adverse weather conditions, a ship is likely to encounter various kinds of dangerous phenomena, which may lead to capsizing or severe roll motions causing damage to cargo, equipment and persons on board. 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 dangerous responses, including capsizing, and its probability of occurrence in a particular sea state may differ for each ship.

1.3 On ships which are equipped with an on-board computer for stability evaluations, and which use specially developed software which takes 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. Results derived from such calculations should only be regarded as a supporting tool during the decision making process.

1.4 Waves should be observed regularly. In particular, the wave period T_w should be measured by means of a stop watch as the time span between the generation of a foam patch by a breaking wave and its reappearance after passing the wave trough. 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 images of waves.

1.5 The wave period and the wave length λ are related as follows:

$$\lambda = 1.56 \cdot T_w^2 \text{ [m]} \text{ or } T_w = 0.8\sqrt{\lambda} \text{ [s]}$$

1.6 The period of encounter T_E could be either measured as the period of pitching by using stop watch or calculated by the formula:

$$T_E = \frac{3T_w^2}{3T_w + V\cos(\alpha)} \text{ [s]}$$

where V = ship's speed [knots]; and

α = angle between keel direction and wave direction ($\alpha = 0^\circ$ means head sea)

1.7 The diagram in figure 1 may as well be used for the determination of the period of encounter.

1.8 The height of significant waves should also be estimated.

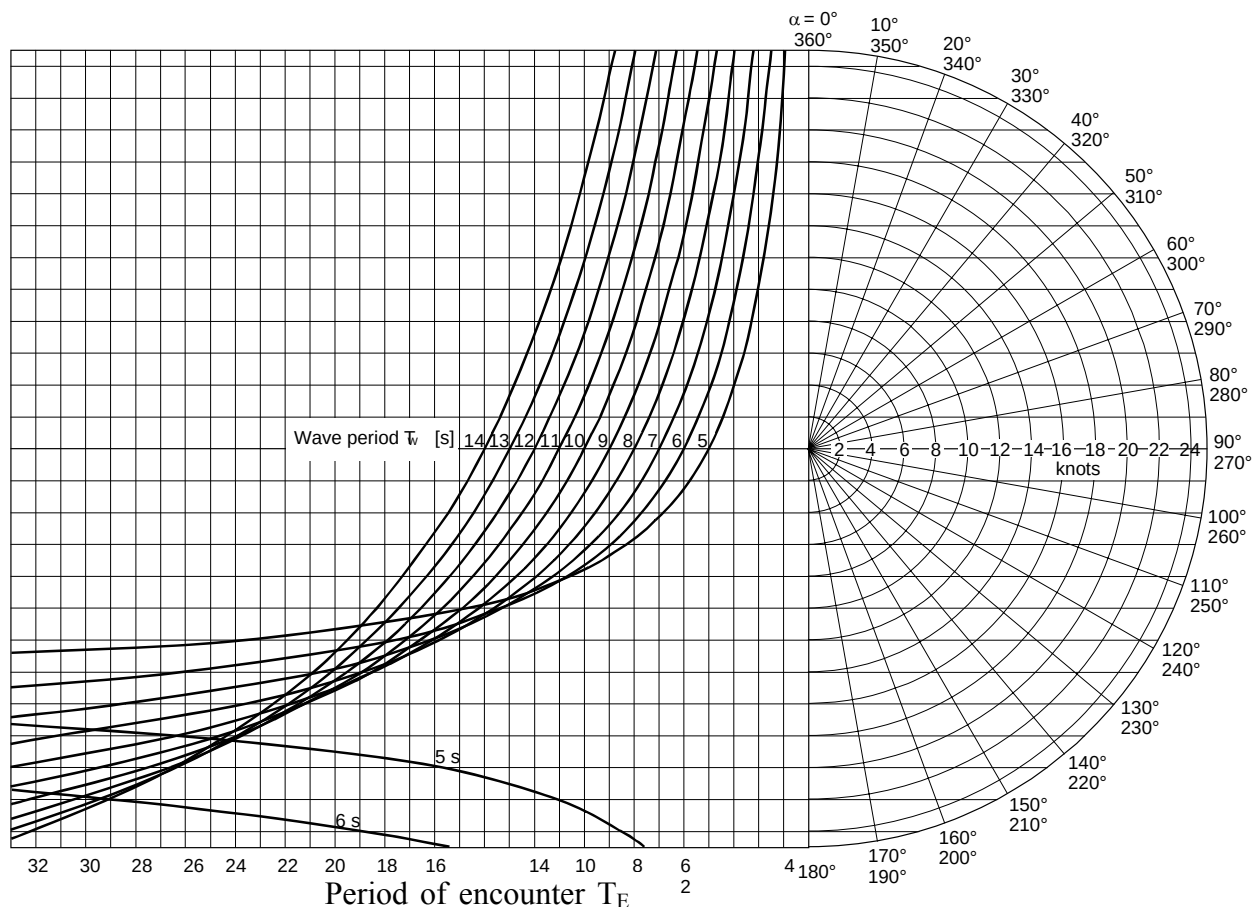


Figure 1: Determination of the period of encounter T_E

2 CAUTIONS

2.1 It should be noted that this guidance to the master has been designed to accommodate for all types of merchant ships. Therefore, being of a general nature, the guidance may be too restrictive for certain ships with more favourable dynamic properties, or too generous for certain other ships. A ship could be unsafe even outside the dangerous zones defined in this guidance if the stability of the ship is insufficient. Masters are requested to use this guidance with fair observation of the particular features of the ship and her behaviour in heavy weather.

2.2 It should further be noted that this guidance is restricted to hazards in adverse weather conditions that may cause capsizing of the vessel or heavy rolling with a risk of damage. Other hazards and risks in adverse weather conditions, like damage through slamming, longitudinal or torsional stresses, special effects of waves in shallow water or current, risk of collision or stranding, are not addressed in this guidance and must be additionally considered when deciding on an appropriate course and speed in adverse weather conditions.

2.3 The master should ascertain that his ship complies with the stability criteria specified in the IS Code or an equivalent thereto. Appropriate measures should be taken to assure the ship's watertight integrity. Securing of cargo and equipment should be re-checked. The ship's natural period of roll T_R should be estimated by observing roll motions in calm sea.

3 DANGEROUS PHENOMENA

3.1 Phenomena occurring in following and quartering seas

A ship sailing in following or stern quartering seas encounters the waves with a longer period than in beam, head or bow waves, and principal dangers caused in such situation are as follows:

3.1.1 *Surf-riding and broaching-to*

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

3.1.2 *Reduction of intact stability when riding a wave crest amidships*

When a ship is riding on the wave crest, the intact stability can be decreased substantially according to changes of the submerged hull form. This stability reduction may become critical for wave lengths within the range of 0.6 L up to 2.3 L, where L is the ship's length in metres. Within this range the amount of stability reduction is nearly proportional to the wave height. This situation is particularly dangerous in following and quartering seas, because the duration of riding on the wave crest, which corresponds to the time interval of reduced stability, becomes longer.

3.2 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.

3.3 Parametric roll motions

3.3.1 Parametric roll motions with large and dangerous roll amplitudes in waves are due to the variation of stability between the position on the wave crest and the position in the wave trough. Parametric rolling may occur in two different situations:

- .1 The stability varies with an encounter period T_E that is about equal to the roll period T_R of the ship (encounter ratio 1:1). The stability attains a minimum once during each roll period. This situation is characterized by asymmetric rolling, i.e. the amplitude with the wave crest amidships is much greater than the amplitude to the other side. Due to the tendency of retarded up-righting from the large amplitude, the roll period T_R may adapt to the encounter period to a certain extent, so that this kind of parametric rolling may occur with a wide bandwidth of encounter periods. In quartering seas a transition to harmonic resonance may become noticeable.
- .2 The stability varies with an encounter period T_E that is approximately equal to half the roll period T_R of the ship (encounter ratio 1:0.5). The stability attains a minimum twice during each roll period. In following or quartering seas, where the encounter period becomes larger than the wave period, this may only occur

with very large roll periods T_R , indicating a marginal intact stability. The result is symmetric rolling with large amplitudes, again with the tendency of adapting the ship response to the period of encounter due to reduction of stability on the wave crest. Parametric rolling with encounter ratio 1:0.5 may also occur in head and bow seas.

3.3.2 Other than in following or quartering seas, where the variation of stability is solely effected by the waves passing along the vessel, the frequently heavy heaving and/or pitching in head or bow seas may contribute to the magnitude of the stability variation, in particular due to the periodical immersion and emersion of the flared stern frames and bow flare of modern ships. This may lead to severe parametric roll motions even with small wave induced stability variations.

3.3.3 The ship's pitching and heaving periods usually equals the encounter period with the waves. How much the pitching motion contributes to the parametric roll motion depends on the timing (coupling) between the pitching and rolling motion.

3.4 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 like additional heeling moments due to deck-edge submerging, water shipping and trapping on deck or cargo shift due to large roll motions may occur in combination with the above mentioned phenomena, simultaneously or consecutively. This may create extremely dangerous combinations, which may cause ship capsize.

4 OPERATIONAL GUIDANCE

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

4.1 Ship condition

This guidance is applicable to all types of conventional ships navigating in rough seas, provided the stability criteria specified in resolution A.749(18), as amended by resolution MSC.75(69), are satisfied.

4.2 How to avoid dangerous conditions

4.2.1 For surf-riding and broaching-to

Surf-riding and broaching-to may occur when the angle of encounter is in the range $135^\circ < \alpha < 225^\circ$ and the ship speed is higher than $(1.8\sqrt{L})/\cos(180 - \alpha)$ (knots). To avoid surf riding, and possible broaching the ship speed, the course or both should be taken outside the dangerous region reported in figure 2.

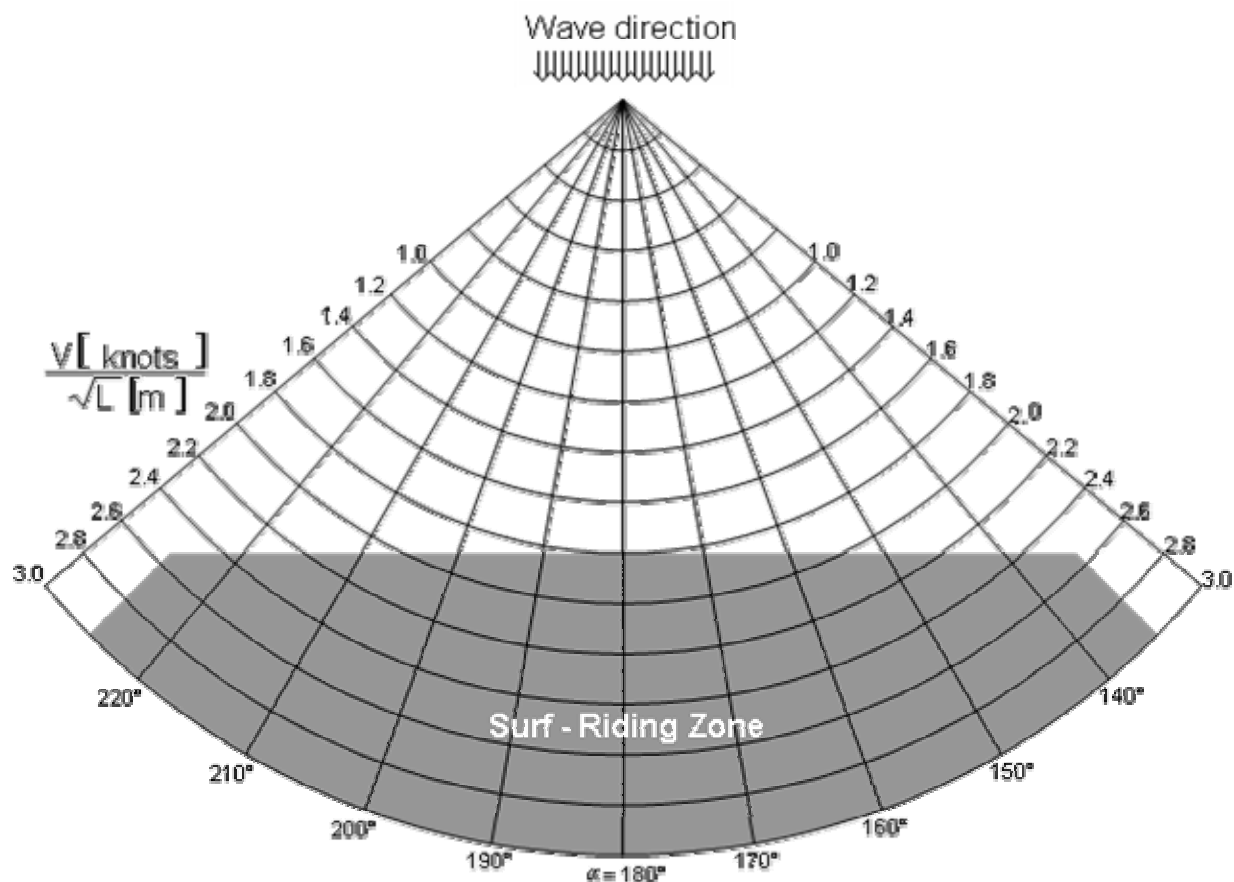


Figure 2: Risk of surf-riding in following or quartering seas

4.2.2 For successive high-wave attack

4.2.2.1 When the average wave length is larger than $0.8 L$ and the significant wave height is larger than $0.04 L$, 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 or the ship course should be changed to prevent successive attack of high waves, which could induce the danger due to the reduction of intact stability, synchronous rolling motions, parametric rolling motions or combination of various phenomena.

4.2.2.2 The dangerous zone indicated in figure 3 corresponds to such conditions for which the encounter wave period (T_E) is nearly equal to double (i.e., about 1.8-3.0 times) of the wave period (T_W) (according to figure 1 or paragraph 1.4).

4.2.3 For synchronous rolling and parametric rolling motions

4.2.3.1 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 .

4.2.3.2 For avoiding parametric rolling in following, quartering, head, bow or beam seas the course and speed of the ship should be selected in a way to avoid conditions for which the encounter period is close to the ship roll period ($T_E \approx T_R$) or the encounter period is close to one half of the ship roll period ($T_E \approx 0.5 \cdot T_R$).

4.2.3.3 The period of encounter T_E may be determined from figure 1 by entering with the ship's speed in knots, the encounter angle α and the wave period T_W .

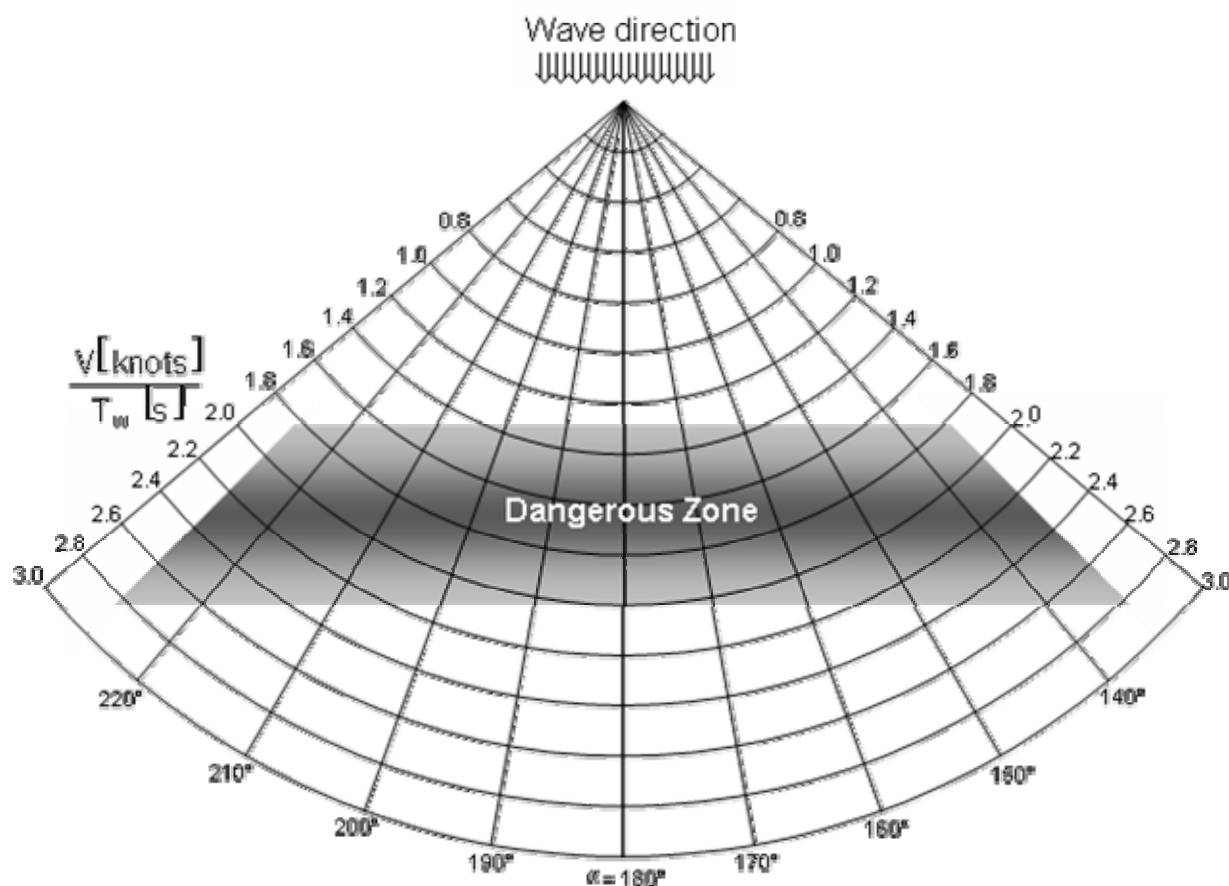


Figure 3: Risk of successive high wave attack in following and quartering seas

Abbreviations and symbols

Symbols	Explanation	Units
T_W	wave period	s
λ	wave length	m
T_E	encounter period with waves	s
α	angle of encounter ($\alpha = 0^\circ$ in head sea, $\alpha = 90^\circ$ for sea from starboard side)	degrees
V	ship's speed	knots
T_R	natural period of roll of ship	s
L	length of ship (between perpendiculars)	m