

GUIDELINES

ON SEAWORTHINESS ASSESSMENT

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GUIDELINES ON SEAWORTHINESS ASSESSMENT

Guidelines on Seaworthiness Assessment of Russian Maritime Register of Shipping (RS, the Register) have been approved in accordance with the established approval procedure and come into force on 1 June 2026.

The Guidelines on Seaworthiness Assessment have been developed considering IMO SDC 2/INF.10, Development of Second Generation Intact Stability Criteria. Information collected by the Correspondence Group on Intact Stability. 2014, IACS Recommendation No. 34 (Rev. 1 June 2000) (Corr.1 Nov 2001) and Collection of Regulating Documents, Book Twenty-Four.

The Guidelines on Seaworthiness Assessment consist of two Parts.

The first Part contains provisions concerning the assessment of the vulnerability to ship's stability failure during dangerous hydrodynamic phenomena.

The second Part contains recommendations to ensure the ship's seaworthiness properties and posing of restrictions on weather conditions during passages.

REVISION HISTORY¹

For this version, there are no amendments to be included in the Revision History.

¹ With the exception of amendments and additions introduced by Rule Change Notices (RCN), as well as of misprints and omissions.

PART I. SEAWORTHINESS ASSESSMENT

1 GENERAL

1.1 APPLICATION

1.1.1 This Part of the Guidelines on Seaworthiness Assessment¹ shall be applied during expansion or changing the permanent restrictions on the navigation area imposed on a ship in accordance with 1.6.4 of Part IV "Stability" of the Rules for the Classification and Construction of Sea-Going Ships².

1.1.2 The provisions of this Part specify the assessment of seaworthiness as a vulnerability to ship's stability failure during dangerous hydrodynamic phenomena specified in [1.1.3](#). The assessment is carried out using criteria considering the characteristics of wind and wave conditions, ship load and its position on a wave surface. The fulfillment of all above mentioned criteria ensures that the stability of these ships during navigation in waves is sufficient.

1.1.3 This Part contains a methodology for assessing the ship's vulnerability to dangerous hydrodynamic phenomena in waves, such as:

- .1 parametric rolling stability failure mode;
- .2 pure loss of stability failure mode;
- .3 surf-riding (broaching) stability failure mode.

1.1.4 The calculation methods provided in this Part shall be applied for all types of ships in service.

1.1.5 The results of calculations of ship's vulnerability to dangerous hydrodynamic phenomena in waves, specified in [1.1.3](#), shall be submitted to the Register for review and approval.

1.1.6 [Section 5](#) of this Part provides operational guidance on avoiding the ship entering the super-harmonic resonance mode.

¹ Hereinafter referred to as "these Guidelines".

² Hereinafter referred to as "the RS Rules/C".

**2 VULNERABILITY CRITERIA
FOR THE PARAMETRIC ROLLING STABILITY FAILURE MODE**

2.1 APPLICATION

2.1.1 The provisions of this Section apply to all ships of $L_1 \geq 24$ m in length,

where L_1 = length, in m, as defined in the Load Line Rules for Sea-Going Ships and the Guidelines on Application of Provisions of the International Convention of Load Lines (LL-66/88).

2.1.2 For each condition of loading, a ship, the stability of which:

- .1** meets the requirements of [2.2](#), is considered not to be vulnerable to the parametric rolling stability failure;
- .2** does not meet the requirements of [2.2](#), shall be assessed according to [2.3](#).

**2.2 LEVEL 1 VULNERABILITY CRITERIA
FOR THE PARAMETRIC ROLLING STABILITY FAILURE MODE**

2.2.1 A ship is considered not to be vulnerable to the parametric rolling stability failure mode if

$$\frac{\Delta h}{h} \leq R_{PR}, \quad (2.2.1)$$

where $R_{PR} = 1,87$, if the ship has a sharp bilge,
otherwise:

$$R_{PR} = 0,17 + 0,425 \left(\frac{100A_k}{L_1 B} \right), \text{ if } C_m > 0,96;$$

$$R_{PR} = 0,17 + (10,625 \times C_m - 9,775) \left(\frac{100A_k}{L_1 B} \right), \text{ if } 0,94 < C_m < 0,96;$$

$$R_{PR} = 0,17 + 0,2125 \left(\frac{100A_k}{L_1 B} \right), \text{ if } C_m < 0,94;$$

$\left(\frac{100A_k}{L_1 B} \right)$ for each formula shall not exceed 4;

A_k = total overall projected area of the bilge keels (no other appendages), m²;

C_m = midship section coefficient of the fully loaded condition in calm water;

B = moulded breadth of the ship, m;

h = metacentric height of the loading condition in calm water including free surface correction, m;

Δh = the amplitude of the variation of the metacentric height, m, calculated as either: a longitudinal wave passes the ship, according to 2.2.3 calculated as provided in (2.2.2).

2.2.2 As provided by 2.2.1, Δh may be determined according to:

$$\Delta h = \frac{I_H - I_L}{2V}, \text{ only if } \frac{V_D - V}{A_W(D-d)} \geq 1,0 \quad (2.2.2)$$

where D = moulded depth at side to the weather deck, m;

V_D = volume of displacement at a waterline equal to the moulded depth at zero trim, m³;

V = volume of displacement corresponding to the loading condition under consideration, m³;

A_W = waterplane area at the draft equal to d , m²;

d = draft amidships corresponding to the loading condition under consideration, m;

$$\delta d_H = \min \left(D - d, \frac{L_1 S_W}{2} \right), \text{ m};$$

$$\delta d_L = \min \left(d - 0,25d_{full}, \frac{L_1 S_W}{2} \right), \text{ m, and } d - 0,25d_{full} \text{ shall not be taken less than zero};$$

$$d_H = d + \delta d_H, \text{ m};$$

$$d_L = d - \delta d_L, \text{ m};$$

$$S_W = 0,0167;$$

I_H = moment of inertia of the waterplane at the draft d_H and at zero trim, m⁴;

I_L = moment of inertia of the waterplane at the draft d_L and at zero trim, m⁴;

d_{full} = draft corresponding to the fully loaded departure condition, m.

2.2.3 As provided by 2.2.1, Δh may be determined as one-half the difference between the maximum and minimum values of the metacentric height calculated for the ship, including free surface correction, corresponding to the loading condition under consideration, taking into account the ship to be balanced in sinkage and trim on a series of waves with the following characteristics:

wavelength $\lambda = L_1$;

wave height $h = L_1 \cdot S_W$, where $S_W = 0,0167$;

the wave crest centred at amidships, and at $0,1L_1$, $0,2L_1$, $0,3L_1$, $0,4L_1$ and $0,5L_1$ forward and $0,1L_1$, $0,2L_1$, $0,3L_1$, $0,4L_1$ aft thereof.

2.3 LEVEL 2 VULNERABILITY CRITERIA FOR THE PARAMETRIC ROLLING STABILITY FAILURE MODE

2.3.1 A ship is considered not to be vulnerable to the parametric rolling stability failure mode if either:

- .1 the value of C_1 , calculated according to [2.3.2](#), is less than R_{PRO} , or;
- .2 the value of C_1 is larger than R_{PRO} and the value of C_2 , calculated according to [2.3.3](#), is less than R_{PR1}

where $R_{PRO} = 0,06$;
 $R_{PR1} = 0,06$.

2.3.2 The value for C_1 is calculated as a weighted average from a set of waves specified in [2.3.2.3](#)

$$C_1 = \sum_{i=1}^N W_i C_i \quad (2.3.2)$$

where W_i = the weighting factor for the respective wave specified in [Table 2.3.2.3](#);
 $C_i = 0$, if the requirements of either the variation of metacentric height h in waves contained in [2.3.2.1](#) or the ship speed in waves contained in [2.3.2.2](#) is satisfied; and
 $C_i = 1$ if not;
 N = the number of wave cases evaluated of those specified in [Table 2.3.2.3](#).

2.3.2.1 The requirement for the variation of metacentric height h in waves is satisfied if, for each wave specified in [2.3.2.3](#):

$$h(H_i, \lambda_i) > 0 \text{ and } \frac{\Delta h(H_i, \lambda_i)}{h(H_i, \lambda_i)} < R_{PR} \quad (2.3.2.1)$$

where R_{PR} = as defined in [2.2.1](#);
 $\Delta h(H_i, \lambda_i)$ = one-half the difference between the maximum and minimum values of the metacentric height calculated with free surface correction for the ship, m, corresponding to the loading condition under consideration, considering the ship to be balanced in sinkage and trim on a series of waves characterized by a H_i and a λ_i ;
 $h(H_i, \lambda_i)$ = the average value of the metacentric height calculated for the ship, m, corresponding to the loading condition under consideration, considering the ship to be balanced in sinkage and trim on a series of waves characterized by a H_i and a λ_i ;
 H_i = a wave height, m, specified in [Table 2.3.2.3](#);
 λ_i = a wave length, m, specified in [Table 2.3.2.3](#).

2.3.2.2 The requirement for the ship speed in waves is satisfied if, for a wave specified in [2.3.2.3](#):

$$V_{PRi} > V_s \quad (2.3.2.2)$$

where V_s = the service speed, m/s;
 V_{PRi} = the reference ship speed (m/s) corresponding to parametric resonance conditions, when $h(H_i, \lambda_i) > 0$, m/s;

$$V_{PRi} = \left| \frac{2\lambda_i}{T_\phi} \cdot \sqrt{\frac{h(H_i, \lambda_i)}{h}} - \sqrt{g \frac{\lambda_i}{2\pi}} \right|;$$

T_ϕ = the roll natural period in calm water, s;
 h = the metacentric height in calm water, m;
 $h(H_i, \lambda_i)$ = as defined in [2.3.2.1](#), m;
 λ_i = a wave length specified in [Table 2.3.2.3](#), m;
 g = gravity acceleration of 9,81 m/s²;
| | = the absolute value operation/operand.

2.3.2.3 The specified wave cases for evaluation of the requirements contained in [2.3.2.1](#) and [2.3.2.2](#) are provided in [Table 2.3.2.3](#), contained values of W_i , H_i , λ_i as defined in [2.3.2](#) and [2.3.2.1](#).

Table 2.3.2.3

Wave cases for parametric rolling evaluation

Wave case number	Weight W_i	Wave length λ_i , m	Wave height H_i , m
1	0,000013	22,574	0,350
2	0,001654	37,316	0,495
3	0,020912	55,743	0,857
4	0,092799	77,857	1,295
5	0,199218	103,655	1,732
6	0,248788	133,139	2,205
7	0,208699	166,309	2,697
8	0,128984	203,164	3,176
9	0,062446	243,705	3,625
10	0,024790	287,931	4,040
11	0,008367	335,843	4,421
12	0,002473	387,440	4,769
13	0,000658	442,723	5,097
14	0,000158	501,691	5,370
15	0,000034	564,345	5,621
16	0,000007	630,684	5,950

2.3.2.4 In the calculation of $\Delta h(H_i, \lambda_i)$ and $h(H_i, \lambda_i)$ in [2.3.2.1](#), the ship centre shall be located at a wave crest, and at $0,1\lambda_i$, $0,2\lambda_i$, $0,3\lambda_i$, $0,4\lambda_i$ and $0,5\lambda_i$ forward and $0,1\lambda_i$, $0,2\lambda_i$, $0,3\lambda_i$, and $0,4\lambda_i$ aft thereof.

2.3.3 The value of C_2 is calculated as an average of values of $C_2(Fn_i, \beta_i)$; each of which is a weighted average from the set of waves specified in [Table 2.3.4.2](#), for each set of Froude numbers and wave directions specified:

$$C_2 = [\sum_{i=1}^3 C_2(Fn_i, \beta_h) + C_2(0, \beta_h) + \sum_{i=1}^3 C_2(Fn_i, \beta_f)]/7 \quad (2.3.3)$$

- where
- $C_2(Fn_i, \beta_h) = C_2(Fn, \beta)$ = calculated as specified in [2.3.3.1](#) with the ship proceeding in head waves with a speed equal to V_i ;
 - $C_2(Fn_i, \beta_f) = C_2(Fn, \beta)$ = calculated as specified in [2.3.3.1](#) with the ship proceeding in following waves with a speed equal to V_i ;
 - $Fn_i = V_i/\sqrt{Lg}$ = Froude number corresponding to ship speed, V_i ;
 - $V_i = V_s K_i$ = ship speed, m/s, for each corresponding wave direction;
 - V_s = ship service speed, m/s;
 - g = gravity acceleration of 9,81 m/s²;
 - K_i = as obtained from [Table 2.3.3](#).

Table 2.3.3

Corresponding wave direction speed factor, K_i

i	K_i	Corresponds to encounter with
1	1,0	Head or following waves at V_s
2	0,866	Waves with 30° relative bearing to ship centerline at V_s
3	0,50	Waves with 60° relative bearing to ship centerline at V_s

2.3.3.1 The value of $C_2(Fn, \beta)$ is calculated as a weighted average from the set of waves specified in [2.3.4.2](#) for a given Froude number and wave direction.

$$C_2(Fn, \beta) = \sum_{i=1}^N W_i C_i, \quad (2.3.3.1)$$

where W_i = the weighting factor for the respective wave cases specified in [2.3.4.2](#);
 $C_i = 1$ = if the maximum roll angle evaluated according to [2.3.4](#) exceeds 25° , and
 $C_i = 0$ = otherwise;
 N = total number of wave cases for which the maximum roll angle is evaluated for a combination of speed and ship heading.

2.3.4 The maximum roll amplitude in head and following waves is evaluated as recommended in [2.3.4.1](#) for each speed, V_i , defined in [2.3.3](#).

For each evaluation, the calculation of stability in waves shall assume the ship to be balanced in sinkage and trim on a series of waves with the following characteristics:

wavelength $\lambda = L_1$;

wave height $h_j = 0,01 \cdot jL$, where $j = 0,1 \dots, 10$.

the wave crest centred at amidships, and at $0,1L_1, 0,2L_1, 0,3L_1, 0,4L_1$ and $0,5L_1$ forward and $0,1L_1, 0,2L_1, 0,3L_1, 0,4L_1$ aft thereof.

For each wave height, h_j , the maximum roll amplitude is evaluated.

For each wave height for which $C_j = 1$, by the requirement given in [2.3.3.1](#), the representative wave height, H_i and associated W_i are determined according to [2.3.4.2](#).

2.3.4.1 The evaluation of the maximum roll amplitude shall be calculated using an equation of uncoupled roll motion, in which the following components shall be included:

- inertia term including added moment of inertia in roll in calm water;
- linear and nonlinear roll damping moment in calm water;
- linear and nonlinear roll restoring moment in calm water;
- variation of stability in waves on the roll restoring moment.

The evaluation of maximum roll amplitude shall be carried out using the method specified in [2.3.5](#) or other method approved by the Register.

2.3.4.2 For each case indicated in [Table 2.3.4.2](#), W_i is obtained from [Table 2.3.2.3](#). Each cell of the Table corresponds to an average zero up-crossing wave period, T_z , and a significant wave height, H_s , and is associated with a representative wave height from [Table 2.3.2.3](#). The maximum roll amplitude, corresponding to the significant wave height, H_s , is obtained by linear interpolation of the maximum roll amplitudes for wave heights, h_i , obtained in [2.3.4.1](#).

Table 2.3.4.2

**Wave case occurrences per 100 000 observations
for roll response evaluation in parametric rolling**

H_s , m	T_z , s — average zero up-crossing wave period															
	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	18,5
0,5	1,3	133,7	865,6	1186,0	634,2	186,3	36,9	5,6	0,7	0,1	0,0	0,0	0,0	0,0	0,0	0,0
1,5	0,0	29,3	986,0	4976,0	7738,0	5569,7	2375,7	703,5	160,7	30,5	5,1	0,8	0,1	0,0	0,0	0,0
2,5	0,0	2,2	197,5	2158,8	6230,0	7449,5	4860,4	2066,0	644,5	160,2	33,7	6,3	1,1	0,2	0,0	0,0
3,5	0,0	0,2	34,9	695,5	3226,5	5675,0	5099,1	2838,0	1114,1	337,7	84,3	18,2	3,5	0,6	0,1	0,0
4,5	0,0	0,0	6,0	196,1	1354,3	3288,5	3857,5	2685,5	1275,2	455,1	130,9	31,9	6,9	1,3	0,2	0,0
5,5	0,0	0,0	1,0	51,0	498,4	1602,9	2372,7	2008,3	1126,0	463,6	150,9	41,0	9,7	2,1	0,4	0,1
6,5	0,0	0,0	0,2	12,6	167,0	690,3	1257,9	1268,6	825,9	386,8	140,8	42,2	10,9	2,5	0,5	0,1
7,5	0,0	0,0	0,0	3,0	52,1	270,0	594,4	703,2	524,9	276,7	111,7	36,7	10,2	2,5	0,6	0,1
8,5	0,0	0,0	0,0	0,7	15,4	197,0	255,9	350,6	296,9	174,6	77,6	27,7	8,4	2,2	0,5	0,1
9,5	0,0	0,0	0,0	0,2	4,3	933,2	101,9	159,9	152,2	99,2	48,3	18,7	6,1	1,7	0,4	0,1
10,5	0,0	0,0	0,0	0,0	1,2	10,7	37,9	67,5	71,7	51,5	27,3	11,4	4,0	1,2	0,3	0,1
11,5	0,0	0,0	0,0	0,0	0,3	3,3	13,3	26,6	31,4	24,7	14,2	6,4	2,4	0,7	0,2	0,1

H_s , m	T_z , s — average zero up-crossing wave period															
	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	18,5
12,5	0,0	0,0	0,0	0,0	0,1	1,0	4,4	9,9	12,8	11,0	6,8	3,3	1,3	0,4	0,1	0,0
13,5	0,0	0,0	0,0	0,0	0,0	0,3	1,4	3,5	5,0	4,6	3,1	1,6	0,7	0,2	0,1	0,0
14,5	0,0	0,0	0,0	0,0	0,0	0,1	0,4	1,2	1,8	1,8	1,3	0,7	0,3	0,1	0,0	0,0
15,5	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,4	0,6	0,7	0,5	0,3	0,1	0,1	0,0	0,0
16,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,2	0,2	0,2	0,1	0,1	0,0	0,0	0,0

2.3.5 Calculation of maximum rolling amplitude:

2.3.5.1 The dependence for determination of resonance rolling amplitude in the main parametric resonance mode caused by relative heaving and ship involvement in reduced orbital motion at any course with respect to waves shall be as follows:

$$4\omega_{\theta}^2(\theta_m) = \left(\frac{\alpha_0}{2}\right)^2 \frac{\omega_{\theta}^4}{(kh_0)^2} \frac{\theta_m^2}{f_1^2(\theta_m)} \left\{ \left(\frac{\zeta_{gm}}{\zeta_A}\right)^2 \left(\frac{z_p}{\chi T}\right)^2 \left(1 - \frac{\theta_m^2}{12}\right) + \left[\frac{z_p}{T}d_2 + kT\left(\bar{M}_X^{23} + \bar{M}_X^{24}\frac{\theta^2}{2}\right)\right]^2 - \right. \\ \left. 2\left[\frac{z_p}{T}d_2 + kT\left(\bar{M}_X^{23} + \bar{M}_X^{24}\frac{\theta^2}{2}\right)\right] \cdot \frac{\zeta_{gm}}{\zeta_A} \frac{z_p}{\chi T} \frac{h_0}{\zeta_A} \cos \delta_{\zeta} \right\} + 4 \frac{f_1^2(\theta_m)}{\theta_m^2} \quad (2.3.5.1)$$

- where
- ω_{θ} = natural frequency of rolling, rad/s;
 - θ_m = maximum rolling amplitude, deg.;
 - $\alpha_0 = \pi \frac{h_B}{\lambda}$ = maximum wave slope angle;
 - h_B = wave height, m;
 - λ = wave length, m;
 - $k = \frac{2\pi}{\lambda}$ = wave number, (rad/m);
 - h_0 = initial transverse metacentric height, m;
 - $f_1(\theta_m) = \frac{4\omega_{\theta}}{3\pi} W\theta_m^2$;
 - $W = W_0(1 + 2Fr + 10Fr^2)$ = roll damping coefficient with speed consideration;
 - W_0 = quadratic damping without speed consideration, determined by calculation or experiment;
 - $\zeta_A = 0,17\lambda^{0,75}$;
 - $z_p = T - Z_g$, m;
 - $\chi = V/(S_{WL}T)$ = vertical prismatic coefficient;
 - V = volume of the submerged part of a ship hull, m^3 ;
 - S_{WL} = waterplane area, m^2 ;
 - T = mean draught, m;
 - θ = roll amplitude, rad.

Coefficient d_2 is determined as follows:

$$d_2 = \frac{\chi_{\beta}^I}{\chi} - \frac{1}{2}(k|\sin \beta|T)^2 \frac{r}{T} \chi_{\beta}^{II} + \frac{1}{24}(k|\sin \beta|B)^4 \chi_{\beta}^{III} \frac{f_4(\alpha)}{\chi}$$

where α = waterplane area coefficient,

$$\left\{ \begin{array}{l} \chi_{\beta}^I = \sum_{i=0}^{\infty} (-1)^i \frac{u^{2i}}{(2i+1)!} \frac{1}{\alpha + (2i+1)(1-\alpha)}, \\ \chi_{\beta}^{II} = \sum_{i=0}^{\infty} (-1)^i \frac{u^{2i}}{(2i+1)!} \frac{\alpha + 1}{\alpha + (2i+1)(1-\alpha)} \cdot \frac{2\alpha + 1}{[2\alpha + (2i+1)(1-\alpha)][3\alpha + (2i+1)(1-\alpha)]}, \\ \chi_{\beta}^{III} = \sum_{i=0}^{\infty} (-1)^i \frac{u^{2i}}{(2i+1)!} \frac{(\alpha + 1)}{[\alpha + (2i+1)(1-\alpha)]} \cdot \frac{(2\alpha + 1)}{[2\alpha + (2i+1)(1-\alpha)][3\alpha + (2i+1)(1-\alpha)]} \cdot \frac{(3\alpha + 1)(4\alpha + 1)}{[4\alpha + (2i+1)(1-\alpha)][5\alpha + (2i+1)(1-\alpha)]} \end{array} \right.$$

$$u = \frac{L}{2T} kT \cos \beta$$

where κ_β = reduction factors;
 r = small metacentric radius, m;
 β = ship direction angle, deg.;
 h_w = wave height, m;
 B = design waterline breadth, m.

2.3.5.2 The non-linear moment \overline{M}_X^{23} is calculated by the following formula:

$$\begin{aligned} \overline{M}_X^{23} = & \kappa_\beta^{II} \frac{r}{T} - \kappa_\beta^I \frac{\alpha}{T} - kT \left\{ \kappa_\beta^{II} \left(\frac{B}{T} \right)^2 \frac{f_2}{\chi} \cdot \left[p_4(1 + \sin^2 \beta) - \frac{z_p}{T} \sin^2 \beta \right] - \kappa_\beta^I \left[p_1(1 + \sin^2 \beta) - \right. \right. \\ & \left. \left. 2 \frac{z_p z_w}{T^2} \right] \right\} + \frac{(kT)^2}{2} \left[\kappa_\beta^{II} \left(\frac{B}{T} \right)^2 \frac{f_2 p_5}{\chi} (2 + 7 \sin^2 \beta) - \kappa_\beta^I p_2 (1 + \sin^2 \beta) - \kappa_\beta^{III} \left(\frac{B}{T} \right)^4 \frac{f_4}{\chi} \sin^2 \beta \right] - \frac{(kT)^3}{6} \cdot \\ & \left[\kappa_\beta^{II} \left(\frac{B}{T} \right)^2 \frac{f_2 p_6}{\chi} \frac{1 + 6 \sin^2 \beta + \sin^4 \beta}{2} - \kappa_\beta^I p_3 \cdot (1 + 3 \sin^2 \beta) - \kappa_\beta^{III} \frac{f_4 p_5}{\chi} \sin^2 \beta (3 + \sin^2 \beta) \right] \quad (2.3.5.2) \end{aligned}$$

$$z_w = T - Z_c.$$

2.3.5.3 The functions depending on waterline area coefficient and vertical prismatic coefficient $f_i(\alpha)$ and $p_i(\chi)$, are determined as follows:

$$\left\{ \begin{aligned} f_2(\alpha) &= \frac{\alpha^2}{2(\alpha+1)(2\alpha+1)}, \\ f_4(\alpha) &= \frac{3\alpha^4}{2(\alpha+1)(2\alpha+1)(3\alpha+1)(4\alpha+1)}, \\ p_1(\chi) &= \frac{1}{3(3-2\chi)}, \quad p_2(\chi) = \frac{1}{4(4-3\chi)}, \quad p_3(\chi) = \frac{1}{5(5-4\chi)}, \\ p_4(\chi) &= 1 - 3(1-\chi) + \frac{3(1-\chi)}{1+\chi} - \frac{1-\chi}{1+2\chi}, \\ p_5(\chi) &= 3 \left[\frac{1}{2} - \frac{3(1-\chi)}{2-\chi} + \frac{3(1-\chi)}{1+\chi} - \frac{1-\chi}{1+2\chi} \right], \\ p_6(\chi) &= 6 \left[\frac{1}{3} - \frac{3(1-\chi)}{3-2\chi} + \frac{3(1-\chi)}{3-\chi} - \frac{1-\chi}{3} \right], \\ p_7(\chi) &= 1 - 5(1-\chi) + \frac{10(1-\chi)}{1+\chi} - \\ & \frac{10(1-\chi)}{1+2\chi} + \frac{5(1-\chi)}{1+3\chi} - \frac{1-\chi}{1+4\chi} \end{aligned} \right. \quad (2.3.5.3)$$

2.3.5.4 The nonlinear addition to the excitation moment for a wall-sided ship, which contours are approximated by parabolas

$$\begin{aligned} \overline{M}_X^{24} = & \frac{r}{3T} \kappa_\beta^{II} + \frac{\alpha}{6T} \kappa_\beta^I - kT \left[1,33\psi_1 + \frac{z_p}{T} \left(1,33 \frac{z_w}{T} \kappa_\beta^I - 0,67\psi_5 \right) \right] + \frac{(kT)^2}{2} \left[4,5\psi_2 - 8,5 \left(\frac{B}{T} \right)^2 \psi_4 - \right. \\ & \left. 4,5 \frac{z_p}{T} \psi_1 \right] - \frac{(kT)^3}{6} \left[10,65\psi_3 - \frac{z_p}{T} \left(10,65\psi_2 - 2,64 \left(\frac{B}{T} \right)^2 \psi_4 \right) \right] \quad (2.3.5.4) \end{aligned}$$

where $\psi_1 - \psi_5$ = reduction factors

$$\begin{aligned} \psi_1 &= \left(\frac{B}{T} \right)^2 f_2(\alpha) \frac{p_4(\chi)}{\chi} \kappa_\beta^{II} - p_1(\chi) \kappa_\beta^I, \\ \psi_2 &= \left(\frac{B}{T} \right)^2 f_2(\alpha) \frac{p_5(\chi)}{\chi} \kappa_\beta^{II} - p_2(\chi) \kappa_\beta^I, \\ \psi_3 &= \left(\frac{B}{T} \right)^2 \left[f_2(\alpha) \frac{p_6(\chi)}{\chi} - f_4(\alpha) \frac{p_7(\chi)}{\chi} \right] \kappa_\beta^{II} - p_3(\chi) \kappa_\beta^I, \\ \psi_4 &= \left(\frac{B}{T} \right)^2 \frac{f_4(\alpha)}{\chi} \kappa_\beta^{III}, \\ \psi_5 &= \left(\frac{B}{T} \right)^2 \frac{f_2(\alpha)}{\chi} \kappa_\beta^{II}. \end{aligned}$$

2.3.5.5 The determination of amplitude of heaving ζ_{gm} and phase δ_ζ is based on solution of the differential equations system of heaving and pitching

$$\begin{aligned}
 & \left(\frac{D}{g} + \lambda_{33k}\right) \ddot{\zeta}_g + v_{33k} \dot{\zeta}_g + \rho g S_0 \zeta_g - \\
 & \quad - \lambda_{35k} \ddot{\psi} - (v_{35k} - v_0 \lambda_{35k}) \dot{\psi} - \\
 & \quad - (\rho g S_0 x_f - v_0 v_{33k}) \psi = \\
 = & r_0 \left(\rho g a_0 - \omega b'_{00} - \omega^2 a''_{00} \right) \cos \omega_k t - \\
 & - r_0 \left(\rho g b_0 - \omega a'_{00} - \omega^2 b''_{00} \right) \sin \omega_k t, \\
 & (J_y + \lambda_{55k}) \ddot{\psi} + \left(v_{55k} - \frac{v_0^2}{\omega^2} v_{35k} \right) \dot{\psi} + \\
 & \quad + (DH_0 - v_0^2 \lambda_{35k}) \psi - \lambda_{35k} \ddot{\zeta}_g - \\
 & \quad - (v_{35k} + v_0 \lambda_{33k}) \dot{\zeta}_g - \\
 & \quad - (\rho g S_0 x_f - v_0 v_{35k}) \zeta_g = \\
 = & -r_0 \left(\rho g a_1 - \omega b'_{11} - \omega^2 a''_{11} \right) \cos \omega_k t + \\
 & + r_0 \left(\rho g b_1 - \omega a'_{11} - \omega^2 b''_{11} \right) \sin \omega_k t
 \end{aligned} \tag{2.3.5.5}$$

where

$\lambda_{33k}, \lambda_{55k}, \lambda_{35k}$	=	added mass coefficients at heaving, pitching and their interaction;
$v_{33k}, v_{55k}, v_{35k}$	=	damping ratios;
S_0	=	waterplane area, m ² ;
x_f	=	longitudinal centre of flotation, m;
H_0	=	longitudinal metacentric height, m;
$a_1, b'_1, a''_1, b_1, a'_1, b''_1$	=	coefficients of exciting forces;
v_0	=	ship speed, m/s.

System coefficients can be calculated in any way generally accepted in ship theory, for example, based on the use of a combined method adapted from application of conformal approximation of frames and the method of hydrodynamic features.

3 VULNERABILITY CRITERIA FOR THE PURE LOSS OF STABILITY FAILURE MODE

3.1 APPLICATION

3.1.1 The provisions of the present Section apply to all ships of $L_1 \geq 24$ m in length, for which the Froude number, F_n , corresponding to the service speed exceeds 0,24.

For the purposes of this Section, it is determined as follows:

$$F_n = \frac{V_s}{\sqrt{gL_1}} \quad (3.1.1)$$

where V_s = service speed, m/s;
 g = gravity acceleration, equal to 9,81 m/s².

3.1.2 For all conditions of loading, a ship, the stability of which:

.1 meets the requirements specified in [3.2](#), is considered not to be vulnerable to the pure loss of stability failure mode;

.2 does not meet the requirements provided in [3.2](#), shall be subject to assessment according to [3.3](#).

Value of h_{min} shall be corrected for the effect of free surfaces of liquid cargoes in accordance with 1.4.7, Part IV "Stability" of the RS Rules/C. The use of simplified estimation h_{min} , given in [3.2.1](#), without initial trim effect can be applied for ships having non-even keel condition as a conservative estimation.

3.2 LEVEL 1 VULNERABILITY CRITERIA FOR THE PURE LOSS OF STABILITY FAILURE MODE

3.2.1 A ship is considered not to be vulnerable to the pure loss of stability failure mode if

$$h_{min} > R_{PLA} \quad (3.2.1)$$

where $R_{PLA} = 0,05$, m;
 h_{min} = the minimum value of the metacentric height taking consideration of free surface effects of liquid cargoes calculated under one of the following conditions: when a longitudinal wave passes the ship, calculated as per [3.2.2](#) or [3.2.3](#), m.

3.2.2 According to [3.2.1](#), h_{min} can be determined by the formula:

$$h_{min} = z_c + \frac{I_L}{V} - z_g \quad \text{only if } \frac{V_D - V}{A_w(D-d)} \geq 1,0, \quad (3.2.2)$$

where z_c = height of the centre of buoyancy corresponding to the loading condition under consideration, m;
 z_g = height of the center of gravity corresponding to the loading condition under consideration, m;
 I_L = moment of inertia of the waterplane at the draft d_L , m⁴;
 V = volume of displacement corresponding to the loading condition under consideration, m³;
 $d_L = d - \delta d_L$, m;
 d = draft amidships corresponding to the loading condition under consideration, m;
 $\delta d_L = \min(d - 0,25d_{full}, \frac{L_1 \cdot S_w}{2})$, m;
 $S_w = 0,0334$;
 D = moulded depth at side to the weather deck, m;
 V_D = volume of displacement at waterline equal to the moulded depth D , m³;
 A_w = waterplane area at the draft equal to d , m².

3.2.3 As provided by [3.2.1](#), h_{min} may be determined as the minimum value of metacentric height calculated for the ship with free surface correction corresponding to the loading condition under consideration, considering the ship to be balanced in sinkage and trim on waves with the following characteristics:

wavelength $\lambda = L_1$;

wave height $h = L_1 \cdot S_w$, where $S_w = 0,0334$;

the wave crest centered at amidships and at $0,1L_1$, $0,2L_1$, $0,3L_1$, $0,4L_1$ and $0,5L_1$ forward and $0,1L_1$, $0,2L_1$, $0,3L_1$, $0,4L_1$ aft thereof.

3.2.4 As provided in [3.2.2](#), if $\frac{V_D - V}{A_w(D-d)} < 1,0$, the righting lever at a heel angle of 30° shall be positive in each specified case.

**3.3 LEVEL 2 VULNERABILITY CRITERIA
FOR THE PURE LOSS OF STABILITY FAILURE MODE**

3.3.1 A ship is considered not to be vulnerable to the pure loss of stability failure mode if the largest value among CR_1, CR_2, CR_3 calculated according to [3.3.3](#), [3.3.4](#) and [3.3.5](#), under the service speed is less than R_{pL_0}

where $R_{pL_0} = 0,06, m.$

3.3.2 Each of the three criteria CR_1, CR_2, CR_3 represents a weighted average of certain stability parameters for a ship considered to be statically positioned in waves of defined height H_i and length λ_i , obtained from [Table 3.3.2](#)

where $CR_1 = \sum_{i=1}^N W_i C1_i =$ weighted criterion 1;
 $CR_2 = \sum_{i=1}^N W_i C2_i =$ weighted criterion 2;
 $CR_3 = \sum_{i=1}^N W_i C3_i =$ weighted criterion 3;
 $W_i =$ a weighting factor obtained from [Table 3.3.2](#);
 $N =$ total number of cases for which $C1_i, C2_i$ and $C3_i$ are evaluated (272 for an option);
 $C1_i =$ criterion 1 evaluated according to [3.3.3](#);
 $C2_i =$ criterion 2 evaluated according to [3.3.4](#);
 $C3_i =$ criterion 3 evaluated according to [3.3.5](#).

For calculating the restoring moment in waves, the following wavelength and wave height shall be used:

wavelength $\lambda = L_1$;
 wave height $h_B = 0,01 \cdot iL_1$, where $i = 0,1, \dots, 10.$

The values of three criteria $C1_i, C2_i, C3_i$ shall be calculated by [formulas 3.3.3 — 3.3.5](#), respectively, using wavelengths and heights obtained from [Table 3.3.2](#).

Specified wave cases for evaluation of the criteria are given in [Table 3.3.2](#). For use in [3.3.3 — 3.3.5](#), N shall be taken equal to 272. For each combination of H_s and T_z , W_i is obtained as the value in [Table 3.3.2](#) divided by 100000, which is associated with a H_i calculated below and λ_i is taken equal to L . The values shall be interpolated from the relationship between h_B and values obtained above.

Table 3.3.2

**Wave case occurrences per 100000 observations
for evaluation of the pure loss of stability failure mode**

$H_s,$ m	Tz, s — average zero up-crossing wave period															
	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	18,5
0,5	1,3	133,7	865,6	1186,0	634,2	186,3	36,9	5,6	0,7	0,1	0,0	0,0	0,0	0,0	0,0	0,0
1,5	0,0	29,3	986,0	4976,0	7738,0	5569,7	2375,7	703,5	160,7	30,5	5,1	0,8	0,1	0,0	0,0	0,0
2,5	0,0	2,2	197,5	2158,8	6230,0	7449,5	4860,4	2066,0	644,5	160,2	33,7	6,3	1,1	0,2	0,0	0,0
3,5	0,0	0,2	34,9	695,5	3226,5	5675,0	5099,1	2838,0	1114,1	337,7	84,3	18,2	3,5	0,6	0,1	0,0
4,5	0,0	0,0	6,0	196,1	1354,3	3288,5	3857,5	2685,5	1275,2	455,1	130,9	31,9	6,9	1,3	0,2	0,0
5,5	0,0	0,0	1,0	51,0	498,4	1602,9	2372,7	2008,3	1126,0	463,6	150,9	41,0	9,7	2,1	0,4	0,1
6,5	0,0	0,0	0,2	12,6	167,0	690,3	1257,9	1268,6	825,9	386,8	140,8	42,2	10,9	2,5	0,5	0,1
7,5	0,0	0,0	0,0	3,0	52,1	270,1	594,4	703,2	524,9	276,7	111,7	36,7	10,2	2,5	0,6	0,1
8,5	0,0	0,0	0,0	0,7	15,4	97,9	255,9	350,6	296,9	174,6	77,6	27,7	8,4	2,2	0,5	0,1
9,5	0,0	0,0	0,0	0,2	4,3	33,2	101,9	159,9	152,2	99,2	48,3	18,7	6,1	1,7	0,4	0,1
10,5	0,0	0,0	0,0	0,0	1,2	10,7	37,9	67,5	71,7	51,5	27,3	11,4	4,0	1,2	0,3	0,0
11,5	0,0	0,0	0,0	0,0	0,3	3,3	13,3	26,6	31,4	24,7	14,2	6,4	2,4	0,7	0,2	0,0
12,5	0,0	0,0	0,0	0,0	0,1	1,0	4,4	9,9	12,8	11,0	6,8	3,3	1,3	0,4	0,1	0,0
13,5	0,0	0,0	0,0	0,0	0,0	0,3	1,4	3,5	5,0	4,6	3,1	1,6	0,7	0,2	0,1	0,0
14,5	0,0	0,0	0,0	0,0	0,0	0,1	0,4	1,2	1,8	1,8	1,3	0,7	0,3	0,1	0,0	0,0
15,5	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,4	0,6	0,7	0,5	0,3	0,1	0,1	0,0	0,0
16,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,2	0,2	0,2	0,1	0,1	0,0	0,0	0,0

3.3.3 Criterion 1.

Criterion 1 is determined by the following formula:

$$C1_i = \begin{cases} 1 & \phi_V < R_{PL1}; \\ 0 & \text{otherwise} \end{cases} \quad (3.3.3)$$

The angle of vanishing stability, ϕ_V , with free surface correction may be determined as the minimum value calculated for the ship corresponding to the loading condition under consideration, considering the ship to be balanced in sinkage and trim on a series of waves with the characteristics specified in [Table 3.3.2](#).

The wave crest is centred at the amidships and at $0,1L_1$, $0,2L_1$, $0,3L_1$, $0,4L_1$ and $0,5L_1$ forward and $0,1L_1$, $0,2L_1$, $0,3L_1$, $0,4L_1$ aft thereof.

$$R_{PL1} = 30^\circ.$$

3.3.4 Criterion 2.

Criterion 2 is determined by a calculation of the ship's stable heel angle in the formula:

$$C2_i = \begin{cases} 1 & \phi_s > R_{PL2a} \text{ or } \phi_{roll}(\text{degrees}) > R_{PL2b}; \\ 0 & \text{otherwise} \end{cases} \quad (3.3.4)$$

The angle of stable heel, ϕ_s , under action of heeling lever specified by R_{PL3} , with free surface correction in case of positive metacentric height h at the upright condition, may be determined as the minimum value calculated for the ship considering to the loading condition under consideration, considering the ship to be balanced in sinkage and trim on a series of waves with the characteristics given in [Table 2.3.2](#).

The wave crest is centred at the amidships and at $0,1L_1$, $0,2L_1$, $0,3L_1$, $0,4L_1$ and $0,5L_1$ forward and $0,1L_1$, $0,2L_1$, $0,3L_1$, $0,4L_1$ aft thereof.

$$R_{PL2a} = 15^\circ;$$

$$R_{PL2b} = 25^\circ.$$

3.3.5 Criterion 3.

Criterion 3 is determined by a calculation of the maximum value of the righting lever curve as provided in the following formula:

$$C3_i = \begin{cases} 1 & l_{max}(m) < R_{PL3}; \\ 0 & \text{otherwise} \end{cases} \quad (3.3.5)$$

l_{max} is determined as the smallest of maxima of the righting lever curves calculated for the ship, with free surface correction, corresponding to the loading condition under consideration, considering the ship to be balanced in sinkage and trim on a series of waves with the characteristics given in [Table 3.3.2](#).

The wave crest is centred at the amidships and at $0,1L_1$, $0,2L_1$, $0,3L_1$, $0,4L_1$ and $0,5L_1$ forward and $0,1L_1$, $0,2L_1$, $0,3L_1$, $0,4L_1$ aft thereof;

$$R_{PL3} = 8(H_i/\lambda)dF_n^2.$$

4 VULNERABILITY CRITERIA FOR THE SURF-RIDING (BROACHING) STABILITY FAILURE MODE

4.1 APPLICATION

4.1.1 The provisions of this Section apply to all ships of $L_1 \geq 24$ m in length.

4.1.2 For each condition of loading, a ship, the stability of which:

.1 meets the requirements specified in [4.2](#), is considered not to be vulnerable to the surf riding (broaching) stability failure mode;

.2 does not meet the requirements specified in [4.2](#), shall be subject to:

to the procedures of ship-handling on how to avoid dangerous conditions for surf-riding and broaching-to recommended in Section 4.2.1 of IMO circular MSC.1/Circ.1228 "Revised guidance to the master for avoiding dangerous situations in adverse weather and sea conditions", information about which is provided in the Stability Booklet and shall be agreed by the Register; or

assessment according to [4.3](#).

4.1.3 For each condition of ship loading, that does not meet the requirements of [4.2](#) and [4.3](#), the ship specific operational limitations shall be introduced to the Stability Booklet based on calculations in accordance with [4.3](#) and shall be approved by the Register.

**4.2 LEVEL 1 VULNERABILITY CRITERIA
FOR THE SURF RIDING (BROACHING) STABILITY FAILURE MODE**

4.2.1 The ship is considered not to be vulnerable to the surf riding (broaching) stability failure mode if one of the following conditions is met:

.1 $L_1 > 200$ m;

or

.2 $F_n > 0,3$.

where F_n = Froude number = $V_s / \sqrt{L_1 g}$;
 V_s = service speed in calm water, m/s.

**4.3 LEVEL 2 VULNERABILITY CRITERIA
FOR THE SURF RIDING (BROACHING) STABILITY FAILURE MODE**

4.3.1 A ship is considered not to be vulnerable to the surf riding/broaching stability failure mode if the value of C is less than R_{SR} :

$$C = \sum_{H_S} \sum_{T_Z} \left(W2(H_S, T_Z) \frac{\sum_{i=1}^{N_\lambda} \sum_{j=1}^{N_a} W_{ij} C2_{ij}}{\sum_{i=1}^{N_\lambda} \sum_{j=1}^{N_a} W_{ij}} \right) \quad (4.3.1)$$

- where $R_{SR} = 0,0001$;
 $W2(H_S, T_Z)$ = the weighting factor of short-term sea state specified in 4.3.2 as a function of the significant wave height, H_S , and the zero-crossing wave period, T_Z ;
 W_{ij} = a statistical weight of a wave specified in 4.3.3 with steepness $(H/\lambda)_j$ and wavelength to ship length ratio $(\lambda/L_{BP})_j$, calculated with the joint distribution of local wave steepness and lengths, which is, with specified discretization $N_\lambda = 80$ and $N_a = 100$;
 $C2_{ij}$ = the value calculated according to 4.3.4.

4.3.2 The value of $W2(H_S, T_Z)$ is obtained as the value in Table 4.3.2 divided by 100000. The number of short-term sea state is 272. Other sources of wave statistics can be used on the discretion of the Register.

Table 4.3.2

**Wave case occurrences per 100 000 observations
for roll response evaluation in parametric rolling**

H_s , m	T_z , s — average zero up-crossing wave period															
	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	18,5
0,5	1,3	133,7	865,6	1186,0	634,2	186,3	36,9	5,6	0,7	0,1	0,0	0,0	0,0	0,0	0,0	0,0
1,5	0,0	29,3	986,0	4976,0	7738,0	5569,7	2375,7	703,5	160,7	30,5	5,1	0,8	0,1	0,0	0,0	0,0
2,5	0,0	2,2	197,5	2158,8	6230,0	7449,5	4860,4	2066,0	644,5	160,2	33,7	6,3	1,1	0,2	0,0	0,0
3,5	0,0	0,2	34,9	695,5	3226,5	5675,0	5099,1	2838,0	1114,1	337,7	84,3	18,2	3,5	0,6	0,1	0,0
4,5	0,0	0,0	6,0	196,1	1354,3	3288,5	3857,5	2685,5	1275,2	455,1	130,9	31,9	6,9	1,3	0,2	0,0
5,5	0,0	0,0	1,0	51,0	498,4	1602,9	2372,7	2008,3	1126,0	463,6	150,9	41,0	9,7	2,1	0,4	0,1
6,5	0,0	0,0	0,2	12,6	167,0	690,3	1257,9	1268,6	825,9	386,8	140,8	42,2	10,9	2,5	0,5	0,1
7,5	0,0	0,0	0,0	3,0	52,1	270,1	594,4	703,2	524,9	276,7	111,7	36,7	10,2	2,5	0,6	0,1
8,5	0,0	0,0	0,0	0,7	15,4	97,9	255,9	350,6	296,9	174,6	77,6	27,7	8,4	2,2	0,5	0,1
9,5	0,0	0,0	0,0	0,2	4,3	33,2	101,9	159,9	152,2	99,2	48,3	18,7	6,1	1,7	0,4	0,1
10,5	0,0	0,0	0,0	0,0	1,2	10,7	37,9	67,5	71,7	51,5	27,3	11,4	4,0	1,2	0,3	0,1
11,5	0,0	0,0	0,0	0,0	0,3	3,3	13,3	26,6	31,4	24,7	14,2	6,4	2,4	0,7	0,2	0,1
12,5	0,0	0,0	0,0	0,0	0,1	1,0	4,4	9,9	12,8	11,0	6,8	3,3	1,3	0,4	0,1	0,0
13,5	0,0	0,0	0,0	0,0	0,0	0,3	1,4	3,5	5,0	4,6	3,1	1,6	0,7	0,2	0,1	0,0
14,5	0,0	0,0	0,0	0,0	0,0	0,1	0,4	1,2	1,8	1,8	1,3	0,7	0,3	0,1	0,0	0,0
15,5	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,4	0,6	0,7	0,5	0,3	0,1	0,1	0,0	0,0
16,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,2	0,2	0,2	0,1	0,1	0,0	0,0	0,0

4.3.3 The value of W_{ij} shall be calculated using the following formula:

$$W_{ij} = \frac{4\sqrt{g}L_1^{5/2}T_{01}}{\pi v(H_s)^3} s_j^2 r_i^{3/2} \left(\frac{\sqrt{1+v^2}}{1+\sqrt{1+v^2}} \right) \Delta r \Delta s \cdot \exp \left[-2 \left(\frac{L_1 \cdot r_i \cdot s_j}{H_s} \right)^2 \left\{ 1 + \frac{1}{v^2} \left(1 - \sqrt{\frac{gT_{01}^2}{2\pi r_i L_1}} \right)^2 \right\} \right] \quad (4.3.3)$$

- where $v = 0,425$;
 $T_{01} = 1,086 T_Z$;
 $s_j = (H/\lambda)_j$ = wave steepness. It varies from 0,03 to 0,15 with the increment $\Delta s = 0,0012$;
 $r_i = (\lambda/L)_i$ = wavelength to ship length ratio. It varies from 1,0 to 3,0 with the increment $\Delta r = 0,025$.

4.3.4 For each wave case, the value of $C2_{ij}$ is calculated as follows:

$$C2_{ij} = \begin{cases} 1 & \text{if } \left| \frac{u}{c_i} - 1 \right| < f_{ij}; \\ 0 & \text{if } \left| \frac{u}{c_i} - 1 \right| \geq f_{ij}, \end{cases} \quad (4.3.4)$$

where u = service speed in calm water, m/s;
 c_i = wave velocity = $\sqrt{\frac{g}{k_i}}$ m/s;
 k_i = wave number = $\frac{2\pi}{r_i L}$ m⁻¹;
 g = gravity acceleration, equal to 9,81 m/s²;
 f_{ij} = empirical limitation on the difference between the relative speed and the wave velocity.

4.3.4.1 The empirical limitation on the difference between the relative speed and the wave velocity is calculated as follows:

$$f_{ij} = 0,534 \cdot \sqrt{\frac{g \cdot k_i \cdot H_{ij} \cdot A_i}{2M}} \quad (4.3.4.1)$$

where H_{ij} = wave height = $s_j r_i L$, m;
 k_i = wave number = $\frac{2\pi}{r_i L}$ m⁻¹;
 g = gravity acceleration equal to 9,81 m/s²;
 M = ship weight in engineering system of units (kgF·sec²/m);
 A_i = amplitude of the volumetric component of the Froude-Krylov wave-exciting force, m³.

4.3.4.2 Amplitude of the volumetric component of the Froude-Krylov wave-exciting force is calculated by the following formula:

$$A_i = \sqrt{F c_i^2 + F S_i^2} \quad (4.3.4.2)$$

where

$$F c_i = \sum_{m=N+1}^1 \{Q_m \cdot \cos[k_i \cdot (x_m - x_G)] + Q_{m-1} \cdot \cos[k_i \cdot (x_{m-1} - x_G)]\} \cdot (x_m - x_{m-1});$$

$$F S_i = \sum_{m=N+1}^1 \{Q_m \cdot \sin[k_i \cdot (x_m - x_G)] + Q_{m-1} \cdot \sin[k_i \cdot (x_{m-1} - x_G)]\} \cdot (x_m - x_{m-1})$$

where

$$Q_m = \frac{1}{2} \cdot \sum_{n=1}^{S(m)-1} \{y_m(z_{n+1}) \cdot \exp[k_i(z_{n+1} - T_m)] + y_m(z_n) \cdot \exp[k_i \cdot (z_n - T_m)]\} \cdot (z_{n+1} - z_n);$$

$F c_i$; $F S_i$ = volumetric components of the Froude-Krylov force in wave exciting force of pitching, m³;

k_i = wave number = $\frac{2\pi}{r_i L}$ m⁻¹;

x_G = abscissa of the centre of gravity, m;

x_m = abscissa of the section under consideration, m;

N = number of sections considered for calculation;

$S(m)$ = number of design waterlines at m-th section;

T_m = hull draught at m-th section;

z_n = applicate of n-th waterline at m-th section.

4.3.5 For the purpose of the proposed vulnerability criterion, the result $C \geq 1$ indicates falling outside the Froude numbers range limits corresponding to the ship capture by a passing wave.

5 OPERATIONAL GUIDEDANCE FOR REDUCING ROLLING PARAMETERS IN THE SUPER-HARMONIC RESONANCE MODE

5.1 The super-harmonic resonances of heaving, rolling, and pitching are resonances that occur at frequencies two times lower than the corresponding natural frequencies. The reason for their occurrence is the polyharmonic form of exciting forces and moments, containing nonlinear components that are always present.

5.2 Based on the calculations performed for various types of ships and the conclusions drawn, the following operational guidelines can be formulated to reduce rolling parameters in these resonance areas.

5.2.1 In case of regular waves:

.1 To avoid intense rolling and heaving at super-harmonic resonant modes, the ship beam to waves shall be avoided, regardless of the ship speed.

.2 At an oblique head wave, the ships speed shall be increased to the design value, which leads to a decrease in amplitudes of rolling and heaving in the super-harmonic resonance areas. At an oblique following wave, on the contrary, the speed shall be reduced in half.

.3 At head regular waves, on the contrary, the ship speed shall be reduced in half.

5.2.2 In case of irregular waves:

.1 The nonlinear forces have the greatest effect on the rolling and acceleration amplitudes at the wave states of 6, 7 and 8 as per the Sea State Code, regardless of the heading angle and speed.

.2 It is necessary to avoid the ship beam to the waves at any wave state, regardless of the speed value.

.3 To reduce vertical and longitudinal accelerations in head irregular waves, the ship's speed shall be reduced by half at any wave state.

5.3 Operational guidance of [5.2](#) shall be included into Section "Guidance to the Master" of the Stability Booklet.

PART II. RECOMMENDATION ON SEAWORTHINESS ASSESSMENT DURING PASSAGES

1 RECOMMENDATIONS TO ENSURE SEAWORTHINESS PROPERTIES AND POSING OF RESTRICTIONS DUE TO WEATHER CONDITIONS DURING PASSAGES

1.1 Provisions of this Part may apply to ships when posing restrictions due to weather conditions during passages.

1.2 Where higher freeboard, enhanced stability or strength of the ship are required by the RS rules for the area of passage, the shipowner shall make all reasonable and practicable arrangements to meet the RS rules requirements by choosing favourable ballasting or loading of the ship, hull reinforcement or dismantling of structures and equipment that can be considered not necessary for the passage.

1.3 Where substantial structural alterations that are hard to make are required to satisfy fully the requirements of the RS rules, prescribed weather restrictions may be applied.

The prescribed weather restrictions shall be substantiated by calculations of wave and wind loads which meet the RS rules requirements as regards strength, stability and freeboard, the experience gained in passages of sister or similar ships within this area being taken into account.

Recommended methods of evaluating limit sea states based on ship strength and limit wind force based on stability are given in [Sections 2](#) and [3](#) of this Part.

1.4 Weather restrictions for the passage shall be not less stringent than the restrictions set in the RS rules for the prescribed area of navigation provided the possibility of applying other, less stringent restrictions, is not confirmed by calculations of the strength, stability and freeboard of the ship, performed for the relevant area of the passage and agreed with RS.

1.5 When setting weather restrictions, apart from regulated sea-keeping qualities such as strength, stability, buoyancy and unsinkability (freeboard), account shall be taken of the extent to which the general seaworthiness is ensured, i.e. governed by the ship size, relationship of principal dimensions, hull lines, height of ship ends above the waterline, availability of superstructures, types of closing arrangements, adequate speed.

1.6 If in case of set weather restrictions, the general seaworthiness of the ship, its stability and draughts cannot provide adequate prevention of excessive accelerations due to ship motions and/or dangerous impacts of the hull against water (slamming) when moving in a seaway, in addition to the weather restrictions, substantiated recommendations on choosing the course and speed in a seaway shall be elaborated. The substantiated recommendations shall be included in the instructions for ship's master or tug master (in case of passage by towing) of passage draft.

For ships limited by wind force 8 (fresh gale) and more and by sea state 7 (rather rough sea) and more, no weather restrictions are normally set.

1.7 In no case shall the limit wave height applied in setting weather restrictions exceed twice the bow freeboard height.

In order to ensure the general (navigational) seaworthiness, the ship shall have an adequate draught on even keel or have a moderate trim by the stern and full submergence of the propeller (for passage under ship's own propulsion). In general case, the draught amidships equal to $L/40 + 1,0$ with a trim by the stern not more than $0,015L$,

where L is the length of the ship, in m, as determined in the Load Line Rules for Sea-Going Ships and in the Guidelines on Application of Provisions of the International Convention on Load Lines (LL-66/88).

In no case shall the limit wave height applied in setting weather restrictions exceed twice the draught amidships.

1.8 When setting weather restrictions for a passage of ships of inland navigation, use shall be made of the specified conditions that shall be met by such ship proceeding to sea.

The conditions are summarised in [Table 1.8](#).

Geographic areas shall be considered and agreed upon with the Register in each particular case. Ships of category "П" are not allowed for sea passage without the hull reinforcement.

Table 1.8

Category in accordance with the Rules for the Classification and Construction of Ships for Inland Waterways of the Russian Federation	Permitted wave height with 3 % probability, m		Corresponding sea state, numbers (range of wave heights, in m, is given in brackets)
	In accordance with the Rules for the Classification and Construction of Ships for Inland Waterways of the Russian Federation	At passage by sea	
М-СП	3,5	≤ 3,5	5 (2–3,5)
М-ПП	3,0	≤ 2,5	5 (2–3,5)
М	3,0	≤ 2,5	5 (2–3,5)
О-ПП	2,0	≤ 2,0	4 (1,25–2,0)
О	1,75 ($h_1\% = 2,0$)	≤ 1,7	4 (1,25–2,0)
П	1,05 ($h_1\% = 1,2$)	≤ 1,0	3 (0,75–1,25)

1.9 The lesser the ship, the more severe are weather restrictions.

Based on the ship size, the wave height with 3 % probability of exceeding level used in setting weather restrictions shall not exceed $h_{3\%} = 0,25L^{3/4}$. For ships of $L \geq 70$ m weather restrictions based on the ship size are not set. For ships of $L < 70$ m weather restrictions shall not be less severe than those prescribed for the particular area of navigation in compliance with the requirements of the RS Rules/C.

1.10 In addition to the limitations on strength and stability conditions or on the freeboard and irrespective of them, for ships with unseaworthy and poorly seaworthy hull shape, characterized by unusual relationship of dimensions, non-streamlined hull, the lack of superstructures (especially a forecastle), the insufficient elevation of the fore end (for example, for pontoon-type ships), weather restrictions attributed to the unseaworthy hull shape shall be set.

These restrictions are motivated by the experience gained in passages or mathematical simulation of the seaworthiness carried out by the competent organization of sister or similar ships and, as a rule, do not exceed 5 by sea state (unless the more stringent restriction is required for other reasons).

When imposing the strength restrictions on a floating dock, the requirements of 3.12.4.7, Part II "Hull" of the RS Rules/C shall be met.

In all cases, the most severe restriction is imposed when restrictions based on several reasons (for example, strength and stability) are set.

1.11 Weather restrictions are set by specifying the common data on wind and wave conditions, adopted in the Hydrometeorological Service, which are limiting for the particular ship.

Wind restrictions are specified in Beaufort numbers relating to the mean equivalent wind speeds in the wind speed range which includes the ultimate wind speed established.

Sea state restrictions are specified in numbers of the sea state scale in force relating to wave heights with 3 % probability of exceeding level in the wave height range which includes the ultimate wave height established.

Specifying the weather (in numbers) and sea state (by the established wave height with 3 % probability of exceeding level) restriction, it is necessary to proceed from the following provision: where the ultimate wave height with 3 % probability of exceeding level for the given ship and the wave range for a particular sea state number is equal to or less than the mean wave height value of the range (the arithmetic mean of boundary values), the sea state restriction is specified one number less.

The same approach shall be followed when the weather restriction in wind force numbers is specified.

1.12 The observance of weather restrictions depends, in particular, on the receipt of forecasts correspondingly to data on wind and wave restrictions specified. The adoption of sea state ranges in wave heights with 3 % probability of exceeding level requires forecasts on the same wave heights. Thus, it shall be taken into consideration that if in the forecast the especially predictable wave height with 3 % probability of exceeding level is not given, the wave height with 5 % probability of exceeding level is specified in national forecasts for the seas washing the Russian Federation and with 13,5 % probability of exceeding level — for other seas and in all foreign forecasts. Connection between these heights is determined by the following formulae:

$$h_{3\%} = 1,08h_{5\%};$$

$$h_{3\%} = 1,33h_{13,5\%}.$$

The adoption of wind number intervals in mean equivalent speeds for calculations by these formulae does not require the consideration of gusts in forecasts.

1.13 Ballasting of ships for a passage or loading of ships lacking the sufficient ballast capacity, shall provide for the most favourable condition to ensure strength, stability and buoyancy (freeboard). In the same time, ballasting combined with loading shall ensure the sufficient draught to avoid excessive wave impacts against the bottom at the fore end and the necessary submergence of the screw (in passage under the ship's own steam).

1.14 Conditions of passage are established in the passage plan (refer to Section 4.5 of Part IV "Occasional and other surveys" of the Rules for Technical Supervision of Ships in Service).

1.15 Ship's passage in ice conditions shall be considered by the Register in each particular case, taking into account the ice reinforcements of the hull, as well as provisions of 2.2.3.1, Part I "Classification" of the RS Rules/C regarding recommendations on ship operation in ice conditions.

2 EVALUATION OF LIMIT SEA STATES BASED ON SHIP' HULL STRENGTH

2.1 In order to roughly evaluate the limit sea state in passage of a ship outside the prescribed area of navigation based on ship's hull strength, the methods given below may be used.

2.2 Ships with longitudinal strength of the hull inadequate for the passage area:

.1 the design ultimate wave height $h_{3\%}$ determined by the conditions of longitudinal strength (for the most weakened cross-section amidships) is defined by the formula

$$h_{3\%} = \frac{2|M_u - M_{sw}|}{C_b B L (L - 2x)} \leq 2d \quad (2.2.1)$$

where M_u = ultimate bending moment for the hull cross-section in question, in kN·m, determined according to 2.3;
 M_{sw} = still water bending moment at the hull cross-section in question for the loaded ship in passage, in kN·m;
 L, B and d = ship's length, breadth and draught in passage respectively, in m;
 C_b = ship's block coefficient at the displacement in passage;
 x = distance from the hull cross-section in question to the amidships, in m ($x = 0,2L$ if $x < 0,2L$).

.2 the absolute difference of M_{ux} and M_{swx} is calculated subject to their signs.

M_{ux} and M_{swx} are assumed positive in hogging and negative in sagging;

.3 an ultimate bending moment M_{ux} for the hull cross-section in question is assumed equal to the lesser of values determined by the following formulae:

$$M'_{ux} = \frac{I}{Z_{max}} R_{eH} 10^{-5}; \quad (2.2.3-1)$$

$$M'_{ux} = \frac{I}{Z_i} \sigma_{cr} 10^{-5} \quad (2.2.3-2)$$

where R_{eH} = the upper yield stress of steel, in MPa;
 Z_{max} = distance from the horizontal neutral axis of the hull cross-section in question to the most remote member in tension, in m;
 I = inertia moment of the ship's hull cross-section in question about the horizontal neutral axis, in cm⁴;
 Z_i = distance from the horizontal neutral axis to the centre of gravity of the cross section of the i -th compressed member of the strength deck, bottom or inner bottom (carling, bottom stringer, longitudinal), in m;
 σ_{cr} = critical stress of the i -th member specified, in MPa, in the hull cross-section in question.

The possibility of reducing the flexible members (plates) subjected to rated compressing stresses shall be considered when the hull cross-section inertia moment is determined. In this case, the plate parts adjacent to longitudinals on each side within 0,25 of the size of the short side of a support contour are not subject to reducing.

The flexible member parts being reduced are entered into calculation with a reduction factor ψ determined by the formula

$$\psi = \sigma_{cr} / \sigma_{rm} \quad (2.2.3-3)$$

where σ_{cr} = critical stress of the i -th plate, in MPa, in the hull cross-section in question;
 σ_{rm} = compressing stresses in rigid members due to a longitudinal bending, in MPa.

2.3 The height of a design wave with 3 % probability for the ships having local hull strength inadequate for the passage area is determined on the basis of the quantity of a rated load p which does not cause stresses in hull members over the following values:

$0,85R_{eH}$ = for floors and web frames;

R_{eH} = for stringers and keelsons;

R_{eH} = for shell plating;

$0,80R_{eH}$ = for framing and plating of superstructure end bulkheads and deckhouse walls;

where R_{eH} = yield strength of steel.

The wave height with 3 % probability $h_{3\%}$, in m, is determined for different grillages by the following formulae:

.1 for bottom and side plating and framing amidships

$$h_{3\%} = \frac{4}{3}(0,1p - d) \quad (2.3.1-1)$$

where p (for bottom) = uniform load, in kPa;

p (for sides) = design head of the load at the bottom level distributed to a triangle or trapezoid, in kPa;

d = ship's draught, in m.

The counter pressure P_L , in kPa, of a cargo (ballast) on the bottom may be considered for the members carrying this counter pressure as follows:

$$\text{at } P_L \leq 10d \quad h_{3\%} = \frac{4}{3}(0,1p - d + 0,1P_L); \quad (2.3.1-2)$$

$$\text{at } P_L > 10d \quad h_{3\%} = \frac{4}{3}(0,1p + d - 0,1P_L). \quad (2.3.1-3)$$

The counter pressure of a liquid cargo only may be considered for sides;

.2 for bottom within $0,25L$ from the fore perpendicular

$$h_{3\%} = \frac{2}{3}(0,1p - d) \text{ for a wedge-shaped forward end}; \quad (2.3.2-1)$$

$$h_{3\%} = \frac{1}{2}(0,1p - d) \text{ for a spoon-shaped forward end}; \quad (2.3.2-2)$$

$$h_{3\%} = \frac{2}{5}(0,1p - d) \text{ for a sledge-shaped forward end} \quad (2.3.2-3)$$

where p = uniform load on bottom, in kPa.

.3 for end superstructure bulkheads and deckhouse walls on the exposed deck

$$h_{3\%} = k_p(0,07L + l) \quad (2.3.3)$$

where $k = 1$ for forward bulkheads;

$k = 2$ for forward walls of deckhouse;

$k = 4$ for aft bulkheads;

p = uniform load on the wall (bulkhead), in kPa.

2.4 Restrictions on the limit sea state from the conditions of longitudinal ([refer to 2.2](#)) and local ([refer to 2.3](#)) strength are established from the least calculated value of a wave with 3 % probability. However, in all cases the least wave height is to be assumed not greater than $2d$.

The limit sea state is determined in accordance with [Table 2.4](#) from the least wave height with 3 % probability. The wave height according to the Table is assumed equal to the arithmetic mean of extreme wave heights specified in Table for the given sea state.

Table 2.4

Wave height with 3 % probability, in m	Mid-range (interval), in m	Degree of sea state, numbers	Seas
0,75–1,25	1,0	3	moderate (rough) sea
1,25–2,0	1,63	4	rough sea
2,0–3,5	2,75	5	rather rough sea
3,5–6,0	4,75	6	rather rough sea
6,0–8,5	7,25	7	precipitous sea
8,5–11,0	9,75	8	precipitous sea

If the design wave height with 3 % probability is under 1,5 m, the possibility of a sea passage for such a ship without hull reinforcements shall be considered by RHO in order to take special precautions for actual prevention of an opportunity to violate weather restrictions during the passage.

No strength restrictions are specified when the design wave height with 3 % probability is 10 m and over.

2.5 For ships which have not yet approached the residual thickness measurement dates prescribed for the relevant ship age and type by the Rules for Technical Supervision of Ships in Service, as-built scantlings of the hull members shall be adopted as effective ones. For hulls in respect of which residual thickness measurements are assumed in compliance with the Rules for Technical Supervision of Ships in Service conditional on the age and type, actual residual thicknesses of the hull members shall be adopted as effective ones proceeding from proper hull condition assessment reports.

3 EVALUATION OF LIMIT WIND FORCE BASED ON SHIP'S STABILITY

3.1 In order to roughly evaluate the limit wind force based on ship's stability, the method given below may be used.

The limit wind force is determined depending on the parameter P calculated by the formula

$$P = 109k_6 \sqrt{\frac{l_m D \theta_c}{(A - B \theta_c) S_w}} (1 - 1,4\theta_m / \theta_v) \quad (3.1-1)$$

where k_6 = coefficient of wind velocity reduction to a height of 6 m above the sea level determined by the formula $k_6 = 1,11 - 0,02(Z_w - T)$;
 S_w = windage area, in m²;
 Z_w = elevation of the centre of effort above the base plan, in m;
 T = ship's draught, in m;
 D = ship's displacement, in t;
 θ_m = roll amplitude, in degrees, recommended to be assumed according to the data of model and full-scale tests or according to a calculation. If those data are lacking, it may be determined by the formulae given in Part IV "Stability" of the RS Rules/C;
 θ_v = angle of vanishing stability, in rad;
 θ_c = capsizing angle, in deg;
 l_m = mean arm corresponding to the capsizing angle, in m, determined by the formula

$$l_m = 1/\theta_c \int_0^{\theta_c} l d\theta \quad (3.1-2)$$

$$A = Z_w - T/4 - Z_g/2 \quad (3.1-3)$$

$$B = 0,155(Z_w - T) \quad (3.1-4)$$

where Z_g = elevation of the ship's centre of gravity above the base plane, in m.

3.2 The limit wind force is determined by the determined parameter P in accordance with the [Table 3.2](#).

The wind force obtained shall be corrected to match the materials of service experience of ships similar in type. If such a material is unavailable, the determined limit wind force shall be reduced by a number.

The calculation of the limit wind force shall be effected for loading under the conditions of a passage with minimum stability.

Table 3.2

P , in m/s	Wind	Limit wind force
1,0	calm	0
3,2	light air	1
6,2	light breeze	2
9,6	gentle breeze	3
13,6	moderate breeze	4
17,8	fresh breeze	5
22,3	strong breeze	6
26,2	high wind	7
31,6	fresh gale	8
36,7	strong gale	9
42,0	whole gale	10
47,5	storm	11
53,0	hurricane	12

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