Strength Assessment by Cargo Hold Analysis

Amended Rules

Rules for the Survey and Construction of Steel Ships Part C

Reason for Amendment

The comprehensive revision of Part C of the Rules, which began in the latter half of 2017 and continued until early 2022, was approved by the Technical Committee at its first meeting in 2022. An impact study of new Part C was subsequently carried out with the cooperation of various shipyards, and this study confirmed that there were several requirements still need in some further brushing up. Based on the feedback received from the study, some of the requirements related to strength assessments based on cargo hold analysis, such as load requirements and strength assessment requirements, were further revised.

Relevant requirements are therefore amended to reflect the feedback received from the impact study.

Outline of Amendment

(1) Amends some of loads requirements in flooded condition among the loads considered in strength assessment by cargo hold analysis.
(2) Amends carrying out yield strength assessment in addition to buckling strength assessment in the strength assessments for region other than the region of rigidity reduction among the strength assessment considering effect of surrounding structures
(3) Amends some of loads in 30-degree static heel condition and collision condition among the loads considered in strength assessment by cargo hold analysis for ships carrying liquefied gases in bulk (independent prismatic tanks type A/B).

"Rules for the survey and construction of steel ships" has been partly amended as follows:

Part C HULL CONSTRUCTION AND EQUIPMENT

Part 1 GENERAL HULL REQUIREMENTS

Chapter 4 LOADS

4.6 Loads to be Considered in Strength Assessment by Cargo hold Analysis

4.6.5 Flooded Condition

4.6.5.2 External Pressure

Table 4.6.5-1 has been amended as follows.

Table 4.6.5-1 External Pressure P_{FD-ex} in Flooded Condition

~~External pressure P_{FD-ex} (kN/m^2)~~
~~$P_{FD-ex} = \rho g h_{FD}$~~
~~Notes:~~ ~~h_{FD}: Assumed draught height (m) in the flooded condition from the position under consideration, as given by the following formula (1):~~ ~~$h_{FD} = \max(z_{FB} - z, \lvert y \rvert \sin\theta_{FD} + (z_{FB} - z)\cos\theta_{FD})$~~ ~~$z_{FB}$: Z coordinate (m) of the freeboard deck at side in way of the transverse section under consideration~~ ~~z_{FD}: Z coordinate (m) of the greatest value among deepest equilibrium waterline at the centreline amidships, excluding flooded conditions where the probability of survival in damage stability calculations is 0.~~ ~~θ_{FD}: Greatest value among the deepest equilibrium heel angle (rad), excluding flooded conditions where the probability of survival in damage stability calculations is 0.~~
~~(1) When the maximum draught was obtained based on the combination of z_{FB} and z_{FD} in each case to be considered in damage stability calculations, the said draught may be regarded as the assumed draught height.~~

External pressure P_{FD-ex} (kN/m^2)	
$FD1$[(1)(2)]	$P_{FD-ex} = \rho g h_{FD1}$
$FD2$[(1)(2)]	$P_{FD-ex} = \rho g h_{FD2}$
$FD3$[(1)]	$P_{FD-ex} = \rho g (z_{FB} - z)$
Notes: h_{FD1}, h_{FD2}: Assumed draught height (m) in the flooded condition from the position under consideration, as given by the following formulae [(3)]: $h_{FD1} = y \sin\theta_{FD} + (z_{FD} - z)\cos\theta_{FD}$ $h_{FD2} = -y \sin\theta_{FD} + (z_{FD} - z)\cos\theta_{FD}$ z_{FD}: Z coordinate (m) of the greatest value among deepest equilibrium waterline at the centreline amidships, excluding flooded conditions where the probability of survival in damage stability calculations is 0. θ_{FD}: Greatest value among the deepest equilibrium heel angle (rad), excluding flooded conditions where the probability of survival in damage stability calculations is 0. z_{FB}: Z coordinate (m) of the freeboard deck at side in way of the transverse section under consideration	

(1) In case of $z_{FD} \geq z_{FB}$, *FD*3 may not be considered.
(2) For ships with structure symmetrical about centreline, either *FD*1 or *FD*2 may be considered.
(3) When the maximum draught was obtained based on the combination of z_{FD} and θ_{FD} in each case to be considered in damage stability calculations, the said draught may be regarded as the assumed draught height.

4.6.5.3 Internal Pressure

Table 4.6.5-2 has been amended as follows.

Table 4.6.5-2 Internal Pressure P_{FD-in} in Flooded Condition

~~Internal pressure P_{FD-in} (kN/m^2)~~
~~$P_{FD-in} = \rho g h_{FD}$~~
~~Notes:~~ ~~h_{FD}: Assumed draught height (*m*) in the flooded condition from the position under consideration, as given by the following formula (1).~~ ~~$h_{FD} = \max(z_{FB} - z, \lvert y \rvert \sin\theta_{FD} + (z_{FB} - z)\cos\theta_{FD})$~~ ~~$z_{FB}$: Z coordinate of the freeboard deck (*m*) at side in way of the transverse section of the hull under consideration~~ ~~z_{FD}: Z coordinate of the greatest value (*m*) among deepest equilibrium waterline at the centreline amidships, excluding flooded conditions where the probability of survival in damage stability calculations is 0.~~ ~~θ_{FD}: Greatest value among deepest equilibrium heel angle (*rad*), excluding flooded conditions where the probability of survival in damage stability calculations is 0.~~
~~(1) When the maximum draught was obtained based on the combination of z_{FD} and θ_{FD} in each case to be considered in damage stability calculations, the said draught may be regarded as the assumed draught height.~~

Internal pressure P_{FD-in} (kN/m^2)	
*FD*1(1)(2)	$P_{FD-in} = \rho g h_{FD1}$
*FD*2(1)(2)	$P_{FD-in} = \rho g h_{FD2}$
*FD*3(1)	$P_{FD-in} = \rho g (z_{FB} - z)$
Notes: h_{FD1}, h_{FD2}: As specified in **Table 4.6.5-1** (3) z_{FB} : As specified in **Table 4.6.5-1**	
(1) In case of $z_{FD} \geq z_{FB}$, *FD*3 may not be considered. (2) For ships with structure symmetrical about centreline, either *FD*1 or *FD*2 may be considered. (3) When the maximum draught was obtained based on the combination of z_{FD} and θ_{FD} in each case to be considered in damage stability calculations, the said draught may be regarded as the assumed draught height.	

4.6.5.4 has been amended as follows.

4.6.5.4 Weight of Hull Structure, Etc.

The effect of gravitational acceleration acting on the hull structure ~~in still water~~ is to be considered. In case of *FD*1 and *FD*2, the effect of heel angle is to be considered.

Chapter 8 STRENGTH ASSESSMENT BY CARGO HOLD ANALYSIS

8.6 Strength Assessment

8.6.2 Buckling Strength Assessment*

8.6.2.1 has been amended as follows.

8.6.2.1 Criteria

1 In principle, all members in the target hold are to satisfy the buckling assessment criteria specified in **Annex 8.6 "BUCKLING STRENGTH ASSESSMENT BASED ON CARGO HOLD ANALYSIS"**. The permissible utilisation factor in this assessment is to be in accordance with **Table 8.6.2-1**.

2 Notwithstanding **-1** above, strength assessment considering the characteristics of a member to be assessed and surrounding structures of the member may be carried out where the surrounding structures are able to withstand compressive loads instead of the member due to load redistribution after the elastic buckling of the member occurs and where the strength deemed as sufficient by the Society. In this case, the strength assessment specified in **Annex 8.6A "STRENGTH ASSESSMENT CONSIDERING EFFECT OF SURROUNDING STRUCTURES"** may be applied. Where **Annex 8.6A** is applied, the permissible utilisation factor is to be 0.8 for the utilisation factor specified in **An2.6.1**. As for the yield strength assessment and buckling assessment specified in **An2.7.1** in the said Annex, **8.6.1** and **8.6.2.1-1** are to be satisfied.

3 Notwithstanding **-1** above, where compliance with **Annex 8.6** is recognised as difficult due to the stress distribution or deformation characteristics assumed for the buckling strength assessment method specified in **Annex 8.6**, requirements deemed appropriate by the Society are to be followed.

Annex 8.6A STRENGTH ASSESSMENT CONSIDERING EFFECT OF SURROUNDING STRUCTURES

An2 Strength Assessment Method Considering the Effect of the Surrounding Structures

An2.7 has been amended as follows.

An2.7 Strength Assessments of Surrounding Structures After Rigidity Reduction

An2.7.1

1 The yield strength and buckling strength assessments ~~specified in **Annex 8.6 "BUCKLING STRENGTH ASSESSMENT BASED ON CARGO HOLD ANALYSIS"**~~ are to be performed for the region other than the region of rigidity reduction determined in **An2.2.1**, based upon stress obtained from finite element analysis in consideration of the rigidity reduction specified in **An2.3.2**. The buckling strength assessment is to be accordance with **Annex 8.6 "BUCKLING STRENGTH ASSESSMENT BASED ON CARGO HOLD ANALYSIS".**

2 ~~Buckling~~ In application of **-1** above, the strength assessments may be omitted for ~~stiffened panels and plate~~ elements and panels to which the appropriate ~~buckling~~ strength assessment is not applicable ~~because of applying the rigidity reduction. As for the region, strength assessments based on this Annex are not to be performed for the stress obtained in accordance with **An2.3.2.**~~

3 In application of **-1** above, the strength assessment based upon the requirements of **An2.2** to **An2.6** is not to be carried out for the region other than the region of rigidity reduction.

Part 2-1 CONTAINER CARRIERS

Chapter 8 STRENGTH ASSESSMENT BY CARGO HOLD ANALYSIS

8.6 Strength Assessment

8.6.1 has been amended as follows.

8.6.1 Yield Strength Assessment and Buckling Strength Assessment

8.6.1.1 Buckling Strength Assessment of Girders Attached to Partial Bulkheads

1 In the buckling strength assessment of the girders attached to the partial bulkheads, the buckling strength of a plate panel or an opening panel is to be assessed as well as the bucking strength of the struts in **An2.5** of **Annex 8.6, Chapter 8, Part 1** (*See* **Table 8.6.1-1**). Where the buckling strength assessment of the struts is carried out, the struts may be taken as the members without openings.

2 In applying the requirements of **-1** above, the following **(1)** and **(2)** are to be followed.

(1) For the plate panel adjacent to the inner bottom plating and longitudinal bulkheads, the boundary conditions of **An2.5.1-2(1)(ii)** of **Annex 8.6, Part 1 "Buckling Strength Assessment Based on Cargo Hold Analysis"** are to be used.

(2) For other plate panels, the boundary conditions of **An2.5.1-2(1)(iii)** of **Annex 8.6, Part 1** are to be used.

3 Notwithstanding the requirements in **-1** above, where the primary supporting members attached to the partial bulkheads are sandwiched between plate members on both sides, the boundary conditions of **An2.5.1-2(1)(i)** of **Annex 8.6, Part 1** are to be used where deemed appropriate by the Society.

8.6.1.2 Strength Assessment of Side Shell in Beam Sea

1 When a strength assessment is performed considering the load based on the equivalent design waves *BR* and *BP* in maximum load condition, **8.6.2.1-2, Part 1** may be applied for stiffened panels of side shell instead of **8.6.2.1-1, Part 1** where the stress in the direction parallel to the shorter edge of the panels, which is due to bending deformation of side transverse and side shell, is dominant component (*See* **Table 8.6.1-1**).

2 In application of **-1** above, yield strength assessment of side shell may not be carried out.

3 ~~Further, in applying~~ In application of **-1** above, where the yield strength assessment and buckling strength assessment specified in **An2.7 in Annex 8.6A, Part 1 "STRENGTH ASSESSMENT CONSIDERING THE EFFECT OF SURROUNDING STRUCTURES"** are carried out, ~~a~~ the yield strength and buckling strength assessments may not be required for the following stiffened panels, ~~and~~ plate panels and elements including these panels.

(1) Stiffened panels within the rigidity reduction range

(2) Plate panels which include elements of the side transverse sharing nodes included in elements forming **(1)** above

Table 8.6.1-1 Relationship between the application of Part 1 and Part 2

<table>
<tr><td rowspan="2">Member to be assessed</td><td colspan="2">Maximum load condition</td></tr>
<tr><td>Equivalent design wave HM and FM</td><td>Equivalent design wave BR and BP</td></tr>
<tr><td>Side shell
(Annex 8.6A, Part 1 is applied for equivalent design wave BR and BP)</td><td rowspan="2">・Yield strength assessment:
As specified in 8.6.1, Part 1
・Buckling strength assessment:
As specified in 8.6.2.1-1, Part 1</td><td>・An2.2 to An2.6 of Annex 8.6A, Part 1 are applied.
・Permissible utilization factor (buckling): 0.8
・Yield strength assessment: NA</td></tr>
<tr><td>Members other than side shell
(Annex 8.6A, Part 1 is applied for equivalent design wave BR and BP)</td><td>・An2.7 of Annex 8.6A, Part 1 is applied.
・Yield strength assessment: As specified in 8.6.1, Part 1.
・Buckling strength assessment: As specified in 8.6.2.1-1, Part 1.</td></tr>
<tr><td>Girders attached to partial bulkhead(1)</td><td colspan="2">・Yield strength assessment: As specified in 8.6.1, Part 1.
・Buckling strength assessment: As specified in 8.6.2.1-1, Part 1. In addition, as specified in 8.6.1.1.</td></tr>
<tr><td colspan="3">Notes:
(1) The same requirements apply to harbour condition, testing condition and flooded condition.</td></tr>
</table>

Part 2-2 BOX-SHAPED BULK CARRIERS

Chapter 8 STRENGTH ASSESSMENT BY CARGO HOLD ANALYSIS

8.5 Strength Assessment

8.5.1 has been amended as follows.

8.5.1 Yield Strength Assessment and Buckling Strength Assessment

8.5.1.1 Strength Assessment of Side Shell in Beam Sea

1 Where strength assessment is performed considering the load based on the equivalent design waves *BR* and *BP* in the maximum load condition, **8.6.2.1-2, Part 1** may be applied for stiffened panels of side shell instead of **8.6.2.1-1, Part 1** where the compressive stress in the shorter side direction of the panels, which is due to bending deformation of side transverse and side shell, is a dominant component (*See* **Table 8.5.1-1**).

2 In application of **-1** above, yield strength assessment of side shell may not be carried out.

3 ~~Further, in applying~~ In application of **-1** above, where the yield strength assessment and buckling strength assessment specified in **An2.7 in Annex 8.6A, Part 1 "STRENGTH ASSESSMENT CONSIDERING THE EFFECT OF SURROUNDING STRUCTURES"** are carried out, ~~a~~ the yield strength and buckling strength assessments may not be required for the following stiffened panels, ~~and~~ plate panels and elements including these panels.

(1) Stiffened panels within the rigidity reduction range

(2) Plate panels which include elements of the side transverse sharing nodes included in elements forming **(1)** above

8.5.1.2 Buckling Strength Assessment of Cross Deck in Head sea and Following sea

Where strength assessment is performed considering the load based on the equivalent design waves *HM*-1 and *FM*-1 in the maximum load condition, assessment of **8.6.2.1-1, Part 1** may not be carried out for plate panel on cross deck stiffened in transverse direction when the following is satisfied (*See* **Table 8.5.1-1**):

(1) The stress in longitudinal direction on cross deck due to vertical bending moment is act on the narrow area enough compared to the length of cross deck in transverse direction.

(2) Thickness of cross deck adjacent to upper deck longitudinally stiffened is greater than 50% of thickness of the upper deck.

Table 8.5.1-1 Relationship between the application of Part 1 and Part 2

Member to be assessed	Maximum load condition	
	Equivalent design wave *HM* and *FM*	Equivalent design wave *BR* and *BP*
Side shell (**Annex 8.6A, Part 1** is applied for equivalent design wave *BR* and *BP*)	・Yield strength assessment: As specified in **8.6.1, Part 1** ・Buckling strength assessment: As specified in **8.6.2.1-1, Part 1**	・**An2.2** to **An2.6** of **Annex 8.6A, Part 1** are applied. ・Permissible utilization factor (buckling): 0.8 ・Yield strength assessment: *NA*
Members other than side shell (**Annex 8.6A, Part 1** is applied for equivalent design wave *BR* and *BP*)		・**An2.7** of **Annex 8.6A, Part 1** is applied. ・Yield strength assessment: As specified in **8.6.1, Part 1.** ・Buckling strength assessment: As specified in **8.6.2.1-1, Part 1.**
Cross deck	・Yield strength assessment: As specified in **8.6.1, Part 1.** ・Buckling strength assessment: As specified in **8.5.1.2.**	・Yield strength assessment: As specified in **8.6.1, Part 1.** ・Buckling strength assessment: As specified in **8.6.2.1-1, Part 1.**

Part 2-3 ORE CARRIERS

Chapter 8 STRENGTH ASSESSMENT BY CARGO HOLD ANALYSIS

8.5 Strength Assessment

8.5.1 has been amended as follows.

8.5.1 Yield Strength Assessment and Buckling Strength Assessment

8.5.1.1 Strength Assessment of Side Shell in Beam Sea

1 Where strength assessment is performed considering the load based on the equivalent design waves *BR* and *BP* in the maximum load condition, **8.6.2.1-2, Part 1** may be applied for stiffened panels of side shell instead of **8.6.2.1-1, Part 1** where the compressive stress in the shorter side direction of the panels, which is due to bending deformation of side transverse and side shell, is dominant component (*See* **Table 8.5.1-1**).

2 In application of **-1** above, yield strength assessment of side shell may not be carried out.

3 ~~Further, in applying~~ In application of **-1** above, where the yield strength assessment and buckling strength assessment specified in **An2.7 in Annex 8.6A, Part 1 "STRENGTH ASSESSMENT CONSIDERING THE EFFECT OF SURROUNDING STRUCTURES"** are carried out, ~~a~~ the yield strength and buckling strength assessments may not be required for the following stiffened panels, ~~and~~ plate panels and elements including these panels.

(1) Stiffened panels within the rigidity reduction range

(2) Plate panels which include elements of the side transverse sharing nodes included in elements forming **(1)** above

(3) Plate panels on lower stool plating

8.5.1.2 Strength Assessment of Lower Stool Plating in Beam Sea

1 Where strength assessment is performed considering the load based on the equivalent design waves *BR* and *BP* in the maximum load condition, **8.6.2.1-2, Part 1** may be applied for plate panels of lower stool plating instead of **8.6.2.1-1, Part 1** (*See* **Table 8.5.1-1**).

2 In application of **-1** above, yield strength assessment of lower stool plating may not be carried out.

3 ~~Further, in applying~~ In application of **-1** above, where the yield strength assessment and buckling strength assessment specified in **An2.7 in Annex 8.6A, Part 1 "STRENGTH ASSESSMENT CONSIDERING THE EFFECT OF SURROUNDING STRUCTURES"** are carried out, the yield strength and buckling strength assessments may not be required for the following plate panels and elements including the panels.

(1) Plate panels within the region of rigidity reduction

8.5.1.3 Buckling Strength Assessment of Cross Ties in Wing Tanks

In applying **8.6.2, Part 1**, when assessing the column buckling of cross ties in ore carrier's wing tanks based upon the requirements specified in **An2.5, Annex 8.6, Part 1 "Buckling Strength Assessment Based on Cargo Hold Analysis"**, the cross tie span l is to be the distance from the flange of the side stringer attached to the longitudinal bulkhead where the horizontal girder for the cross tie is mounted, to the flange of the side stringer attached to the side shell (*See* **Table 8.5.1-1**). However, if this is difficult to determine based on this definition, the cross-tie span l may be determined upon prior consultation with the Society.

8.5.1.4 Buckling Strength Assessment of Cross Deck in Head sea and Following sea

Where strength assessment is performed considering the loads based on the equivalent design waves *HM*-1 and *FM*-1 in the maximum load condition, the assessment specified in **8.6.2.1-1, Part 1** may not be carried out for plate panels on cross deck stiffened in transverse direction where the following is satisfied (*See* **Table 8.5.1-1**).:

(1) The stress in longitudinal direction on cross deck due to vertical bending moment is act on the narrow area enough compared to the length of cross deck in transverse direction.

(2) Thickness of cross deck adjacent to upper deck longitudinally stiffened is greater than 50% of thickness of the upper deck.

Table 8.5.1-1 Relationship between the application of Part 1 and Part 2

<table>
<tr><td rowspan="2">Member to be assessed</td><td colspan="2">Maximum load condition</td></tr>
<tr><td>Equivalent design wave HM and FM</td><td>Equivalent design wave BR and BP</td></tr>
<tr><td>Side shell and lower stool plating
(Annex 8.6A, Part 1 is applied for equivalent design wave BR and BP)</td><td rowspan="2">・Yield strength assessment:
As specified in 8.6.1, Part 1
・Buckling strength assessment:
As specified in 8.6.2.1-1, Part 1</td><td>・An2.2 to An2.6 of Annex 8.6A, Part 1 are applied.
・Permissible utilization factor (buckling): 0.8
・Yield strength assessment: NA</td></tr>
<tr><td>Members other than side shell and lower stool plating
(Annex 8.6A, Part 1 is applied for equivalent design wave BR and BP)</td><td>・An2.7 of Annex 8.6A, Part 1 is applied.
・Yield strength assessment:
As specified in 8.6.1, Part 1.
・Buckling strength assessment:
As specified in 8.6.2.1-1, Part 1.</td></tr>
<tr><td>Cross deck</td><td>・Yield strength assessment:
As specified in 8.6.1, Part 1.
・Buckling strength assessment:
As specified in 8.5.1.4.</td><td>・Yield strength assessment:
As specified in 8.6.1, Part 1.
・Buckling strength assessment:
As specified in 8.6.2.1-1, Part 1.</td></tr>
<tr><td>Cross ties in wing tanks(1)</td><td colspan="2">・Yield strength assessment: As specified in 8.6.1, Part 1.
・Buckling strength assessment: As specified in 8.6.2.1-1, Part 1. In addition, as specified in 8.5.1.3.</td></tr>
<tr><td colspan="3">Notes:
(1) The same requirements apply to harbour condition, testing condition and flooded condition.</td></tr>
</table>

Part 2-9 SHIPS CARRYING LIQUEFIED GASES IN BULK (INDEPENDENT PRISMATIC TANKS TYPE A/B)

Chapter 4 Loads

4.3 Loads to be Considered in Strength Assessment by Cargo Hold Analysis

4.3.4 30-Degree Static Heel Condition

4.3.4.5 has been renumbered to 4.3.4.6, and 4.3.4.5 has been added as follows.

4.3.4.5 Weight of Hull Structure, Etc.

Self-weight of hull structure and cargo tank structure depending on 30-degree heel is to be considered.

4.3.4.~~5~~6 Hull Girder Loads

(Omitted)

4.3.5 Collision Condition

4.3.5.4 has been amended as follows.

4.3.5.4 Internal Pressure

The internal pressure P_{in-COL} due to cargo (kN/m^2) acting on the cargo tank is to be in accordance with the following formula. Dynamic pressure in two conditions that acceleration of $0.5g$ in aft direction and $0.25g$ in forward direction is to be considered. ~~However~~ In addition, ~~it~~P_{in-COL} is not to be less than 0.