

Lecture Note of Innovative Ship and Offshore Plant Design

Innovative Ship and Offshore Plant Design

Part I. Ship Design

Ch. 5 Freeboard Calculation

Spring 2016

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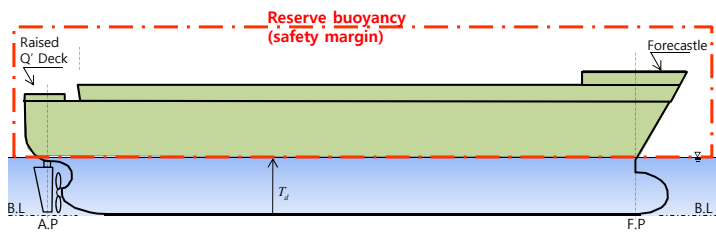
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Ch. 5 Freeboard Calculation

1. Concept
2. International Convention on Load Lines (ICLL) 1966
3. Procedure of Freeboard Calculation

1. Concept

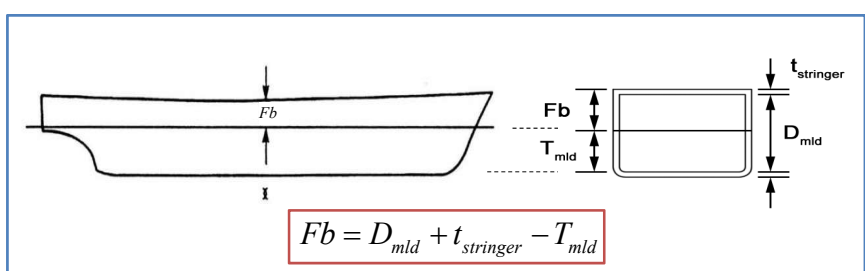
Purpose

- The purpose of the freeboard**

 - The ship needs an additional safety margin to maintain buoyancy and stability while operating at sea.
 - This safety margin is provided by _____ of the hull located above the water surface (_____).
- The regulation of the freeboard**
 - International Convention on Load Lines 1966 (_____)

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Definition (1/2)

- Freeboard (Fb)**


$$Fb = D_{mid} + t_{stringer} - T_{mid}$$
 - **Definition:** The freeboard is the _____ measured at the deck edge at the mid-length between the perpendiculars. It includes the thickness of stringer plate.¹⁾
 - In other word, the _____ between the _____ and the _____ (at the deck line). It includes the thickness of stringer.
 - **Molded Depth (D_{mid}):** The molded depth is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side.
 - **Depth for freeboard (D):** The depth for freeboard is the molded depth amidships, plus the stringer thickness at side.
 $D_f = D_{mid} + t_{stringer}$; $t_{stringer}$: Thickness of the stringer

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1) International Convention on Load Lines 1966, ANNEX1 Chapter 1, Reg.3-(9), 2003
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Definition (2/2)

▪ **Freeboard (Fb)**

$$D_f - T_{mld} \geq Fb_{req.}$$

- **Requirement**
: Actual freeboard should **not be less** than the required freeboard of ICLL 1966.

$$Fb = D_{mld} + t_{stringer} - T_{mld}$$

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Effect of Freeboard on Ships' Characteristics (1/3)

: The freeboard influences the following ship's characteristics.

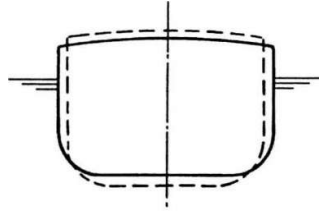
1. Dryness of deck.
 - (a) because walking on wet deck can be dangerous
 - (b) as a safety measure against water entering through deck openings
 - (c) to prevent violent seas destroying the superstructure
2. in damaged condition.
3. (characteristics of righting arm curve).
4. .

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Effect of Freeboard on Ships' Characteristics (2/3)

▪ Large Freeboard



Greater freeboard at the expense of breadth decreases stability.

A large freeboard improves stability. It is difficult to consider this factor in the design.

Since for reasons of cost **the necessary minimum underdeck volume** should not be exceeded and the length is based [on economic considerations](#), [only a decrease in breadth](#) would [compensate](#) for an [increase in freeboard](#) and depth.

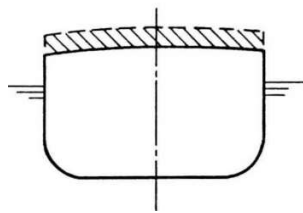
* H. Schneekluth, V. Bertram, Ship Design for Efficiency and Economy, pp. 15, 1998
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Effect of Freeboard on Ships' Characteristics (3/3)

▪ Increasing Freeboard



Freeboard increased by additional superstructure

Increasing depth and decreasing breadth would decrease both the initial stability and the righting arm curve.

[The stability would only be improved](#) if [the underwater form of the ship and the height of the centre of gravity remained unchanged](#) and the freeboard were increased.

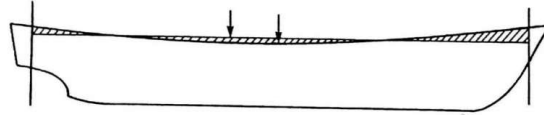
* H. Schneekluth, V. Bertram, Ship Design for Efficiency and Economy, pp. 16, 1998
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Effect of Sheer

Advantages and Disadvantages of a Construction 'Without Sheer'



Ship with and without sheer with same underdeck volume (the differences in freeboard are exaggerated in the diagram)

Advantages of a construction 'without sheer'

- + Better stowage of containers in holds and on deck
- + Cheaper construction method, easier to manufacture
- + Greater carrying capacity with constant underdeck volume

Disadvantages of a construction 'without sheer'

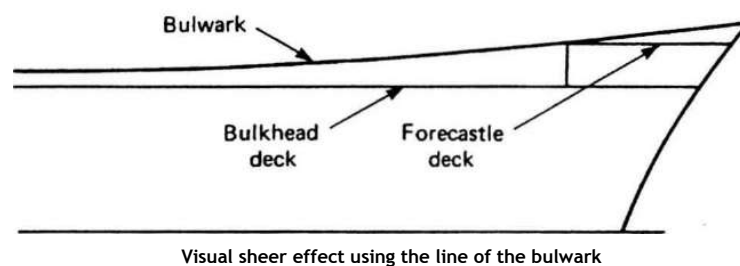
- If the fore-castle is not sufficiently high, reduced seakeeping ability
- **Less aesthetic** in appearance

* H. Schneekluth, V. Bertram, Ship Design for Efficiency and Economy, pp. 16, 1998
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Freeboard and Sheer

Compensation for a Lack of Sheer



The '[upper edge of bulwark](#)' line can be extended to **give the appearance of sheer**.

* H. Schneekluth, V. Bertram, Ship Design for Efficiency and Economy, pp. 17, 1998
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2. International Convention on Load Lines (ICLL) 1966

Regulation of the International Convention on Load Lines (ICLL) 1966

- The ICLL 1966 is structured as follows:

Chapter I – [General](#)

- [Terms and concepts](#) are defined.
All the definitions of terms and concepts associated with freeboard and the freeboard calculation, and a description of how the freeboard is marked.

Chapter II – [Conditions for the assignment of freeboard](#)

- [Structural requirements](#) are defined.
Conditions for the assignment of freeboard structural requirements under which freeboard is assigned.

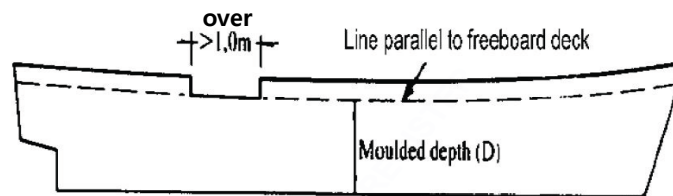
Chapter III – [Freeboards](#)

- [Procedure of freeboard calculation](#) is described.
The freeboard tables and the regulations for correcting the basis values given by the tables. This is [the central part](#) of the freeboard regulations.

The agreement is valid for cargo ships over [24 m in length](#) and for non-cargo-carrying vessels, e.g. floating dredgers.
[Warships](#) are not subject to the freeboard regulations.

1. General Definitions (1/5)

Freeboard Deck¹⁾

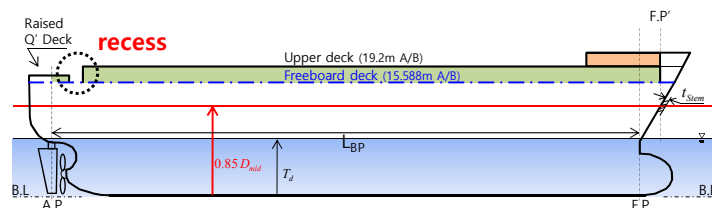


- (a) The freeboard deck is normally **the uppermost complete deck** exposed to weather and sea, which has permanent means of **closing all openings in the weather part thereof**, and below which all openings in the sides of the ship are fitted with permanent means of **watertight closing**.
- (b) Where a recess in the freeboard deck extends to the sides of the ship and is in excess of one meter in length, the lowest line of the exposed deck and **the continuation of that line parallel to the upper part of the deck** is taken as **the freeboard deck**.

¹⁾ International Convention on Load Lines 1966, ANNEX1 Chapter 1, Reg.3-(9), 2003
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1. General Definitions (2/5)

Ex) Freeboard of 3,700TEU Container Carrier



- There is a **recess in the upper deck** of the container carrier. In other words, the upper deck is **discontinuous**.
- This 3,700TEU container carrier is designed to assign 2nd deck as freeboard deck considering other design factors.
- Quarter deck: deck at after part, in general, at $\frac{1}{4}$ of the ship's length after

1. General Definitions (3/5)

▪ Freeboard Length (L_f): $L_f = \max(L_1, L_2)$

L_1 : 96% of the total length (including thickness of stem and stern) on a of the keel measured from the top

※ Perpendicular: In the freeboard regulation, the forward perpendicular is located at the point of the intersection of the waterline at 85% depth with the forward edge of the stem.

Example) L_1 of 3,700TEU container carrier

$$L_1 = (t_{stern} + L_{Aft,0.85D} + L_{BP} + L_{Forward,0.85D} + t_{stem}) \times 0.96$$

$$= (0.015 + 5.0 + 245.24 + 0.024 + 0.015) \times 0.96$$

$$= 250.294 \times 0.96 = 240.282 [m]$$

$L_{Aft,0.85D}$:	5.0m
$L_{Forward,0.85D}$:	0.024m
t_{stern} :	0.015m
t_{stem} :	0.015m
L_{BP} :	245.24m

* International Convention on Load Lines 1966, ANNEX1 Chapter 1, Reg.3-(1), 2003
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1. General Definitions (4/5)

▪ Freeboard Length (L_f): $L_f = \max(L_1, L_2)$

L_2 : The length on a of the fore side of the keel to from

Example) L_2 of 3,700TEU container carrier

$$L_2 = L_{BP} + L_{Forward,0.85D} + t_{stem}$$

$$= 245.24 + 0.024 + 0.015 = 245.279 [m]$$

$$L_f = \max(L_1, L_2)$$

$$= \max(240.282, 245.279) = 245.279 [m] (L_2)$$

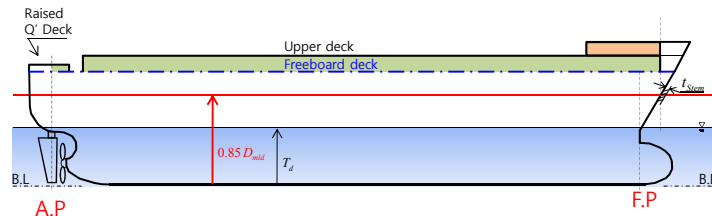
$L_{Aft,0.85D}$:	5.0m
$L_{Forward,0.85D}$:	0.024m
t_{stern} :	0.015m
t_{stem} :	0.015m
L_{BP} :	245.24m

* International Convention on Load Lines 1966, ANNEX1 Chapter 1, Reg.3-(1), 2003
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1. General Definitions (5/5)

Perpendiculars



Why do we use perpendiculars at $0.85D_{mld}$ instead of T_d ?

The aft perpendicular is established using the rudder axis. This somewhat anomalous approach due to the forward perpendicular makes sense, because the draft (to which usually the length is related) is not available as an input value.

The draft is only known after the freeboard calculation is finished.

2. Structural Requirements

The requirement for the assignment of freeboard is that the ship is sufficiently safe and has adequate strength. The requirements in detail are:

- The particular structural requirements of the freeboard regulation must be satisfied. Particular attention should be given to : external doors, sill heights and ventilator heights, hatches and openings of every kind plus their sealing arrangements on decks and sides.

(e.g. engine room openings, side windows, scuppers¹⁾, freeing ports²⁾ and pipe outlets)

1) Scupper: Openings in the shell plating just above deck plating to allow water to run overboard.

2) Freeing ports: An opening in the bulwark or rail for discharging large quantities of water, when thrown by the sea upon the ship's deck.

(<http://www.libertyship.com/html/glossary/glosbody.htm> : Project Liberty Ship - Glossary of Nautical and Shipbuilding Terms)

3. Required Data for the Calculation of Freeboards

To calculate the freeboard of a ship in accordance with [ICLL 1966](#), some data and plans are required as follows:

- Lines or Offset Table (Fared Lines)
- General Arrangement Plan (G/A)
- Hydrostatic Table
- Midship Section Plan (M/S)
- Shell Expansion Plan
- Construction Profile & Decks Plan
- Superstructure Construction Plan,
- Aft body Construction, Fore body Construction Plans

3. Procedure of Freeboard Calculation

Types of Ships

For the purpose of freeboard calculation, ships shall be divided into type 'A' and type 'B'.

- **Type 'A' ships**
 : A type 'A' ship is designed to
 - Example) Crude Oil Carrier, LNG Carrier, etc.
 - The type 'A' ship has a high integrity of the exposed deck with only small access openings to cargo compartments, closed by watertight gasketed covers of steel or equivalent material.
 - The type 'A' ship has low permeability of loaded cargo compartments.
- **Type 'B' ships**
 :
 - shall be considered as type 'B' ships.

Example) Container Carrier, Bulk Carrier, Ore Carrier, etc.

*** 3,700TEU container carrier is a type 'B' ship.**

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Freeboard Calculation Procedure

- 1 Tabular freeboard (F_t) calculation
- ↓
- 2 Correction for block coefficient
($C_{B,0.85D_{mld}} \neq 0.68$)
- ↓
- 3 Correction for depth ($D_f \neq L_f/15$)
- ↓
- 4 Deduction for superstructure and trunks
- ↓
- 5 Correction for sheer
(sheer \neq standard sheer)
- ↓
- 6 Minimum bow height
- ↓
- 7 Maximum molded summer draft

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(1) Tabular Freeboard (F_t) Calculation

- 1 Tabular freeboard(F_t) calculation
- 2 Correction for block coefficient ($C_{B,0.85D_{mld}} \neq 0.68$)
- 3 Correction for depth ($D_t \neq L_t/15$)
- 4 Deduction for superstructure and trunks
- 5 Correction for sheer (sheer \neq standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

Length of ship (m)	Freeboard (mm)
240	3690
241	3705
242	3720
243	3735
244	3750
245	3765
246	3780
247	3795
248	3808
249	3821
250	3835

$L_f = \max(L_1, L_2) = 245.279[m]$

The tabular freeboard for type 'B' ships shall be for type 'B' ships.

Freeboards at intermediate lengths of ship shall be obtained by linear interpolation.

[Table 1] Freeboard table for type 'B' ships

Example 3,700TEU Container Carrier)

$$L_f = 245.279[m]$$

$$\therefore F_t = \frac{3,765 \cdot (246 - 245.279) + 3,780 \cdot (245.279 - 245)}{(245.279 - 245) + (246 - 245.279)} = 3,770[mm]$$

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(2) Correction for Block Coefficient (C_B)

- 1 Tabular freeboard(F_t) calculation
- 2 Correction for block coefficient ($C_{B,0.85D_{mld}} \neq 0.68$)
- 3 Correction for depth ($D_t \neq L_t/15$)
- 4 Deduction for superstructure and trunks
- 5 Correction for sheer (sheer \neq standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

Block coefficient (C_B) at $0.85D_{mld}$

$$C_{B,0.85 \cdot D_{mld}} = \frac{\nabla}{L_f \cdot B \cdot 0.85D_{mld}}$$

Where, the volume (∇) of the molded displacement of the ship is taken at a molded draft of $0.85D_{mld}$.

If the block coefficient $C_{B,0.85 \cdot D_{mld}} < 0.68$, the tabular freeboard specified in Regulation 28 shall be multiplied by the factor.

$$C_{B,0.85 \cdot D_{mld}} \geq 0.68 \text{ Correction for block coefficient} = F_t \cdot \frac{(C_{B,0.85 \cdot D_{mld}} + 0.68)}{1.36}$$

$$C_{B,0.85 \cdot D_{mld}} < 0.68 \text{ There is no correction for block coefficient.}$$

Example 3,700TEU Container Carrier)

3,700TEU Container Carrier	
D_{mld}	13.250 m
$C_{B,0.85D_{mld}}$	0.6705

$$C_{B,0.85 \cdot D_{mld}} = 0.6705 < 0.68$$

→ There is no correction for block coefficient.

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(3) Correction for Depth (D_f)

$L_f = \max(L_1, L_2) = 245.279[m]$
 $D_f = D_{mld} + t_{stringer}$

1 Tabular freeboard(F_f) calculation
 2 Correction for block coefficient ($C_{B,0.85D_{mld}} \neq 0.68$)
 3 Correction for depth ($D_f \neq L_f/15$)
 4 Deduction for superstructure and trunks
 5 Correction for sheer (sheer \neq standard sheer)
 6 Minimum bow height
 7 Maximum molded summer draft

3,700TEU Container Carrier

D_{mld}	13.250 m
$t_{stringer}$	0.013m
$C_{B,0.85D_{mld}}$	0.6705

▪ **Depth for freeboard (D_f)**

$D_f = D_{mld} + t_{stringer}$ (where, freeboard deck = upper deck)
 $t_{stringer}$: Thickness of the freeboard deck

$D_f \leq L_f / 15$
 There is no correction for depth.

$D_f > L_f / 15$
 Correction for depth = $(D_f - L_f / 15) \cdot R$
 $R = L_f / 0.48 : L_f < 120 m$
 $R = 250 : L_f \geq 120 m$

Example 3,700TEU Container Carrier

$D_f \neq D_{mld} + t_{stringer}$ (\because freeboard deck \neq upper deck)
 $D_f = 15.601[m]$, $L_f / 15 = 245.279 / 15 = 16.352[m]$
 $\therefore D_f < L_f / 15 \rightarrow$ There is no correction for depth.

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(4) Deduction for Superstructure and Trunks (1/6)

1 Tabular freeboard(F_f) calculation
 2 Correction for block coefficient ($C_{B,0.85D_{mld}} \neq 0.68$)
 3 Correction for depth ($D_f \neq L_f/15$)
 4 Deduction for superstructure and trunks
 5 Correction for sheer (sheer \neq standard sheer)
 6 Minimum bow height
 7 Maximum molded summer draft

▪ **Superstructure**

Raised Q' Deck: Superstructure which extends forward from the after perpendicular, generally has a height less than a normal superstructure, and has an intact front bulkhead
 Forecastle DK: Superstructure which extends from the forward perpendicular aft to a point which is forward of the forward perpendicular

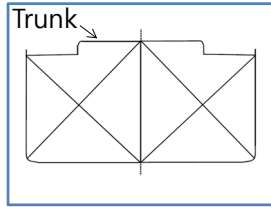
A superstructure is a _____, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than **4% of the breadth**.

The height of a superstructure: The least vertical height measured at side from **the top of the superstructure deck beams to the top of the freeboard deck beams**.

The length of a superstructure (L_s): The mean length of the part of the superstructure which lies within the freeboard length.

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[Appendix] Regulations for Superstructure, Trunk, and Raised Quarter Deck



- There are special regulations for trunks (Reg. 36) which are not covered here. $E = S$ for an enclosed superstructure of standard height.
- S is the superstructure's length within L .

- If the superstructure is set in from the sides of the ship, E is modified by a factor b/B_s , where b is the superstructure width and B_s the ship width, both at the middle of the superstructure length (Reg. 35).
- For superstructures ending in curved bulkheads, S is specially defined by Reg. 34. If the superstructure height d_v is less than standard height d_s (Table 1.5a), E is modified by a factor d_v/d_s .
- The effective length of a raised quarter deck (if fitted with an intact front bulkhead) is its length up to a maximum of $0.6L$.
- Otherwise the raised quarterdeck is treated as a poop of less than standard height.

(4) Deduction for Superstructure and Trunks (2/6)

- 1 Tabular freeboard(F_f) calculation
- 2 Correction for block coefficient ($C_{B,standard} \neq 0.68$)
- 3 Correction for depth ($D_f \neq L_f/15$)
- 4 Deduction for superstructure and trunks
- 5 Correction for sheer (sheer \neq standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

▪ **Effective length of superstructure (L_E)**

$$L_E = \text{Mean Length} \times [\min(\text{Standard Height, Actual Height})] / \text{Standard Height}$$

If the height of an enclosed superstructure is

① higher than the standard height, the effective length of an enclosed superstructure of standard height shall be its length.

② less than the standard height, the effective length shall be its length reduced in the ratio of the actual height to the standard height.

The standard height of a superstructure shall be as given in the following table:

3,700TEU Container Carrier

Item	Mean length (m)	Height (m)
Superstructure	225.28	3.71
Raised Q Deck	11.20	1.24

L_f (m)	Raised quarterdeck (m)	All other superstructures (m)
30 or less	0.90	1.80
75	1.20	1.80
125 or more	1.80	2.30

The standard heights at intermediate lengths of the ship shall be obtained by linear interpolation.

(4) Deduction for Superstructure and Trunks (3/6)

$L_E = \text{Mean Length} \times [\min(\text{Standard Height, Actual Height}) / \text{Standard Height}]$

- 1 Tabular freeboard(F_f) calculation
- 2 Correction for block coefficient (C_{B,0.95min}≠0.68)
- 3 Correction for depth (D_i ≠L_f/15)
- 4 Deduction for superstructure and trunks
- 5 Correction for sheer (sheer ≠ standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

Item	Mean length (m)	Height (m)
Superstructure	225.28	3.71
Raised Q' Deck	11.20	1.24

L _f (m)	Raised quarterdeck (m)	All other superstructures (m)
30 or less	0.90	1.80
75	1.20	1.80
125 or more	1.80	2.30

L_f: Length of a superstructure

Example 3,700TEU Container Carrier)

$$L_{E, \text{superstructure}} = 225.28 \cdot 2.30 / 2.30 [m] (\because 3.71 > 2.30)$$

$$L_{E, \text{Raised Q' deck}} = L_{s, \text{Raised Q' deck}} \cdot H_{\text{Raised Q' deck}} / H_{\text{standard}}$$

$$= 11.20 \cdot 1.24 / 1.80 (\because 1.24 < 1.80)$$

$$= 7.72 [m]$$

$$\therefore L_E = L_{E, \text{Raised Q' deck}} + L_{E, \text{superstructure}} = 7.72 + 225.28 = 233.00 [m]$$

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(4) Deduction for Superstructure and Trunks (4/6)

▪ **Deduction from the freeboard**

Where the effective length (L_E) of superstructures and trunk is

① $1.0 L_f$

Deduction from the freeboard =

$$\begin{cases} 350mm & : L_f = 24m \\ 860mm & : L_f = 85m \\ 1,070mm & : L_f \geq 122m \end{cases}$$

$$L_f = \max(L_1, L_2) = 245.279[m]$$

$$L_E = 233.00[m]$$

② **less than $1.0L_f$** , the deduction shall be a percentage obtained from the following table:
Percentage of deduction for type 'A' and 'B' ships

	Total Effective Length Superstructures and Trunks										
	0	0.1 L	0.2 L	0.3 L	0.4 L	0.5 L	0.6 L	0.7 L	0.8 L	0.9 L	1.0 L
Percentage of deduction for all types of superstructures	0	7	14	21	31	41	52	63	75.3	87.7	100

Percentages at intermediate lengths of superstructures and trunks shall be obtained by linear interpolation.

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(4) Deduction for Superstructure and Trunks (5/6)

▪ Deduction from the freeboard

Example 3,700TEU Container Carrier)

$$L_f = 245.279[m]$$

$$L_E = 233.00[m]$$

$$\therefore L_E < L_f$$

Where the effective length (L_E) of superstructures and trunk is less than $1.0L_f$, the deduction shall be a percentage obtained from the following table:

$L_E / L_f = 0.95$

Percentage of deduction for all types of superstructures	Total Effective Length Superstructures and Trunks										
	0	0.1 L	0.2 L	0.3 L	0.4 L	0.5 L	0.6 L	0.7 L	0.8 L	0.9 L	1.0 L
	0	7	14	21	31	41	52	63	75.3	87.7	100

Percentage of deduction for superstructures

$$= 87.7 + (100 - 87.7) \times (0.05 / 0.1) = 93.85\%$$

- 1 Tabular freeboard(F_f) calculation
- 2 Correction for block coefficient ($C_{B,SPONS} \neq 0.68$)
- 3 Correction for depth ($D_f \neq L_f/15$)
- 4 Deduction for superstructure and trunks
- 5 Correction for sheer (sheer \neq standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

$L_f = \max(L_1, L_2) = 245.279[m]$
 $L_E = 233.00[m]$

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(4) Deduction for Superstructure and Trunks (6/6)

▪ Deduction from the freeboard

Example 3,700TEU Container Carrier)

$$L_f = 245.279[m]$$

$$\text{Deduction from the freeboard} = \begin{cases} 350mm & : L_f = 24m \\ 860mm & : L_f = 85m \\ 1,070mm & : L_f \geq 122m \end{cases}$$

The deduction from the freeboard is multiplied by the percentage of deduction for superstructure.

$$\text{Deduction from the freeboard} = 1,070 \cdot 0.9385 = 1,004 [mm]$$

- 1 Tabular freeboard(F_f) calculation
- 2 Correction for block coefficient ($C_{B,SPONS} \neq 0.68$)
- 3 Correction for depth ($D_f \neq L_f/15$)
- 4 Deduction for superstructure and trunks
- 5 Correction for sheer (sheer \neq standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

$L_f = \max(L_1, L_2) = 245.279[m]$
Percentage of deduction for superstructures = 93.85%

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1 Tabular freeboard(F_f) calculation
 2 Correction for block coefficient ($C_{B,0.95mid} \neq 0.68$)
 3 Correction for depth ($D_i \neq L/15$)
 4 Deduction for superstructure and trunks
 5 Correction for shear (sheer \neq standard shear)
 6 Minimum bow height
 7 Maximum molded summer draft

(5) Correction for Sheer (1/7)

Sheer

Line which is parallel to the keel

Sheer

AP ∞ FP

Sheer is the upward curvature of a ship's deck from mid length towards the bow and stern.

The shear gives the vessel extra height at the stem and the stern.

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1 Tabular freeboard(F_f) calculation
 2 Correction for block coefficient ($C_{B,0.95mid} \neq 0.68$)
 3 Correction for depth ($D_i \neq L/15$)
 4 Deduction for superstructure and trunks
 5 Correction for shear (sheer \neq standard shear)
 6 Minimum bow height
 7 Maximum molded summer draft

(5) Correction for Sheer (2/7)

Camber

A : Point which is same height over a ship's length
 delta : Elevated height more than mid-ship area

Breadth in aft and forward of a ship

B_{mid}
K

Camber is the upward curvature of the deck.

The curvature helps to ensure sufficient **drainage** of any water on deck.

For ships with camber of beam, care must be taken that the deck without shear do not become too humped at the ends as a result of the deck beam. In other words, the deck 'centre-line' **should have no sheer and the deck edge line should be raised**.

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- 1 Tabular freeboard(F_f) calculation
- 2 Correction for block coefficient (C_{B,0.95min}≠0.68)
- 3 Correction for depth (D_f≠L_f/15)
- 4 Deduction for superstructure and trunks
- 5 Correction for shear (sheer ≠ standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

(5) Correction for Sheer (3/7)

▪ **Correction for sheer**

Correction for sheer = $(S_o - S) \cdot (0.75 - 0.5r_1)$

S_o : Standard height of sheer (mm)

S : Mean height of actual sheer (mm)

r_1 : The effective length (L_E) of superstructures divided by freeboard length (L_f)

$r_1 = L_E / L_f$

- If $S_o > S$, the tabular freeboard is added to the correction for sheer.
- If $S_o < S$, the tabular freeboard is subtracted to the correction for sheer.

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- 1 Tabular freeboard(F_f) calculation
- 2 Correction for block coefficient (C_{B,0.95min}≠0.68)
- 3 Correction for depth (D_f≠L_f/15)
- 4 Deduction for superstructure and trunks
- 5 Correction for sheer (sheer ≠ standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

(5) Correction for Sheer (4/7)

(a) Excess or deficiency of sheer

➔ Design ship has no sheer.

$L_f = 245.279[m]$

Station		Standard*				Actual			
		Height (mm)	Ordinate	Factor	Product	Height (mm)	Ordinate	Factor	Product
After half	A.P	25.0(L _f /3+10)	2,294	1	2,294	S1	0	1	0
	L _f /6(from A.P)	11.1(L _f /3+10)	1,019	3	3,057	S2	0	3	0
	L _f /3(from A.P)	2.8(L _f /3+10)	257	3	771	S3	0	3	0
	Amidship	0	0	1	0	S4	0	1	0
Mean height		$S_A = 8.34(L_f/3 + 10)$			765	S_a			0
Forw ard half	Amidship	0	0	1	0	S4	0	1	0
	L _f /3(from F.P)	5.6(L _f /3+10)	514	3	1,542	S5	0	3	0
	L _f /6(from F.P)	22.2(L _f /3+10)	2,037	3	6,111	S6	0	3	0
	F.P	50.0(L _f /3+10)	4,588	1	4,588	S7	0	1	0
Mean height		$S_f = 16.64(L_f/3 + 10)$			1,526	S_f			0

Standard height of sheer (S_o): $(S_A + S_f)/2 = 1,146$ mm

Mean height of actual sheer (S): $(S_a + S_f)/2 = 0$ mm

$(2,294 + 3,057 + 771 + 0)/(1 + 3 + 3 + 1) = 765$

$(0 + 1,542 + 6,111 + 4,588)/(1 + 3 + 3 + 1) = 1,526$

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(5) Correction for Sheer (5/7)

- 1 Tabular freeboard(F_f) calculation
- 2 Correction for block coefficient (C_{B,0.950m}≠0.68)
- 3 Correction for depth (D_f≠L_f/15)
- 4 Deduction for superstructure and trunks
- 5 Correction for sheer (sheer ≠ standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

*** Standard height of sheer**

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(5) Correction for Sheer (6/7)

- 1 Tabular freeboard(F_f) calculation
- 2 Correction for block coefficient (C_{B,0.950m}≠0.68)
- 3 Correction for depth (D_f≠L_f/15)
- 4 Deduction for superstructure and trunks
- 5 Correction for sheer (sheer ≠ standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

(b) Sheer credit for superstructure

If the forward half of sheer profile or the after half of sheer profile **are greater than the standard**, sheer credit is given for a poop or forecastle. The sheer credit is the following:

$$s = \frac{Y}{3} \cdot \frac{L'}{L_f}$$

s : Sheer credit
Y : Difference between actual and standard height of superstructure at the after or forward perpendicular
L' : Mean enclosed length of poop or forecastle up to a maximum length of 0.5L

① Sheer credit for forecastle

$$S_f = \frac{Y_f}{3} \cdot \frac{L'}{L_f} = \frac{h_a - h_s}{3} \cdot \frac{L'}{L_f} = \frac{3,200 - 2,300}{3} \cdot \frac{25.3}{245.279} = 31$$

→ $S'_f = S_f + s_f = 0 + 31 = 31$ [mm]

L_f = 245.279[m]
h_a (actual height of forecastle) = 3,200 [mm]
h_s = 2,300 [mm]
L' (length of forecastle) = 25.3 [m]
S_a = 0
S_f = 0

② Sheer credit for poop

$$S_p = \frac{Y_p}{3} \cdot \frac{L'}{L_f} = \frac{0 - 2,300}{3} \cdot \frac{0}{245.279} = 0$$

→ $S'_a = S_a + s_p = 0 + 0 = 0$ [mm] No poop deck for design ship (*Y_p* = 0)

S': Actual height of sheer corrected by sheer credit

L _f (m)	Raised quarterdeck (m)	All other superstructures (m)
30 or less	0.90	1.80
75	1.20	1.80
125 or more	1.80	2.30

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(5) Correction for Sheer (7/7)

- 1 Tabular freeboard(F_f) calculation
- 2 Correction for block coefficient (C_{B,0.95DMG}≠0.68)
- 3 Correction for depth (D_i ≠L_f/15)
- 4 Deduction for superstructure and trunks
- 5 Correction for sheer (sheer ≠ standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

Standard height of sheer (S₀) : 1,146 mm

S'_f = 31 [mm]

S'_a = 0 [mm]

r_i = L_a / L_f = 0.95

(c) Correction for sheer

Mean height of actual sheer (S):

$$S = \frac{(S'_a + S'_f)}{2} = \frac{(0 + 31)}{2} = 15.5 \text{ [mm]}$$

Correction for sheer = (S₀ - S) · (0.75 - 0.5r_i)

$$= (1,146 - 15.5) \cdot (0.75 - 0.5 \cdot 0.95)$$

$$= 311 \text{ [mm]}$$

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(6) Minimum Bow Height (1/3)

- 1 Tabular freeboard(F_f) calculation
- 2 Correction for block coefficient (C_{B,0.95DMG}≠0.68)
- 3 Correction for depth (D_i ≠L_f/15)
- 4 Deduction for superstructure and trunks
- 5 Correction for sheer (sheer ≠ standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

■ Bow height

Bow height (H_b) is defined as the distance between the water surface corresponding to the assigned summer freeboard and the designed trim and the top of the exposed deck at side.

Example 3,700TEU Container Carrier)

Actual bow height = D_f(①) + Superstructure height(②) + Forecastle at F.P(③) - T_s

$$= 15.601 + 3.71 + 3.2 - 12.5$$

$$= 10.011 \text{ [m]}$$

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1 Tabular freeboard(F_f) calculation
 2 Correction for block coefficient (C_{B,0.85SD}≠0.68)
 3 Correction for depth (D_f≠L_f/15)
 4 Deduction for superstructure and trunks
 5 Correction for sheer (sheer ≠ standard sheer)
 6 **Minimum bow height**
 7 Maximum molded summer draft

(6) Minimum Bow Height (2/3)

▪ **Minimum bow height**

$$\text{Minimum bow height} = \left[6,075 \left(\frac{L_f}{100} \right) - 1,875 \left(\frac{L_f}{100} \right)^2 + 200 \left(\frac{L_f}{100} \right)^3 \right] \times \left[2.08 + 0.609C_{B,0.85D} - 1.603C_{WF} - 0.0129 \left(\frac{L_f}{D_f} \right) \right] \text{ [mm]}$$

where,
 C_{WF}: freeboard water plane coefficient for L_f/2 forward

$$C_{WF} = \frac{A_{WF}}{(L_f/2) \times B}$$

A_{WF}: Water plane area for L_f/2 forward

- **Actual bow height should be larger than minimum bow height.**

Example 3,700TEU Container Carrier

$$\text{Minimum bow height} = \left[6,075 \left(\frac{245.279}{100} \right) - 1,875 \left(\frac{245.279}{100} \right)^2 + 200 \left(\frac{245.279}{100} \right)^3 \right] \times \left[2.08 + 0.609 \cdot 0.6705 - 1.603 \cdot \left(\frac{26,695}{\left(\frac{245.279}{2} \right) \cdot 32.2} \right) - 0.0129 \left(\frac{245.279}{15.601} \right) \right] \text{ [mm]}$$

L_f = 245.279[m]
 B = 32.2[m]
 C_{B,0.85D} = 0.6705
 A_{WF} = 26,695[m²]
 D_f = 15.601[m]
 Actual bow height = 10.01[m]

= 7,899 [mm]
 ∴ Actual bow height > Minimum bow height

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1 Tabular freeboard(F_f) calculation
 2 Correction for block coefficient (C_{B,0.85SD}≠0.68)
 3 Correction for depth (D_f≠L_f/15)
 4 Deduction for superstructure and trunks
 5 Correction for sheer (sheer ≠ standard sheer)
 6 **Minimum bow height**
 7 Maximum molded summer draft

(6) Minimum Bow Height (3/3)

▪ **Correction for bow height**

If actual bow height

① **is larger** than minimum bow height.
 Correction for bow height = 0

② **is less** than minimum bow height
 Correction for bow height = Minimum bow height – Actual bow height

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(7) Maximum Molded Summer Draft (1/2)

- 1 Tabular freeboard(F_f) calculation
- 2 Correction for block coefficient ($C_{B,0.95D_{max}} \neq 0.68$)
- 3 Correction for depth ($D_f \neq L_f/15$)
- 4 Deduction for superstructure and trunks
- 5 Correction for sheer (sheer \neq standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

▪ **Maximum molded summer draft (d_s)**

$$d_s = D_f - fs$$

*** fs (Calculated summer freeboard)**

= Tabular freeboard + Correction for block coefficient
 + Correction for depth – Deduction for superstructure
 ± Correction for Sheer + Correction for minimum bow height

= 3,770 + 0 + 0 – 1,004 + 311 + 0

= 3,077 [mm]

Tabular freeboard	3,770	mm
Correction for block coefficient	0	mm
Correction for depth (D_f)	0	mm
Deduction for superstructure and trunks	-1,004	mm
Correction for Sheer	311	mm
Correction for minimum bow height	0	mm
Depth for freeboard (D_f)	15.601	m
Molded summer draft required by owner (T_s)	12.50	m

$$d_s = 15.601 - 3.077$$

$$= 12.524 [m] > 12.5 [m]$$

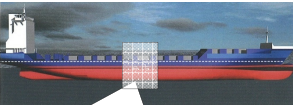
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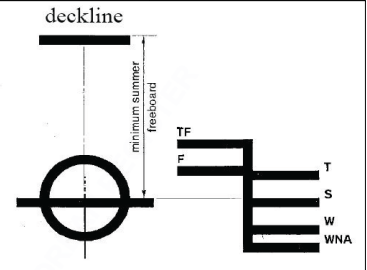
(7) Maximum Molded Summer Draft (2/2)

- 1 Tabular freeboard(F_f) calculation
- 2 Correction for block coefficient ($C_{B,0.95D_{max}} \neq 0.68$)
- 3 Correction for depth ($D_f \neq L_f/15$)
- 4 Deduction for superstructure and trunks
- 5 Correction for sheer (sheer \neq standard sheer)
- 6 Minimum bow height
- 7 Maximum molded summer draft

▪ **Freeboard Mark**



deckline



The Plimsoll¹⁾ mark or Freeboard Mark is a symbol indicating the **of the ship in the water, leaving a minimal freeboard for safety.**

The freeboard is marked according to the result of the freeboard calculation, where the summer freeboard in salt water (d_s) is established.

- Tropical draft

$$d_T = d_s + d_s / 48$$

- Winter draft

$$d_W = d_s - d_s / 48$$

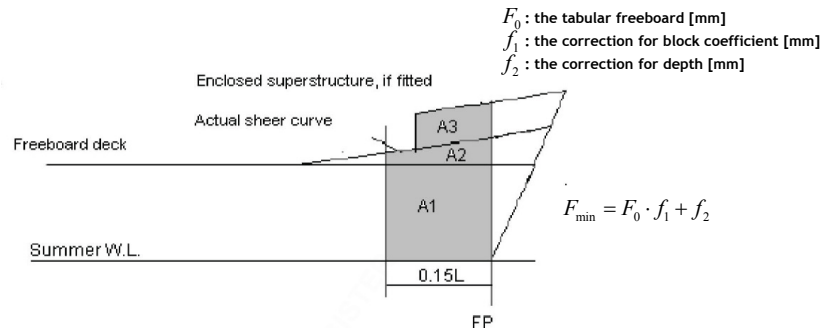
Explanation of abbreviations used on the mark:

TF: Tropical Fresh (for water with a density of 1.000 t/m³)
 F: Fresh (ditto)
 T: Tropical (for water with a density of 1.025 t/m³)
 S: Summer freeboard (ditto)
 W: Winter (ditto)
 WNA: Winter North Atlantic (ditto), only for ships, less than 100 meter
 GL/NK/LR: Germanischer Lloyd / Nippon Kaiji Kyokai / Lloyd's Register

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* Samuel Plimsoll (1825.2.10–1898.6.3) was a British politician and social reformer, now best remembered for having devised the Plimsoll line.
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(8) Reserve Buoyancy¹⁾



All ships assigned a type 'B' freeboard, other than oil tankers*, chemical tankers* and gas carriers*, shall have additional reserve buoyancy in the fore end.

The regulation is satisfied as follows:

$$A_1 + A_2 \geq (0.15 \cdot F_{min} + 4 \cdot (L/3 + 10)) \cdot L / 1000$$

and

$$A_3 \geq (0.15 \cdot F_{min} + 4 \cdot (L/3 + 10)) \cdot L / 1000$$

* International Convention on Load Lines 1966, ANNEX1 Chapter 1, Reg.3-(5), 2003
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(9) Summary

Example 3,700TEU Container Carrier)

Tabular freeboard	3,770 mm
Correction for block coefficient	0 mm
Correction for depth (D_f)	0 mm
Deduction for superstructure and trunks	-1,004 mm
Correction for sheer	311 mm
Correction for minimum bow height	0 mm
Calculated summer freeboard (f_s)	3,077 mm
Depth for freeboard (D_f)	15.601 m
Maximum molded summer draft (d_s)	12.524 m
Molded summer draft required by owner (T_s)	12.500 m
Margin	24 mm

* $d_s = D_f - f_s$

*Margin = $d_s - T_s$

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