Lecture Note of Design Theory of Ships and Offshore Structures

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Ch. 5 Freeboard Calculation

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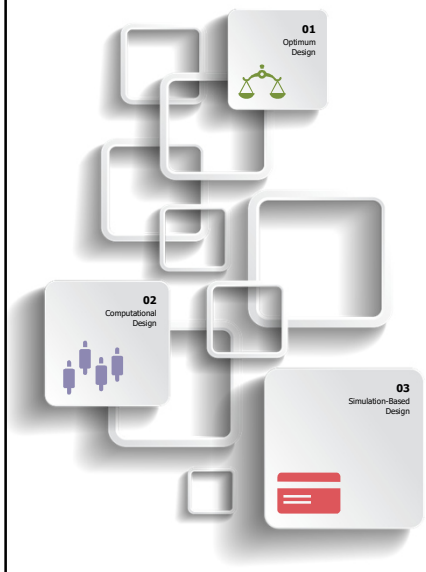

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1. Generals

1. 일반사항

Purpose

- **The purpose of the freeboard**

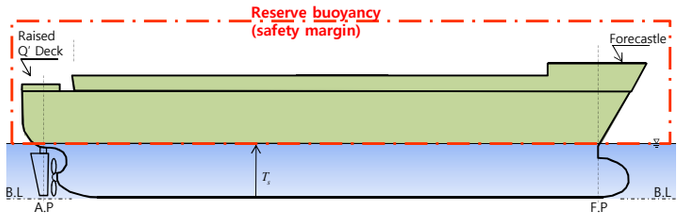
건현의 목적

- **The ship needs an additional safety margin to maintain buoyancy and stability while operating at sea.**

선박은 해상에서 운항하는 동안 부력과 복원성을 유지하기 위해 추가적인 안전 여유를 필요로 한다.

- **This safety margin is provided by the reserve of buoyancy of the hull located above the water surface (freeboard).**

이러한 안전 여유는 수면 위에 위치한 선체의 예비 부력(건현)에 의해 제공된다.



- **The regulation of the freeboard**

건현 규정

- **International Convention on Load Lines 1966 (ICLL 1966)**

국제 만재흘수선 협약(International Convention on Load Lines 1966 (ICLL 1966))

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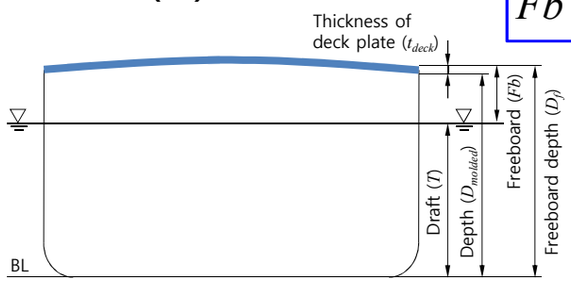
Definition (1/2)

- **Freeboard** (Fb)

$$Fb = D_{mld} + t_{deck} - T$$



건현(Fb)

- **Definition: The freeboard is the height of the freeboard deck above the load line measured at the deck edge at the mid-length between the perpendiculars. It includes the thickness of the deck plate*.**

정의: 건현은 만재흘수선에서 건현갑판까지의 높이로, 양 수직선 사이 중앙의 갑판 가장자리에서 측정한다. 여기에는 갑판판의 두께가 포함된다*.

- **In other words, the distance between the water surface and the top of the deck at the side (at the deck line). It includes the thickness of the deck plate.**

즉, 수면과 선측 갑판 상단(갑판선 위치) 사이의 거리이다. 여기에는 갑판판의 두께가 포함된다.

- **Molded Depth (D_{mld}): The molded depth is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side.**

형깊이(Dmld): 형깊이는 용골 상단에서 건현갑판 보의 선측 상단까지 수직으로 측정한 거리이다

선측 건현갑판 보의

- **Freeboard depth (D_f): The freeboard depth is the molded depth amdiships, plus the thickness of the deck plate at the side.**

$D_f = D_{mld} + t_{deck}$, t_{deck}: **Thickness of the deck plate**

sydlab SEOUL NATIONAL UNIV. * International Convention on Load Lines 1966, ANNEX1 Chapter 1, Reg.3-(9), 2003

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건현 깊이(Df): 건현 깊이는 중앙부의 형깊이에 선측 갑판판의 두께를 더한 값이다.

Definition (2/2)

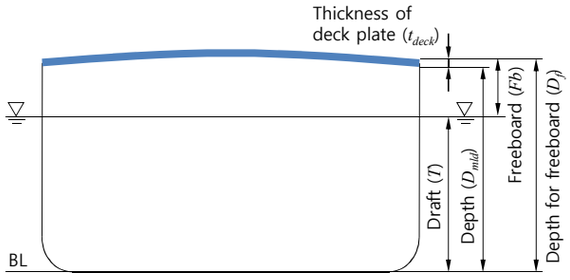
Freeboard Inequality

$$Fb = D_{mld} + t_{deck} - T$$

정의 (2/2) Fb D mld t deck T

- ✓ **Actual freeboard (D_{FB} - T) of a ship should not be less than the required freeboard (Fb_{ICLL}) required by the ICLL 1966 regulation.**

선박의 실제 건현(DFB - T)은 ICLL 1966 규정에서 요구하는 요구 건현(FbICLL)보다 작아서는 안 된다.



$$D_{Fb} - T \geq Fb_{ICLL}(L, B, D, C_B)$$ **: Freeboard inequality**

D T Fb (, , L B D C ,): 건현 부등식

This draft should be the maximum operating draft of the ship, that is, scantling draft (T_s).

How can you determine the required freeboard (Fb)?

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이 흘수는 선박의 최대 운항 흘수이어야 한다. 요구 건현(Fb)은 어떻게 결정하는가?

[Reference] Design Draft vs. Scantling Draft

[참고] 설계 흘수와 구조 흘수 비교

- **Design draft (T_d): Basis for ship design. This is a draft based on the fundamental design parameters of the ship. In general, it is the primary operating draft and the basis for determining the ship's deadweight, power performance, among other factors.**

설계 흘수(Td): 선박 설계의 기준이다. 이는 선박의 기본 설계 매개변수를 바탕으로 정해지는 흘수이다. 일반적으로 주요 운항 흘수이며, 선박의 재화중량과 동력 성능 등을 결정하는 기준이 된다.

- **Scantling draft (T_s): Basis for hull structural design. This draft is the maximum draft at which the ship can safely withstand all the loads. In other words, it is the draft on which the strength of the ship is built. Normally, it is greater than the design draft.**

구조 흘수(Ts): 선체 구조 설계의 기준이다. 이는 선박이 모든 하중을 안전하게 견딜 수 있는 최대 흘수이다. 즉, 선박의 강도가 이를 기준으로 설계된다. 일반적으로 설계 흘수보다 크다.

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

선박 특성에 대한 건현의 영향 (1/3)

- **The freeboard influences the following characteristics of the ship.**

건현은 다음과 같은 선박의 특성에 영향을 미친다.

- **Dryness of deck: A dry deck is desirable**

갑판의 건조성: 건조한 갑판이 바람직하다

  - **because walking on a wet deck can be dangerous**

젖은 갑판 위를 걸으면 위험할 수 있기 때문이다

  - **as a safety measure against water entering through deck openings**

갑판 개구부를 통해 물이 유입되는 것을 방지하기 위한 안전 조치로서

  - **to prevent violent seas from destroying the superstructure**

거친 바다가 상부구조물을 파괴하는 것을 방지하기 위해

- **Reserve buoyancy in damaged conditions**

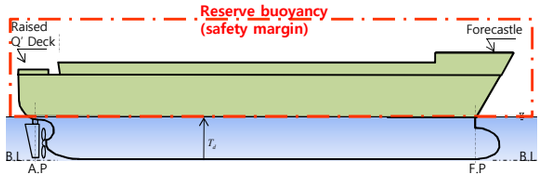
손상 상태에서의 예비 부력

- **Intact stability (characteristics of the righting arm curve)**

비손상 복원성(복원정 곡선의 특성)

- **Damaged stability**

손상 복원성



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

Large Freeboard

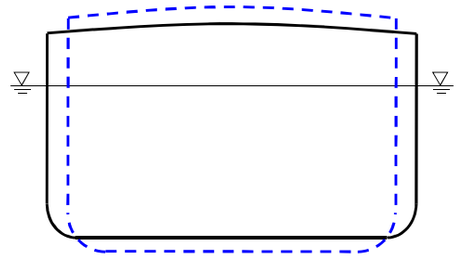
선박 특성에 대한 건현의 영향 (2/3)

- **In general, a large freeboard improves stability.**

일반적으로 건현이 크면 복원성이 향상된다.

- **However, 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.**

그러나 설계 시 이 요소를 고려하기는 어렵다. 비용상의 이유로 갑판 하부의 필요한 최소 용적을 초과해서는 안 되며, 선박의 길이는 경제적 고려에 따라 결정되므로, 건현과 깊이의 증가를 보상할 수 있는 방법은 폭을 줄이는 것뿐이다.



Greater freeboard at the expense of breadth decreases stability

sydlab * H. Schneekluth, V. Bertram, Ship Design for Efficiency and Economy, pp. 15, 1998

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폭을 희생하여 건현을 크게 하면 복원성이 감소한다

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

Increasing Freeboard

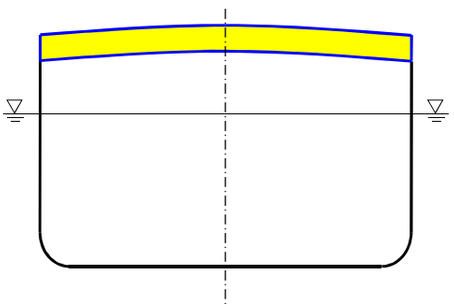
건현이 선박 특성에 미치는 영향 (3/3)

- **Increasing depth and decreasing breadth would decrease both the initial stability and the righting arm (GZ) curve.**

깊이를 증가시키고 폭을 감소시키면 초기 복원성과 복원정(GZ) 곡선이 모두 감소한다.

- **The stability would only be improved if the underwater form of the ship and the height of the center of gravity remained unchanged, and the freeboard were increased.**

수중 형상과 무게중심의 높이가 변하지 않은 상태에서 건현을 증가시킬 때에만 복원성이 향상된다.



Freeboard increased by additional superstructure

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

Effect of Sheer

Advantages and Disadvantages of a Construction 'Without Sheer'

'종굽힘이 없는' 구조의 장단점

- **Advantages of a construction 'without sheer'**

'종굽힘이 없는' 구조의 장점

- **Better stowage of containers in holds and on deck**

선창과 갑판에서 컨테이너를 더 효율적으로 적재할 수 있다.

- **Cheaper construction method, easier to manufacture**

더 저렴하고 제작이 용이한 건조 방식이다.

- **Greater carrying capacity with constant underdeck volume**

갑판 하부 용적이 일정할 때 더 큰 적재 능력을 확보할 수 있다.

- **Disadvantages of a construction 'without sheer'**

'종굽힘이 없는' 구조의 단점

- **If the forecastle is not sufficiently high, reduced seakeeping ability**

선수루가 충분히 높지 않으면 내항성이 저하된다.

- **Less aesthetic in appearance**

외관상 미관이 떨어진다.

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

동일한 갑판 하부 용적을 가진 종굽힘이 있는 선박과 종굽힘이 없는 선박(도면에서는 건현의 차이를 과장하여 나타냈다)

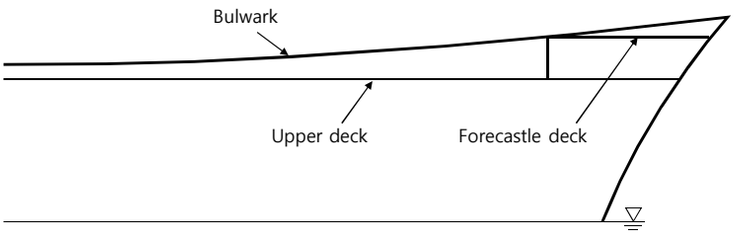
sydlab * H. Schneekluth, V. Bertram, Ship Design for Efficiency and Economy, pp. 16, 1998

Freeboard and Sheer

Compensation for a Lack of Sheer

- **The 'upper edge of bulwark' line can be extended to give the appearance of sheer.**

'불워크 상단' 선을 연장하여 종굽힘이 있는 것처럼 보이게 할 수 있다.



Visual sheer effect using the line of the bulwark

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Forecastle and Poop

- **Forecastle (F'cle)**

선수루(F'cle)

- **A superstructure which extends from the forward perpendicular aft to a point which is forward of the after perpendicular.**

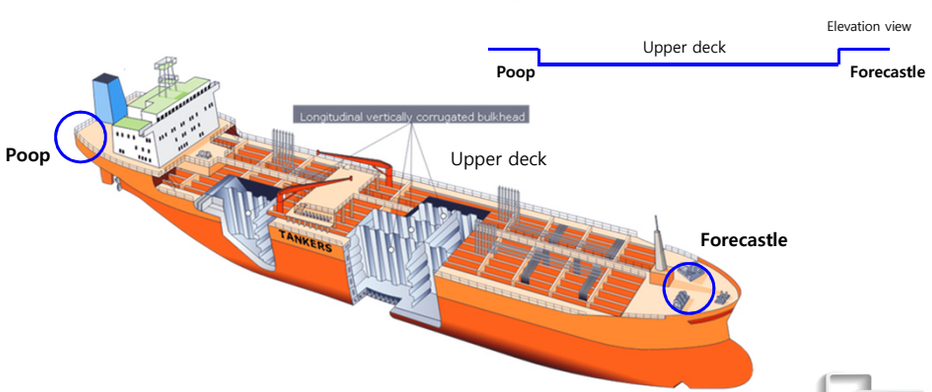
선수 수직선에서 선미 방향으로 연장되어 선미 수직선보다 앞쪽의 지점까지 이어지는 상부구조물이다.

- **Poop**

선미루

- **A superstructure which extends from the after perpendicular forward to a point which is aft of the forward perpendicular.**

선미 수직선에서 선수 방향으로 연장되어 선수 수직선보다 뒤쪽의 지점까지 이어지는 상부구조물이다.



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2. International Convention on Load Lines (ICLL) 1966

2. 만재흘수선에 관한 국제 협약(ICLL) 1966

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

Structure of the ICLL

만재흘수선에 관한 국제 협약(ICLL) 1966의 규정

- **Chapter I: General**

제I장: 총칙

- **Terms and concepts are defined.**

용어와 개념을 정의한다.

- **All the definitions of terms and concepts associated with freeboard and the freeboard calculation, and a description of how the freeboard is marked.**

건현 및 건현 산정과 관련된 모든 용어와 개념의 정의와 건현 표시에 관한 설명을 제시한다.

- **Chapter II: Conditions for the assignment of freeboard**

제II장: 건현 지정 조건

- **Structural requirements are defined.**

구조 요건을 정의한다.

- **Conditions for the assignment of freeboard structural requirements under which freeboard is assigned.**

건현을 지정하기 위해 충족해야 하는 구조 요건을 규정한다.

- **Chapter III: Freeboards**

제III장: 건현

- **Procedure of freeboard calculation is described.**

건현 산정 절차를 설명한다.

- **The freeboard tables and the regulations for correcting the basis values given by the tables. This is the central part of the freeboard regulations.**

건현 표와 표에 제시된 기준값을 보정하기 위한 규정을 다룬다. 이 부분이 건현 규정의 핵심이다.

- **The convention is valid for cargo ships over 24 m in length and for non-cargo-carrying vessels, e.g. floating dredgers. Naval ships are not subject to the freeboard regulations.**

이 협약은 길이 24 m를 초과하는 화물선과 부유 준설선 등 화물을 운송하지 않는 선박에 적용된다. 군함에는 건현 규정이 적용되지 않는다.

1. General Definitions (1/5)

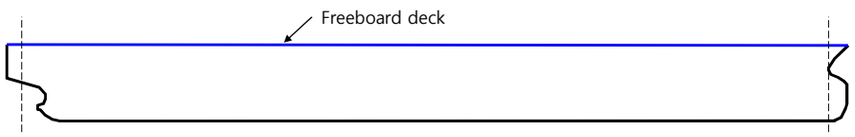
Freeboard Deck

- **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.**

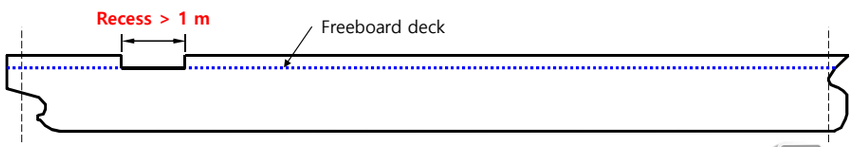
건현갑판은 일반적으로 기상과 해상에 노출된 최상부의 완전한 갑판으로서, 그 노출 부분의 모든 개구를 폐쇄할 수 있는 영구적 수단을 갖추고 있으며, 그 아래 선측의 모든 개구에는 영구적인 수밀 폐쇄 장치가 설치된 갑판이다.

- **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.**

건현갑판에 설치된 리세스가 선측까지 연장되고 그 길이가 1미터를 초과하는 경우에는 노출 갑판의 최저선과 갑판 상부와 평행하게 이어지는 그 선을 건현갑판으로 간주한다.



(a) Freeboard deck of a ship without recess



(b) Freeboard deck of a ship with recess over the length of 1 m

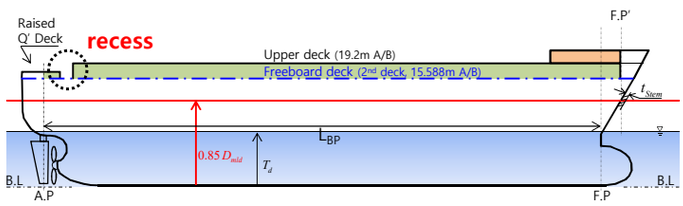
* International Convention on Load Lines 1966, ANNEX1 Chapter 1, Reg.3-(9), 2003

1. General Definitions (2/5)

Freeboard Deck

[Example] Freeboard of the 3,700TEU Container Ship

[예] 3,700TEU Container Ship의 건현



- **There is a recess in the upper deck of the container ship.**

컨테이너선의 상갑판에는 리세스가 있다.

- **In other words, the upper deck is discontinuous.**

다시 말해, 상갑판은 불연속적이다.

- **This 3,700TEU Container Ship is designed to assign the 2nd deck as freeboard deck considering other design factors.**

이 3,700TEU Container Ship은 제2갑판을 다른 설계 요소를 고려하여 건현갑판으로 지정하도록 설계되었다.

* Quarter deck: Deck at after part, in general, at ¼ of the ship's length after

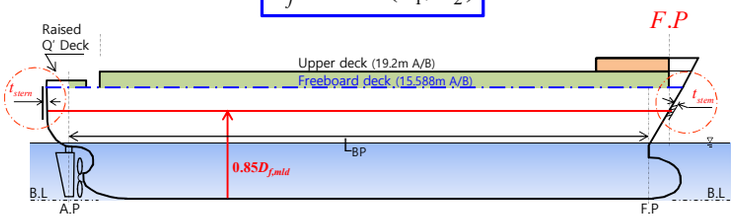
1. General Definitions (3/5)

Freeboard Length (L_f)

3,700TEU Container Ship

Item	Value
$D_{f,mld}$ (freeboard deck)	15.588 m
$0.85D_{f,mld}$	13.250 m

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



L_1: **"96%" of the total length (including thickness of stem and stern) on**

L1: 선수재와 선미재의 두께를 포함한 전체 길이의 "96%"에

a waterline at 85% of the molded depth ($D_{f,mld}$ in this example) measured from the top of the keel

용골 상단에서 측정한 형깊이(이 예에서는 Df,mld)의 85%에 해당하는 수선

※ **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 the 3,700TEU Container Ship**

$$\begin{aligned} L_1 &= (t_{stern} + L_{Aft,0.85D} + L_{BP} + L_{Forward,0.85D} + t_{stem}) \times 0.96 \\ &= (0.015 + 5.0 + 245.24 + 0.024 + 0.015) \times 0.96 \\ &= 250.294 \times 0.96 = 240.282[m] \end{aligned}$$

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

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※ 수직선: 건현 규정에서 선수 수직선은 다음 지점에 위치한다

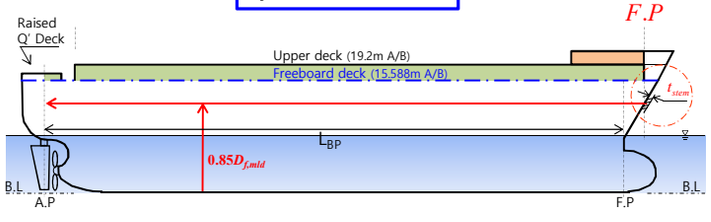
1. General Definitions (4/5)

Freeboard Length (L_f)

3,700TEU Container Ship

Item	Value
$D_{f,mld}$ (freeboard deck)	15.588 m
$0.85D_{f,mld}$	13.250 m

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



L_2: **The length on a waterline at 85% of the molded depth from the fore side of the stem to the axis of the rudder stock**

L2: 선수재 전면에서 타두재 축까지 형깊이의 85% 위치에 있는 수선상의 길이

[Example] L_2 **of the 3,700TEU Container Ship**

$$\begin{aligned} L_2 &= L_{BP} + L_{Forward,0.85D} + t_{stem} \\ &= 245.24 + 0.024 + 0.015 = 245.279[m] \end{aligned}$$

$$\begin{aligned} L_f &= \max(L_1, L_2) \\ &= \max(240.282, 245.279) = 245.279[m]\,(L_2) \end{aligned}$$

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

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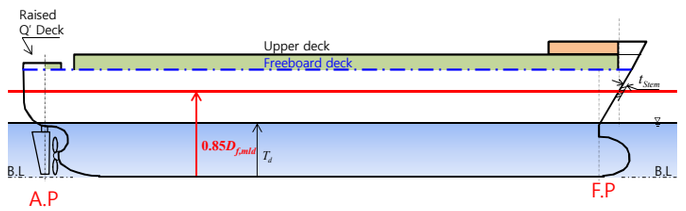
1. General Definitions (5/5)

Perpendiculars

- **Why do we use perpendiculars at 0.85D_{mld} (0.85$D_{f,mld}$ in this example) instead of T_d?**



왜 0.85Dmld(이 예에서는 0.85Df,mld)에서 수직선을 사용하는가

- **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.**

선미 수직선은 타축을 사용하여 설정한다. 선수 수직선으로 인해 다소 이례적으로 보이는 이 접근 방식은 타당하다. 일반적으로 길이와 관련되는 흘수가 입력값으로 주어지지 않기 때문이다.

- **In case the draft is not determined, the draft is only known after the freeboard calculation is finished.**

흘수가 결정되지 않은 경우, 건현 계산이 완료된 후에야 흘수를 알 수 있다.

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:**

건현을 지정하기 위한 요건은 선박이 충분히 안전하고 적절한 강도를 갖추는 것이다. 세부 요건은 다음과 같다.

  - **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.**

건현 규정의 특정 구조 요건을 충족해야 한다. 외부 출입문, 문턱 높이와 통풍관 높이, 해치 및 모든 종류의 개구부와 갑판 및 선측의 밀폐 장치에 특히 주의를 기울여야 한다.

  - **e.g., engine room openings, side windows, scuppers[1)], freeing ports[2)], and pipe outlets**

예: 기관실 개구부, 측면 창, 배수구1), 방수구2) 및 배관 출구

1) Scupper: Openings in the shell plating just above deck plating to allow water to run overboard.
1) 배수구: 물이 선외로 흘러나가도록 갑판 외판 바로 위에 설치한 개구부이다.
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.
2) 방수구: 파도에 의해 선박 갑판으로 올라온 다량의 물을 배출하기 위한 불워크 또는 난간의 개구부이다.
(http://www.libertyship.com/html/glossary/glosbody.htm: Project Liberty Ship - Glossary of Nautical and Shipbuilding Terms)

(http://www.libertyship.com/html/glossary/glosbody.htm: Project Liberty Ship - 항해 및 조선 용어집)

3. Required Data for the Calculation of Freeboards

3. 건현 산정에 필요한 자료

- **To calculate the freeboard of a ship in accordance with ICLL 1966, some data and plans are required as follows:**

ICLL 1966에 따라 선박의 건현을 산정하려면 다음과 같은 자료와 도면이 필요하다.

- **Lines or Offset Table (Fared Lines)**

선도 또는 오프셋 표(정형 선도)

- **General Arrangement (G/A) Plan**

일반배치(G/A)도

- **Hydrostatic Table**

정수력학표

- **Midship Section (M/S) Plan**

중앙횡단면(M/S)도

- **Shell Expansion Plan**

외판 전개도

- **Construction Profile and Decks Plan**

구조 종단면도 및 갑판도

- **Superstructure Construction Plan**

상부구조물 구조도

- **Construction Plans of After Body and Fore Body**

선미부 및 선수부 구조도

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3. Procedure of Freeboard Calculation

3. 건현 산정 절차

Types of Ships

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

건현 산정을 목적으로 선박은 형식 A와 형식 B로 구분한다.

▪ Type 'A' ships

형식 A 선박

: A type 'A' ship is designed to carry only liquid cargoes in bulk.

: 형식 A 선박은 산적 액체 화물만 운송하도록 설계된 선박이다.

[Example] Crude Oil Carrier, LNG Carrier, etc.

[예] 원유 운반선, LNG 운반선 등

- **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.**

형식 A 선박은 노출 갑판의 완전성이 높고, 화물 구획으로 통하는 작은 출입구만 설치되며, 이러한 출입구는 강철 또는 동등한 재료로 제작된 수밀 개스킷 덮개로 폐쇄된다.

- **The type 'A' ship has low permeability of loaded cargo compartments.**

형식 A 선박은 적재된 화물 구획의 투과율이 낮다.

▪ Type 'B' ships

형식 B 선박

: All ships which do not come within the provisions regarding type 'A' ships shall be considered as type 'B' ships.

: 형식 A 선박에 관한 규정의 적용을 받지 않는 모든 선박은 형식 B 선박으로 간주한다.

[Example] Container Ship, Bulk Carrier, Ore Carrier, etc.

[예] 컨테이너선, 산적화물선, 광석 운반선 등

∗ 3,700TEU Container Ship is a type 'B' ship.

∗3,700TEU Container Ship은 형식 B 선박이다.

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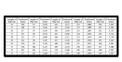
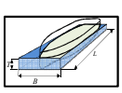
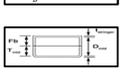
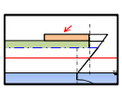
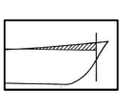
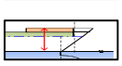
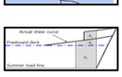
Freeboard Calculation Procedure

건현 산정 절차

1	**Tabular freeboard (F_t)** calculation	
2	Correction for **block coefficient** ($C_{B,0.85Dmld} \neq 0.68$)	
3	Correction for **depth** ($D_f \neq L_f/15$)	
4	Deduction for **superstructure and trunks**	
5	Correction for **sheer** (sheer ≠ standard sheer)	
6	Correction for minimum **bow height**	
7	Correction for **reserve buoyancy**	
8	**Maximum molded summer draft**	

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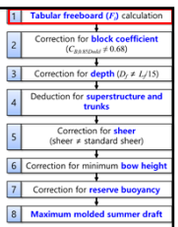
(1) Tabular Freeboard (F_t) Calculation



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

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
:	

The tabular freeboard for type 'B' ships shall be determined from freeboard table for type 'B' ships.

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

(1) 표 건현(Ft) 산정 형식 'B' 선박의 표 건현은 형식 'B' 선박용 건현 표에서 산정한다. 선박의 중간 길이에 해당하는 건현은

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

[표 1] 건현 표 선형 보간으로 산정한다. 형식 'B' 선박의

[Example] 3,700TEU Container Ship

[예] 3,700TEU Container Ship

$$L_f = 245.279[m]$$

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

$$= 3,770[mm]$$

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[References] Freeboard Table

Type A ships

Length of ship (m)	Freeboard (mm)	Length of ship (m)	Freeboard (mm)	Length of ship (m)	Freeboard (mm)	Length of ship (m)	Freeboard (mm)	Length of ship (m)	Freeboard (mm)
24	200	93	1,029	162	2,155	231	2,880	300	3,262
25	208	94	1,044	163	2,169	232	2,888	301	3,266
26	217	95	1,059	164	2,184	233	2,895	302	3,270
27	225	96	1,074	165	2,198	234	2,903	303	3,274
28	233	97	1,089	166	2,212	235	2,910	304	3,278
29	242	98	1,105	167	2,226	236	2,918	305	3,281
30	250	99	1,120	168	2,240	237	2,925	306	3,285
31	258	100	1,135	169	2,254	238	2,932	307	3,288
32	267	101	1,151	170	2,268	239	2,939	308	3,292
33	275	102	1,166	171	2,281	240	2,946	309	3,295

Type B ships

Length of ship (m)	Freeboard (mm)	Length of ship (m)	Freeboard (mm)	Length of ship (m)	Freeboard (mm)	Length of ship (m)	Freeboard (mm)	Length of ship (m)	Freeboard (mm)
24	200	93	1,135	162	2,560	231	3,750	300	4,630
25	208	94	1,154	163	2,580	232	3,765	301	4,642
26	217	95	1,172	164	2,600	233	3,780	302	4,654
27	225	96	1,190	165	2,620	234	3,795	303	4,665
28	233	97	1,209	166	2,640	235	3,808	304	4,676
29	242	98	1,229	167	2,660	236	3,821	305	4,686
30	250	99	1,250	168	2,680	237	3,835	306	4,695
31	258	100	1,271	169	2,698	238	3,849	307	4,704
32	267	101	1,293	170	2,716	239	3,864	308	4,714
33	275	102	1,315	171	2,735	240	3,880	309	4,725

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(2) Correction for Block Coefficient (C_B)

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

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

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

(2) 방형계수(CB) 보정 0.85Dmld에서의 방형계수(CB)

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

3,700TEU Container Ship

Item	Value
$D_{f,mld}$ (freeboard deck)	15.588 m
$0.85D_{f,mld}$	13.250 m
$C_{B,0.85Dmld}$	0.6705

선박의 형배수량 체적( )은 이 예에서는 0.85Dmld(= 0.85Df,mld)의 형흘수에서 취한다.

If the block coefficient exceeds 0.68, the tabular freeboard specified in

방형계수가 0.68을 초과하면, 표 건현은

Regulation 28 shall be multiplied by the factor.

규정 28에 명시된 표 건현에 다음 계수를 곱해야 한다.

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

C 0.68 방형계수 보정(cF)

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

C 0.68 방형계수에 대한 보정은 없다.

[Example] 3,700TEU Container Ship

[예] 3,700TEU Container Ship

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

$$\rightarrow \text{There is no correction for block coefficient. } (c_{CB} = 0)$$

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방형계수에 대한 보정은 없다. (c 0)

(3) Correction for Depth (D_f)

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

Freeboard Depth (D_f)

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

$$D_f = D_{mld} + t_{deck}$$

where $D_{mld} = D_{f,mld}$ (freeboard deck)

$t_{stringer}$: **Thickness of the freeboard deck**

3,700TEU Container Ship

Item	Value
$D_{f,mld}$ (freeboard deck)	15.588 m
t_{deck}	0.013 m
D_f (freeboard deck)	15.601 m

$$D_f \leq L_f/15$$

There is no correction for depth.

$$D_f > L_f/15$$

$$\text{Correction for depth } (c_D) = (D_f - L_f/15) \cdot R \text{ [mm]}$$

깊이 보정(c) (D L /15) R [mm]

$$R = L_f/0.48 : L_f < 120\,m$$

(This value will be added to the required value)

D f f (이 값은 요구값에 더해진다)

$$R = 250 : L_f \geq 120\,m$$

[Example] 3,700TEU Container Ship

[예] 3,700TEU Container Ship

$$D_f \neq D_{mld} + t_{deck}$$

(∵ freeboard deck ≠ upper deck)

D D t (∵ 건현갑판 ≠ 상갑판)

$$D_f = 15.601[m], \quad L_f/15 = 245.279/15 = 16.352[m]$$

$$\therefore D_f < L_f/15 \rightarrow \text{There is no correction for depth. } (c_D = 0)$$

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(3) Correction for Depth (D_f)

Height of the Superstructure

- **If the ship has an enclosed superstructure covering at least 0.6L_f amidships, with a complete trunk, or a combination of detached enclosed superstructures and trunks which extend all fore and aft, the freeboard should be reduced at the rate (c_D).**

선박이 중앙부에서 최소 0.6Lf를 덮고 완전한 트렁크를 갖춘 폐쇄형 상부구조물, 또는 선수에서 선미까지 연장되는 분리된 폐쇄형 상부구조물과 트렁크의 조합을 갖는 경우, 건현은 cD의 비율로 감산해야 한다.

- **At this time, if the actual height of the superstructure or trunk is less than the corresponding standard height, the calculated reduction should be corrected in the ratio of the height of the actual superstructure or trunk to the applicable standard height, as the following equation.**

이때 상부구조물 또는 트렁크의 실제 높이가 해당 표준 높이보다 낮으면, 계산된 감산량을 다음 식과 같이 실제 상부구조물 또는 트렁크 높이와 적용 가능한 표준 높이의 비율에 따라 보정해야 한다.

$$c_D = c_D \cdot \frac{H_S}{H_{S_0}}$$

where
H_S: Actual height of the superstructure
H_{S0}: Standard height of the superstructure

3,700TEU Container Ship

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

[Example] 3,700TEU Container Ship

$$c_D = c_D \cdot \frac{H_S}{H_{S_0}} = 0 \cdot \frac{3.71}{2.30} = 0$$

$\rightarrow$ There is no correction for depth. ($c_D = 0$)

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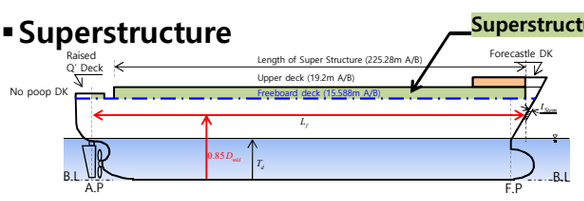
(4) Deduction for Superstructure and Trunks (1/6)

1 Tabular freeboard (F_T) calculation
2 Block coefficient (C_B)
3 Correction for depth ($D_f \neq L_f/15$)
4 Deduction for superstructure and trunks
5 Correction for sheer (sheer ≠ standard sheer)
6 Correction for minimum bow height
7 Correction for reserve buoyancy
8 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 decked structure on the freeboard deck, extending from side to side

(4) 상부구조물 및 트렁크에 대한 감산 (1/6) 상부구조물 상부구조물은 건현갑판 위에 설치된 갑판 구조물로서 선박의 한쪽 현에서 다른 쪽 현까지 연장되거나

of the ship or with the side plating not being inboard of the shell plating more than 4% of the breadth.

선측 외판이 외판보다 선박의 안쪽으로 너비의 4%를 초과하여 들어가지 않는 구조물이다.

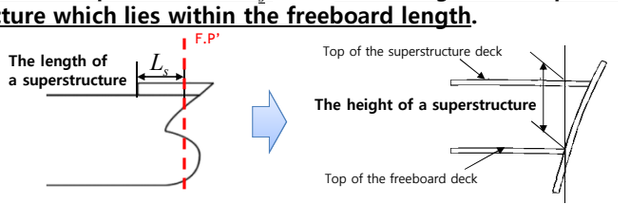
The height of a superstructure: The least vertical height measured at side from the top of the

상부구조물의 높이: 선측에서 상부구조물 갑판 보의 상단부터

superstructure deck beams to the top of the freeboard deck beams.

상부구조물 갑판 보의 상단부터 건현갑판 보의 상단까지 측정한 최소 수직 높이이다.

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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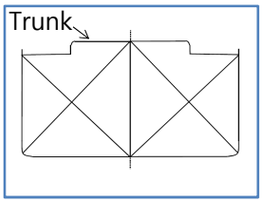
상부구조물의 길이(Ls): 건현 길이 내에 위치하는 상부구조물 부분의 평균 길이이다.

[Reference] 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.

- 트렁크에는 특별 규정이 있다(Reg. 36)는 여기서 다루지 않는다. 표준 높이의 폐쇄형 상부구조물에 대해서는 E = S이다. - S는 L 내에 있는 상부구조물의 길이이다.

- 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).

- 상부구조물이 선박 측면에서 안쪽으로 들어간 경우, E는 다음 계수에 따라 수정된다.

계수는 b/Bs이며, 여기서 b는 상부구조물의 폭이고 Bs는 선박의 폭으로, 둘 다 상부구조물 길이 중앙에서 측정한 값이다(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.

곡선 격벽으로 끝나는 상부구조물의 경우, S는 Reg. 34에 따라 특별히 정의된다. 상부구조물 높이 dv가 표준 높이 ds보다 낮으면

- 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.

유효 길이는 (완전한 전면이 설치된 경우) 융기 선미갑판의

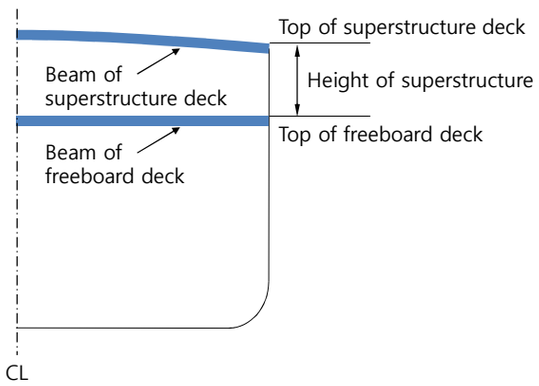
- Otherwise the raised quarterdeck is treated as a poop of less than standard height.

그렇지 않으면 융기 선미갑판은 표준 높이보다 낮은 선미루로 취급한다.

[Reference] Height of Superstructure

Measurement of the Height of Superstructure

[참고] 상부구조물 높이



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

1 Tabular freeboard (F_t) calculation
2 Correction for block coefficient ($C_{B,ASSIGN} \neq C_B$)
3 Correction for depth ($D_s \neq L_f/15$)
4 Deduction for superstructure and trunks
5 Correction for sheer (sheer ≠ standard sheer)
6 Correction for minimum bow height
7 Correction for reserve buoyancy
8 Maximum molded summer draft

3,700TEU Container Ship

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

▪ Effective length of superstructure (L_E)

L_E = Mean Length × [min(Standard Height, Actual Height)] / 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

(4) 상부구조물 및 트렁크에 대한 공제(2/6) 상부구조물의 유효 길이(LE) LE = 평균 길이 [최솟값(표준 높이, 실제 높이)] / 표준 높이 밀폐형 상부구조물의 높이가 표준 높이보다 1만큼 높은 경우, 그 유효 길이는 표준 높이의 밀폐형 상부구조물의 평균 높이는 그 길이이다.

shall be its length reduced in the ratio of the actual height to the standard height.

표준 높이보다 2만큼 낮은 경우, 유효 길이는 실제 높이와 표준 높이의 비율에 따라 그 길이를 줄인 값으로 한다.

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

상부구조물의 표준 높이는 다음 표에 제시된 값으로 한다.

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.

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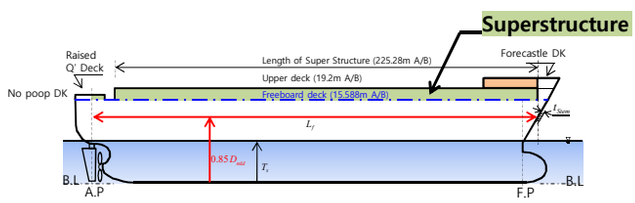
선박의 중간 길이에서의 표준 높이는 선형 보간으로 구한다.

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

1 Tabular freeboard (F_t) calculation
2 Correction for block coefficient ($C_{B,ASSIGN} \neq C_B$)
3 Correction for depth ($D_s \neq L_f/15$)
4 Deduction for superstructure and trunks
5 Correction for sheer (sheer ≠ standard sheer)
6 Correction for minimum bow height
7 Correction for reserve buoyancy
8 Maximum molded summer draft

L_E = Mean Length × [min(Standard Height, Actual Height)] / Standard Height



3,700TEU Container Ship

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_s: Length of a superstructure

[Example] 3,700TEU Container Ship

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

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

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

$$= 7.72\ [m]$$

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

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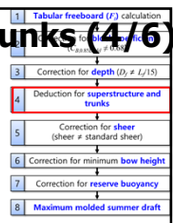
(4) Deduction for Superstructure and Trunks (4/6)



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

▪ Deduction from the freeboard

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

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

(4) 상부구조물 및 트렁크 공제(4/6) 건현 공제 상부구조물 및 트렁크의 유효 길이(LE)가 11.0Lf인 경우 350 mm : Lf 24 m 건현 공제 = 860 mm : Lf 85 m ,1 070 mm : Lf 122 m

(Deductions at intermediate lengths can be obtained by linear interpolation)

(중간 길이에서의 공제는 선형 보간으로 구할 수 있다)

② less than 1.0L_f, the deduction shall be a percentage obtained from the following table:

2 1.0Lf 미만인 경우, 다음 표에서 공제율을 구한다:

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

형식 'A' 및 'B' 선박의 공제율

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

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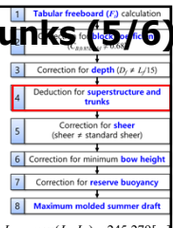
상부구조물 및 트렁크의 중간 길이에서의 비율은 선형 보간으로 구한다.

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



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

▪ Deduction from the freeboard

[Example] 3,700TEU Container Ship

$L_f = 245.279[m]$
$L_E = 233.00[m]$
$\therefore L_E < L_f$

(4) 상부구조물 및 트렁크 공제(5/6) 건현 공제

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

상부구조물 및 트렁크의 유효 길이(LE)가 1.0Lf 미만인 경우, 다음 표에서 공제율을 구한다:

$L_E / L_f = 0.95$

	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

Percentage of deduction for superstructures

상부구조물의 공제율

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

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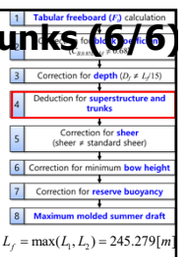
(4) Deduction for Superstructure and Trunks (6/6)



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

Percentage of deduction for superstructures = 93.85%

- **Deduction from the freeboard**

[Example] 3,700TEU Container Ship

$L_f = 245.279[m]$

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

(4) 상부구조물 및 트렁크 공제 (6/6) 건현 공제 [예] 3,700TEU Container Ship 건현 공제량 = 860 mm : L 85 m

(Deductions at intermediate lengths can be obtained by linear interpolation)

(중간 길이에서의 공제량은 선형 보간으로 구할 수 있다)

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

Deduction from the freeboard (c_{ST}) $= 1{,}070 \cdot 0.9385 = 1{,}004[mm]$

건현 공제량에 백분율을 곱한다

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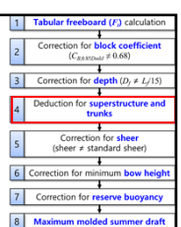
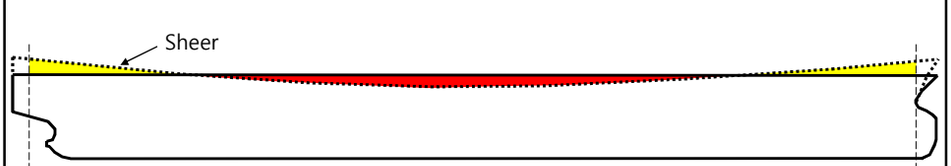
(5) Correction for Sheer (1/7)

Sheer

- **Sheer is the upward rise of a ship's deck from mid length towards the bow and stern.**
- **The sheer gives the ship extra reserve buoyancy at the stem and the stern.**



종굽힘은 선박 갑판이 중앙부에서 선수와 선미를 향해 위쪽으로 상승하는 것을 말한다. 종굽힘은 선수와 선미에서 선박에 추가적인 예비 부력을 제공한다.



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(5) Correction for Sheer (2/7)

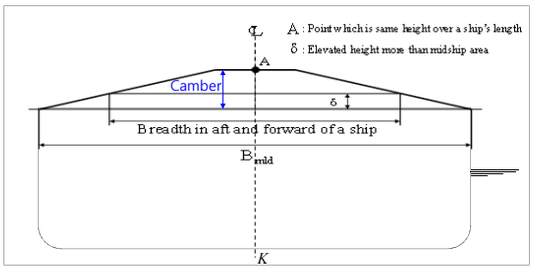
Camber

1 Tabular freeboard (F_1) calculation
2 Correction for block coefficient ($C_{B\,ACTUAL} \neq 0.68$)
3 Correction for depth ($D_s \neq L_s/15$)
4 Deduction for superstructure and trunks
5 Correction for sheer (sheer ≠ standard sheer)
6 Correction for minimum bow height
7 Correction for reserve buoyancy
8 Maximum molded summer draft

- **Camber is the transverse curvature of the weather deck.**
- **The curvature helps to ensure sufficient drainage of any water on deck.**
- **For ships with camber, care must be taken that the deck without sheer do not become too humped at the ends as a result of the deck beam. In other words, the deck centerline should have no sheer and the deck edge line should be raised.**

횡곡률은 노출 갑판의 횡방향 곡률이다. 이 곡률은 갑판 위에 고인 물이 충분히 배수되도록 하는 데 도움이 된다.

횡곡률이 있는 선박에서는 갑판 보의 영향으로 종굽힘이 없는 갑판의 양 끝이 지나치게 솟아오르지 않도록 주의해야 한다. 즉, 갑판 중심선에는 종굽힘이 없어야 하며 갑판 가장자리 선은 높아져야 한다.



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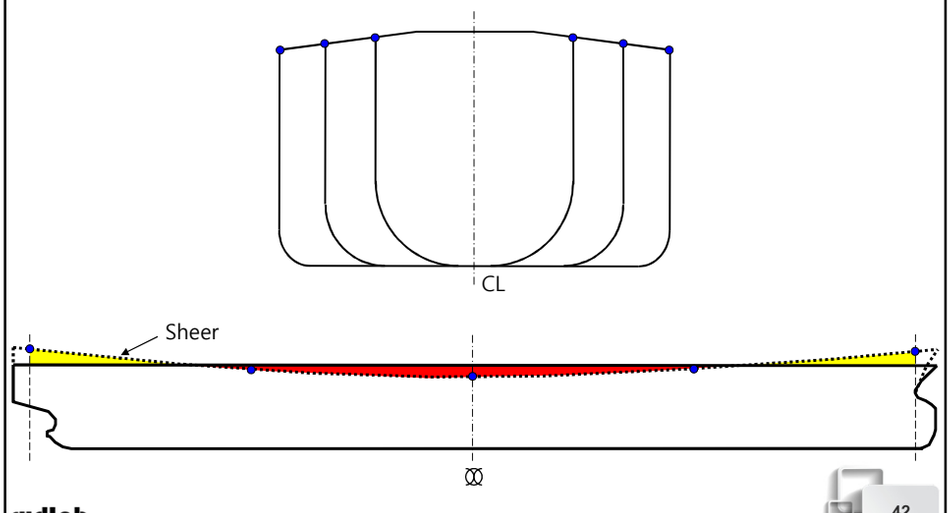
[Reference] Sheer Caused by Camber

- **Even in the case of a ship without a sheer, a small sheer may be generated by the camber.**



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[참조] 횡곡률로 인해 발생하는 종굽힘 종굽힘이 없는 선박의 경우에도 횡곡률로 인해 작은 종굽힘이 발생할 수 있다.

(5) Correction for Sheer (3/7)

1 Tabular freeboard (F_t) calculation
2 Correction for block coefficient ($C_{B,0.85D\text{and}d} \neq 0.68$)
3 Correction for depth ($D_f \neq L_f/15$)
4 Deduction for superstructure and trunks
5 Correction for sheer (sheer ≠ standard sheer)
6 Correction for minimum bow height
7 Correction for reserve buoyancy
8 Maximum molded summer draft

▪ Correction for sheer

$$\text{Correction for shear } (c_S) = (S_o - S)\cdot(0.75 - 0.5r_1)$$

종굽힘 보정 종굽힘 보정 (c) (So − S)(0.75 − 0.5r)

S_o : Standard height of sheer (mm)
S : Mean height of actual sheer, including sheer credit (mm)
r_1 : The effective length (L_E) of superstructures divided by freeboard length (L_f)

$$r_1 = L_E / L_f$$

So: 종굽힘의 표준 높이(mm) S: 종굽힘 여유를 포함한 실제 종굽힘의 평균 높이(mm) 1r: 상부구조물의 유효 길이(LE)를 건현 길이(Lf)로 나눈 값

- If $S_0 > S$, **the correction for sheer is positive. The required freeboard increases.**

S0>S인 경우 종굽힘 보정은 양수이다. 요구 건현이 증가한다.

- If $S_0 < S$, **the correction for sheer is negative. The required freeboard decreases.**

S0<S인 경우 종굽힘 보정은 음수이다. 요구 건현이 감소한다.

Calculation of actual sheer (S) =
(a) Excess or deficiency of sheer + (b) Sheer credit for superstructure

실제 종굽힘(S)의 계산 = (a) 종굽힘의 초과 또는 부족 + (b) 상부구조물에 대한 종굽힘 여유

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(5) Correction for Sheer (4/7)

1 Tabular freeboard (F_t) calculation
2 Correction for block coefficient ($C_{B,0.85D\text{and}d} \neq 0.68$)
3 Correction for depth ($D_f \neq L_f/15$)
4 Deduction for superstructure and trunks
5 Correction for sheer (sheer ≠ standard sheer)
6 Correction for minimum bow height
7 Correction for reserve buoyancy
8 Maximum molded summer draft

(a) Excess or deficiency of sheer
➡ Design ship has no sheer.

(a) 종굽힘의 초과 또는 부족 설계 선박에는 종굽힘이 없다.

$L_f = 245.279[m]$

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
Forward 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	$S_F = 16.68(L_f/3+10)$			1,526	S_f			0

(2,294+3,057+771+0)/(1+3+3+1)=765
(0+1,542+6,111+4,588)/(1+3+3+1)=1,526

Standard height of sheer (S_o): ($S_A + S_F$)/2 = 1,146 mm
Fore height of actual sheer (S_f) = 0 mm
After height of actual sheer (S_a) = 0 mm

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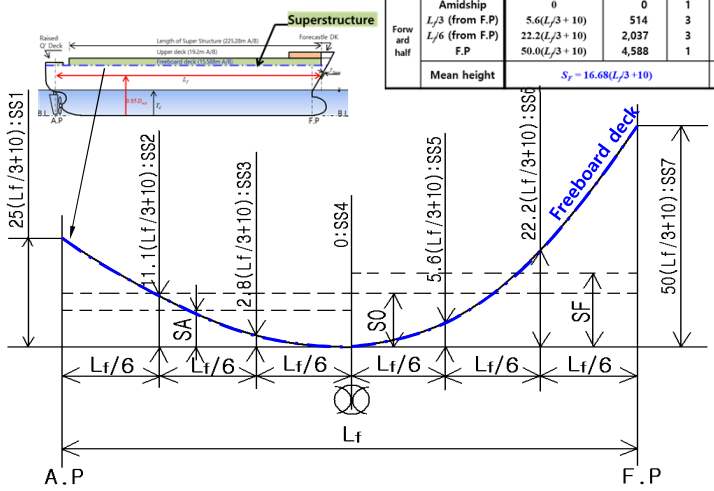
종굽힘의 표준 높이(So): (S_A + S_F)/2 = 1,146 mm 실제 선수 종굽힘의 높이(S_f) = 0 mm 실제 선미 종굽힘의 높이(S_a) = 0 mm

(5) Correction for Sheer (5/7)

1 Tabular freeboard (L_f) calculation
2 Correction for block coefficient ($C_{B@0.85D}$ ≠ 0.68)
3 Correction for depth ($D_f \neq L_f/15$)
4 Deduction for superstructure and trunks
5 Correction for sheer (sheer ≠ standard sheer)
6 Correction for minimum bow height
7 Correction for reserve buoyancy
8 Maximum molded summer draft

* Standard height of sheer

Station		Standard			
		Height (mm)	Ordinate	Factor	Product
After half	A.P	$25.0(L_f/3+10)$	2,294	1	2,294
	$L_f/6$ (from A.P)	$11.1(L_f/3+10)$	1,019	3	3,057
	$L_f/3$ (from A.P)	$2.8(L_f/3+10)$	257	3	771
	Amidship	0	0	1	0
	Mean height	$S_A = 8.34(L_f/3+10)$			765
Forward half	Amidship	0	0	1	0
	$L_f/3$ (from F.P)	$5.6(L_f/3+10)$	514	3	1,542
	$L_f/6$ (from F.P)	$22.2(L_f/3+10)$	2,037	3	6,111
	F.P	$50.0(L_f/3+10)$	4,588	1	4,588
	Mean height	$S_F = 16.68(L_f/3+10)$			1,526



(5) Correction for Sheer (6/7)

1 Tabular freeboard (L_f) calculation
2 Correction for block coefficient ($C_{B@0.85D}$ ≠ 0.68)
3 Correction for depth ($D_f \neq L_f/15$)
4 Deduction for superstructure and trunks
5 Correction for sheer (sheer ≠ standard sheer)
6 Correction for minimum bow height
7 Correction for reserve buoyancy
8 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 ($= \max(0, h_a - h_s)$)

L': Mean enclosed length of poop or forecastle up to a maximum length of $0.5L_f$

① Sheer credit for forecastle

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

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

Fore height of actual sheer of the freeboard deck

S': Actual height of sheer corrected by sheer credit

$L_f = 245.279[m]$
$h_a(actual\ height\ of\ forecastle) = 3{,}200\ [mm]$
$h_s = 2{,}300\ [mm]$
$L'(length\ of\ forecastle) = 25.3\ [m]$
No poop in the example
$S_a = 0 \quad S_f = 0$

② Sheer credit for poop

$$s_p = \frac{Y_p}{3} \cdot \frac{L'}{L_f} = \frac{\max(0, 0 - 2{,}300)}{3} \cdot \frac{0}{245.279} = 0$$

$$\rightarrow S'_a = S_a + s_p = 0 + 0 = 0\ [mm]$$

No poop deck for design ship ($Y_p = 0$)

After height of actual sheer of the freeboard deck

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

(b) 상부구조물에 대한 종균힘 가산 종균힘 형상의 선수측 절반 또는 선미측 절반이 표준보다 큰 경우, 선미루 또는 선수루에 대해 종균힘 가산이 인정된다. 종균힘 가산은 다음과 같다

(5) Correction for Sheer (7/7)

1. Tabular freeboard (F_t) calculation
2. Correction for block coefficient ($C_{B85\%Dmld} \neq 0.68$)
3. Correction for depth ($D_f \neq L_f/15$)
4. Deduction for superstructure and trunks
5. Correction for sheer (sheer ≠ standard sheer)
6. Correction for minimum bow height
7. Correction for reserve buoyancy
8. Maximum molded summer draft

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

$S_f' = 31\,[mm]$

$S_a' = 0\,[mm]$

$r_1 = L_E / L_f = 0.95$

(c) Correction for sheer

Standard height of sheer (S_o):

$$S_o = \frac{(S_A + S_F)}{2} = \frac{(765 + 1,526)}{2} = 1,146\,[mm]$$

Mean height of actual sheer (S):

$$S = \frac{(S_a' + S_f')}{2} = \frac{(0+31)}{2} = 15.5\,[mm]$$

$$\text{Correction for shear } (c_S) = (S_o - S)\cdot(0.75 - 0.5 r_1)$$

전단 보정 (c) (S S) (0.75 0.5) r

$$= (1,146 - 15.5)\cdot(0.75 - 0.5\cdot 0.95)$$
$$= 311\,[mm]$$

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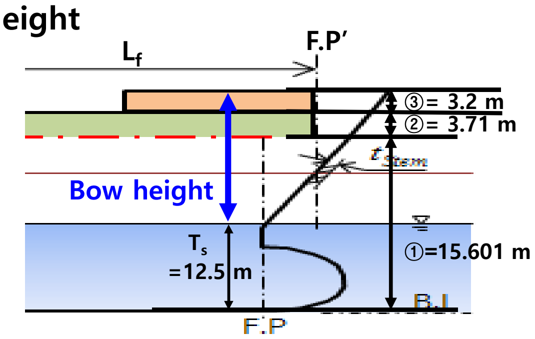
(6) Correction for Minimum Bow Height (1/3)

1. Tabular freeboard (F_t) calculation
2. Correction for block coefficient ($C_{B85\%Dmld} \neq 0.68$)
3. Correction for depth ($D_f \neq L_f/15$)
4. Deduction for superstructure and trunks
5. Correction for sheer (sheer ≠ standard sheer)
6. Correction for minimum bow height
7. Correction for reserve buoyancy
8. Maximum molded summer draft

- **Bow height**



(6) 최소 선수 높이 보정 (1/3) 선수 높이

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

선수 높이 (Hb)는 지정된 여름 건현과 설계 트림에 해당하는 수면과 선측의 노출 갑판 상단 사이를 선수 수직선에서 측정한 수직 거리로 정의한다.

[Example] 3,700TEU Container Ship

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 [m]

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(6) Correction for Minimum Bow Height (2/3)

1 Tabular freeboard (L_f) calculation
2 Correction for block coefficient ($C_B \neq 0.68$)
3 Correction for depth ($D_f \neq L_f/15$)
4 Deduction for superstructure and trunks
5 Correction for sheer (sheer ≠ standard sheer)
6 Correction for minimum bow height
7 Correction for reserve buoyancy
8 Maximum molded summer draft

▪ Minimum bow height

$$Minimm\ bow\ height = \left[6{,}075\left(\frac{L_f}{100}\right) - 1{,}875\left(\frac{L_f}{100}\right)^2 + 200\left(\frac{L_f}{100}\right)^3\right] \times$$

$$\left[2.08 + 0.609C_{B,0.85D} - 1.603C_{WF} - 0.0129\left(\frac{L_f}{D_f}\right)\right] \text{[mm]}$$

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

(6) 최소 선수 높이 보정 (2/3) 최소 선수 높이

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

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

&"#: 전방 /의 수면 면적

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

[Example] 3,700TEU Container Ship

$L_f = 245.279[m]$
$B = 32.2[m]$
$C_{B,0.85D} = 0.6705$
$A_{WF} = 26{,}695[m^2]$
$D_f = 15.601[m]$
$Actual\ bow\ height = 10.011[m]$

$$Minimm\ bow\ height = \left[6{,}075\left(\frac{245.279}{100}\right) - 1{,}875\left(\frac{245.279}{100}\right)^2 + 200\left(\frac{245.279}{100}\right)^3\right]$$

$$\times \left[2.08 + 0.609 \cdot 0.6705 - 1.603 \cdot \left(\frac{2{,}669.5}{\left(\frac{245.279}{2}\right) \cdot 32.2}\right) - 0.0129\left(\frac{245.279}{15.601}\right)\right] \text{[mm]}$$

= 7,899 [mm]

$\therefore Actual\ bow\ height > Minimum\ bow\ height$

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실제 선수 높이는 최소 선수 높이보다 커야 한다.

(6) Correction for Minimum Bow Height (3/3)

1 Tabular freeboard (L_f) calculation
2 Correction for block coefficient ($C_B \neq 0.68$)
3 Correction for depth ($D_f \neq L_f/15$)
4 Deduction for superstructure and trunks
5 Correction for sheer (sheer ≠ standard sheer)
6 Correction for minimum bow height
7 Correction for reserve buoyancy
8 Maximum molded summer draft

▪ Correction for bow height

(6) 최소 선수 높이 보정 (3/3) 선수 높이 보정

If actual bow height

① is larger than minimum bow height.

실제 선수 높이 1이 최소 선수 높이보다 큰 경우

$$\text{Correction for bow height } (c_{BH}) = 0$$

선수 높이 보정 (c) 0

② is less than minimum bow height

$$\text{Correction for bow height } (c_{BH}) = Minimum\ bow\ height - Actual\ bow\ height$$

2가 최소 선수 높이보다 작은 경우 선수 높이 보정 (c) 최소 선수 높이 실제 선수 높이

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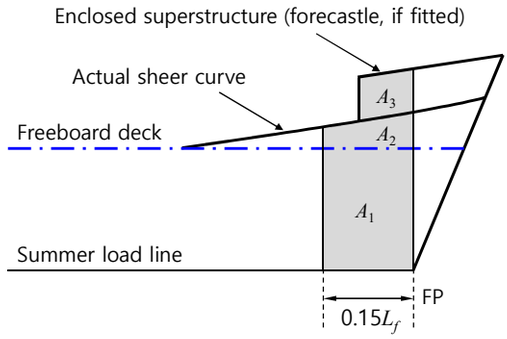
(7) Correction for Reserve Buoyancy

1 Tabular freeboard (F_t) calculation
2 Correction for block coefficient ($C_{B\,STD\,Ref} \neq 0.68$)
3 Correction for depth ($D_f \neq L_f/15$)
4 Deduction for superstructure and trunks
5 Correction for sheer (sheer ≠ standard sheer)
6 Correction for minimum bow height
7 Correction for reserve buoyancy
8 Maximum molded summer draft



$$F_{\min} = F_0 \cdot f_1 + f_2$$

F_0: Tabular freeboard [mm]
f_1: Correction for block coefficient [mm]
f_2: Correction for depth [mm]

(7) 예비 부력 보정 F0: 표 건현 [mm] f1: 방형계수 보정 [mm] f2: 깊이 보정 [mm]

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.

유조선, 화학제품 운반선 및 가스 운반선을 제외하고 형식 'B' 건현이 지정된 모든 선박은 선수부에 추가적인 예비 부력을 확보해야 한다.

The regulation should be satisfied as follows:

다음과 같이 규정을 만족해야 한다.

$$A_1 + A_2 + A_3 \geq (0.15 \cdot F_{\min} + 4 \cdot (L_f / 3 + 10)) \cdot L_f / 1000$$

If this is not satisfied, the correction for reserve buoyancy in mm should be added to the freeboard. This addition will increase the height of the freeboard deck and the freeboard

이 조건을 만족하지 못하면 예비 부력에 대한 보정값을 mm 단위로 건현에 더해야 한다.

depth (D_f), and thus the area of A_1 will increase as well. If necessary, the value (c_{RB}) of

이 추가로 인해 건현갑판의 높이와 건현 깊이(Df)가 증가하므로 A1의 면적도 증가한다.

this correction should be made manually through trial and error, ensuring that the above criterion is met.

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필요한 경우 위 기준을 만족하도록 시행착오를 통해 이 보정값(cRB)을 수동으로 결정해야 한다.

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

* 만재흘수선에 관한 International Convention on Load Lines 1966, 부속서 1 제1장, 규칙 3-(5), 2003

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

1 Tabular freeboard (F_t) calculation
2 Correction for block coefficient ($C_{B\,STD\,Ref} \neq 0.68$)
3 Correction for depth ($D_f \neq L_f/15$)
4 Deduction for superstructure and trunks
5 Correction for sheer (sheer ≠ standard sheer)
6 Correction for minimum bow height
7 Correction for reserve buoyancy
8 Maximum molded summer draft

- **Maximum molded summer draft (d_S)**

Fb_{ICLL} **(the minimum freeboard in summer or summer freeboard)**
= Tabular freeboard (F_t) + Correction for block coefficient (c_{CB}) + Correction for depth (c_D) – Deduction for superstructure (c_{ST}) ± Correction for Sheer (c_S) + Correction for minimum bow height (c_{BH}) + Correction for reserve buoyance (c_{RB})

= 3,770 + 0 + 0 – 1,004 + 311 + 0 + 0

= 3,077 [mm]

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

$$D_f - T_s = 15.601 - 12.5$$
$$= 3.101\ [m] > Fb_{ICLL}$$
$$d_S = D_f - Fb_{ICLL} = 15.601 - 3.077$$
$$= 12.524\ [m]$$

(The maximum draft that the ship can have when the draft is undetermined)

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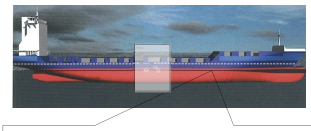
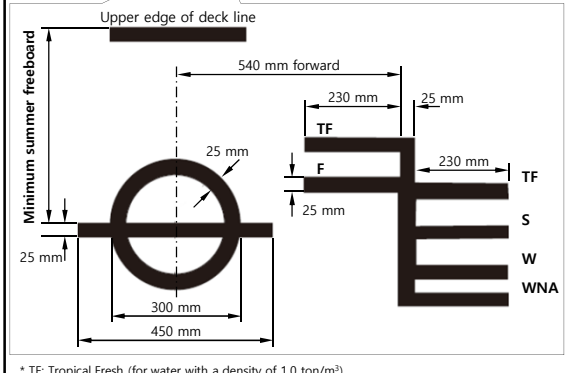
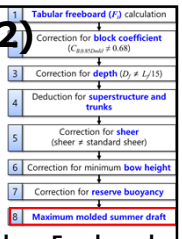
12.524 [ ] m (흘수가 정해지지 않은 경우 선박이 가질 수 있는 최대 흘수 일반)

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

Freeboard Mark







- **The Plimsoll[1)] mark or Freeboard Mark is a symbol indicating the maximal immersion 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 ($d_S = T_d$) is established.**

Tropical draft (d_T)

$$d_T = d_S + d_S / 48$$

Winter draft (d_W)

$$d_W = d_S - d_S / 48$$

* TF: Tropical Fresh (for water with a density of 1.0 ton/m³)
* F: Fresh (for water with a density of 1.0 ton/m³)
* T: Tropical (for water with a density of 1.025 ton/m³)
* S: Summer freeboard (for water with a density of 1.025 ton/m³), normally corresponding to design draft (T_d)
* W: Winter (for water with a density of 1.025 ton/m³)
* WNA: Winter North Atlantic (for water with a density of 1.025 ton/m³), only for ships, less than 100 m

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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.

(9) Summary

Freeboard Calculation of a 3,700TEU Container Ship

3,700TEU Container Ship의 건현 계산

Tabular freeboard	3,770	mm
Correction for block coefficient	0	mm
Correction for depth	0	mm
Deduction for superstructure and trunks	-1,004	mm
Correction for sheer	311	mm
Correction for minimum bow height	0	mm
Correction for reserve buoyancy	0	mm
Calculated summer freeboard (Fb_{ICLL})	**3,077**	**mm**
Freeboard depth (D_f)	15.601	m
Maximum molded summer draft ($d_s = D_f - Fb_{ICLL}$)	**12.524**	**m**
Scantling draft (T_s)	12.500	m
Margin (= $d_s - T_s$)	**24**	**mm**

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Thank you.

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