5. ESTIMATION OF DISPLACEMENT AND MAIN DIMENSIONS

General design characteristics of a ship may be described in three main groups

- The displacement
- The main dimensions, and
- The hull form

In this chapter we will deal with the estimation of size and main dimensions during the early stages of ship design.

5.1. The Displacement of a Ship

The displacement is the weight of the ship, which is equivalent to the weight of water displaced by the ship as it floats. Light ship is the weight of the ship and its permanent equipment. Load displacement is the weight of the ship when it is filled with fuel and cargo to its designed capacity, that is, when it is immersed to its load line. The displacement tonnage is

$$\Delta = \mathrm{DWT} + \mathrm{LS}$$

Where DWT is the Deadweight tonnage and LS indicates the Lightship weight. Light ship displacement is the weight of the ship excluding cargo, fuel, ballast, stores, passengers and crew. The main components of the light ship are the weight of structure, outfit, main and auxiliary machinery, and other equipment.

Deadweight tonnage is the weight, in metric tons, of the cargo, stores, fuel, passengers, and crew carried when the ship is immersed to its maximum summer load line.

Cargo deadweight refers to the revenue generating cargo capacity of a ship and is determined by deducting the weight of fuel, water, stores, crew, passengers and other items necessary for voyage from the deadweight tonnage.

The ratio of the deadweight at the load draught to the corresponding displacement is termed the deadweight coefficient

$$C_D = \frac{\mathrm{DWT}}{\Delta}$$

Typical values of C_D for different ship types are presented in **Table 5.1.**

Table 5.1. DWT/Δ ratios for merchant ships

Ship type	**C_D**
Passenger ship	0.35
General cargo ship	0.62-0.72
Large bulk carrier	0.78-0.84
Small bulk carrier	0.71-0.77
Container ship	0.70-0.75
Oil tanker	0.80-0.86
Product tanker	0.77-0.83
Ro-Ro	0.50-0.59
Trawler	0.37-0.45
LPG carrier	0.62

Kafalı (1988) recommends the following formulae for small cargo ships and tankers

Tanker	$\frac{\mathrm{DWT}}{\Delta} = \frac{0.775\mathrm{DWT}}{\mathrm{DWT}+250}$
Cargo Ship	$\frac{\mathrm{DWT}}{\Delta} = \frac{0.750\mathrm{DWT}}{\mathrm{DWT}+300}$

5.2. Main Dimensions

The main dimensions (L, B, T, D) affect the many techno-economical performance characteristics of a ship. Therefore the proper selection of the main dimensions is vitally important in the early stages of design.

There may be an infinite number of combinations of length, breadth, depth and draught, which satisfy the main requirements, and restrictions of the design problem. The designer will attempt to find the best combination, however there are too many factors to be investigated within a limited time period. Therefore, the designer, most commonly, will use an iterative approach and the resultant main dimensions will be a compromise solution rather than the optimum values.

The estimation of main dimensions will require an iterative process based on the following order

- Estimate the design displacement.
- Estimate length based on displacement and speed
- Estimate breadth based on length
- Estimate block coefficient based on length and speed
- Calculate draught to satisfy $\Delta = \mathrm{LBTC_B}$
- Calculate the required freeboard and hence the minimum required depth

Dimensional constraints may impose a limit on length, breadth, draught and air draught. A constraint on length may be set by the dimensions of canal locks or docks. It may also be set by a need to be able to turn the ship in a narrow waterway. The constrained length is usually the overall length but in some cases the constraint may apply at the waterline at which the ship is floating.

A limit on breadth is usually set by canal or dock lock gates, but the breadth of vehicle ferries is sometimes limited by the dimensions and position of shore ramps giving vehicles access to bow or stern doors. The outreach of other shore based cargo handling devices such as grain elevators or coal hoists can limit the desirable distance of the offshore hatch side from the dockside and thereby limit the breadth of the ship.

A draught limit is usually set by the depth of water in the ports and approaches to which the ship is intended to trade. For very large tankers the depth of the sea itself must be considered.

The air draught of a ship is the vertical distance from the waterline to the highest point of the ship's structure and denotes the ship's ability to pass under a bridge or other obstruction, which forms part of the projected route.

Table 5.2. Dimensional restraints

	Max length (m)	Max breadth (m)	Max draught (m)	Air draught (m)
Suez	-	74.0 48.0	11.0 17.7	-
Panama	289.6 (950 feet)	32.2 (106 feet)	12.04 TFW (39.5 feet)	57.91 (190 feet)
St Lawrence	228.6	22.86	8.0	35.5
Kiel	315	40	9.5	-

5.2.1. Length

The length of a ship will affect most of the technical and economical performance requirements. The following will be observed when two ships with the same displacement but with different length values are compared.

- The longer ship will have larger wetted surface area and hence higher viscous resistance. However, both the wave making resistance and the propulsive performance will improve with and increasing length. Therefore, fast ships should have higher lengths compared with slow speed vessels.
- Both the weight and building cost of ship will increase with length.

- Long ships may achieve the same speed with less engine power; hence the increasing length will reduce the operational costs.
- Increasing length with constant displacement may result in losses in capacity
- Increasing length may detoriate the intact stability characteristics.
- Increasing length will improve the directional stability but worsen the turning ability
- Increasing length will require a higher value of freeboard
- Increasing length will improve the vertical plane motions, including heave, pitch, vertical accelerations, deck wetness and probability of slamming

Many empirical formulae have been proposed to estimate the design length. These formulae are usually based on displacement and design speed.

Ayre ( )

$$L = \Delta^{1/3}\left(\frac{10}{3} + \frac{5}{3}\frac{V}{\sqrt{L}}\right)$$

where L[m], ∆[ton] and V[knot].

Posdunine ( )

$$L = C\left(\frac{V}{V+2}\right)^2 \Delta^{1/3}$$

where L[m], ∆[ton] and V[knot]. C coefficient is recommended as follows

	Watson (1962)	Parsons (1994)	Baxter (1976)
Single screw ships	7.15	7.1 – 7.4 (11-16.5 knots)	7.13
Twin screw ships (slow speed)	7.30	7.4 – 7.7 (15-20 knots)	7.28
Twin screw ships (high speed)	7.90	8.0 – 9.7 (20-30 knots)	7.88

Schneekluth reccommends C=7.25 for freighters with a trial speed of 15.5 to 18.5 knots.

Kafalı (1988) proposes the following values for C coefficient.

$C = 3\frac{V}{\sqrt{L}} + 3.2$ Passenger ship

$C = 1.7\frac{V}{\sqrt{L}} + 4.4$ Cargo ship - tanker

$C = 0.75\frac{V}{\sqrt{L}} + 3.66$ Tug

where V (knot) and L (m)

Gilfillan (1968) proposes the following formula for the length of a bulk carrier

$$L = 7.38\left(\frac{V}{V+2}\right)DWT^{1/3}$$

Völker ( ) proposes the following formula for dry cargo and container ships

$$L = \Delta^{1/3}\left(3.5 + 2.3\frac{V}{\sqrt{g\Delta^{1/3}}}\right)$$

Where L[m], ∆[ton] and V[knot] .

Schneekluth (1987) developed the following formula on the basis of lowest production costs.

$$L = C\Delta^{0.3}V^{0.3}$$

Where L[m], Δ[ton] and V[knot] . C is a coefficient which van be taken 3.2 if the block coefficient has the approximate value of $C_B = \frac{0.145}{F_n}$ within the range of 0.48-0.85. If the block coefficient differs from this value the coefficient C can be modified as follows

$$C = 3.2\frac{C_B + 0.5}{\frac{0.145}{Fn} + 0.5}$$

Where $Fn = \frac{V}{\sqrt{gL}}$ (L [m], V [m/s])

Benford[10] recommends the following formula for liner type general cargo vessels:

$$L = 6.31\left(\frac{V}{V+2}\right)\Delta^{1/3} \qquad V \text{ [knot]}$$

Wright () proposes the following formula for the design length

$$L_{BP} = 5.58\,DWT^{1/3}$$

The relation between the term $\left(\frac{V}{V+2}\right)DWT^{1/3}$ and ship design length has been investigated for a large number of recent designs which resulted in a series of empirical formulae as given in the following table.

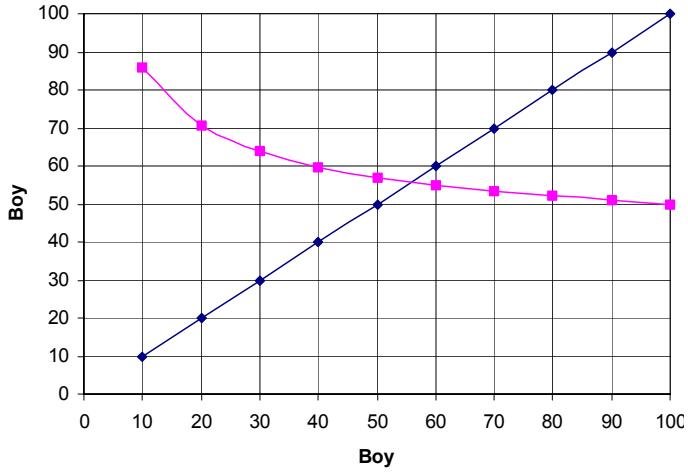
Ship type	Design length (m)	Ship type	Design length (m)
Container	$8.13\left(\frac{V}{V+2}\right)DWT^{1/3} - 33.975$	General Cargo	$5.54\left(\frac{V}{V+2}\right)DWT^{1/3} + 12.041$
Tanker	$5.31\left(\frac{V}{V+2}\right)DWT^{1/3} + 14.743$	Bulk carrier	$5.38\left(\frac{V}{V+2}\right)DWT^{1/3} + 15.461$
Chemical tanker	$5.11\left(\frac{V}{V+2}\right)DWT^{1/3} + 16.945$		

Example 5.1. Estimate the length of a ship with a displacement of 1000 ton and a design speed of 10 knots by using the Ayre formula.

Solution: The Ayre formula will require and iterative approach as shown in the following table

Displacement	Speed	L	$\Delta^{1/3}\left(\frac{10}{3} + \frac{5}{3}\frac{V}{\sqrt{L}}\right)$
1000	10	100.0000	50.0000
1000	10	50.0000	56.9036
1000	10	56.9036	55.4276
1000	10	55.4276	55.7198
1000	10	55.7198	55.6610
1000	10	55.6610	55.6728
1000	10	55.6728	55.6705
1000	10	55.6704	55.6709
1000	10	55.6709	55.6708
1000	10	55.6708	55.6708

This process can also be carried out graphically as shown below.

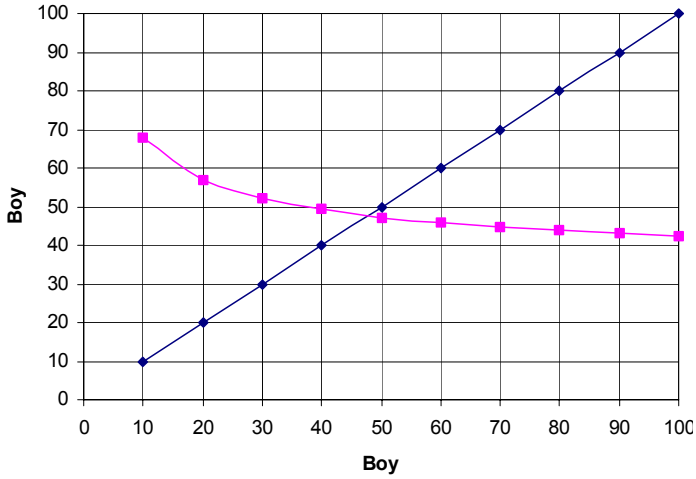


Example 5.2. Estimate the length of a ship with displacement 1000 t and speed 10 knots by using Posdunine's formula. C will be taken as $C = 1.7\frac{V}{\sqrt{L}} + 4.4$

Solution

Displacement	**Speed**	L	$C\left(\frac{V}{V+2}\right)^2 \Delta^{1/3}$
1000	10	100.000	42.361
1000	10	42.361	48.694
1000	10	48.694	47.474
1000	10	47.474	47.690
1000	10	47.690	47.651
1000	10	47.651	47.658
1000	10	47.658	47.657
1000	10	47.657	47.657

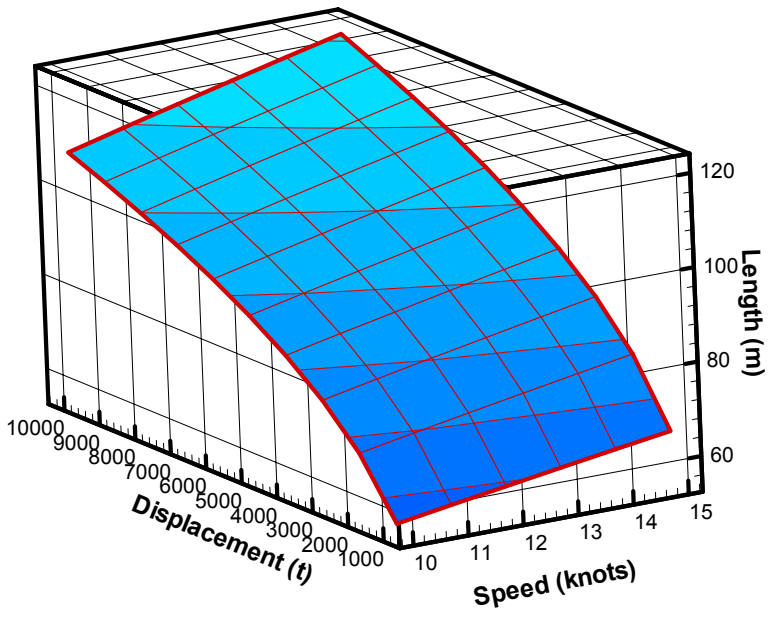
The same result can be obtained graphically as follows:



Example 5.3. Estimate the length for ships with displacement between 1000-10000 t and design speed 10-15 knot by using Ayre, Posdunine, Völker and Schneekluth formulae.

Solution:

Δ	Speed	Ayre	Posdunine	Schneekluth	Völker
1000	10	55,6708	47,6567	50,7166	58,2258
1000	11	57,5088	50,3682	52,1877	60,5484
1000	12	59,3042	52,9278	53,5679	62,8710
1000	13	61,0608	55,3590	54,8698	65,1936
1000	14	62,7817	57,6802	56,1033	67,5161
1000	15	64,4694	59,9062	57,2766	69,8387
2000	10	67,5472	58,0241	62,4394	70,1673
2000	11	69,6706	61,2461	64,2506	72,7743
2000	12	71,7464	64,2814	65,9498	75,3813
2000	13	73,7786	67,1593	67,5526	77,9884
2000	14	75,7704	69,9029	69,0713	80,5954
2000	15	77,7249	72,5302	70,5158	83,2024
3000	10	75,7021	65,1614	70,5158	78,3715
3000	11	78,0116	68,7276	72,5612	81,1607
3000	12	80,2703	72,0831	74,4802	83,9500
3000	13	82,4824	75,2611	76,2903	86,7393
3000	14	84,6513	78,2878	78,0054	89,5286
3000	15	86,7802	81,1840	79,6368	92,3178
4000	10	82,1103	70,7791	76,8720	84,8217
4000	11	84,5611	74,6127	79,1017	87,7480
4000	12	86,9589	78,2165	81,1937	90,6743
4000	13	89,3077	81,6271	83,1670	93,6005
4000	14	91,6114	84,8731	85,0367	96,5268
4000	15	93,8730	87,9771	86,8151	99,4531
5000	10	87,4715	75,4845	82,1942	90,2206
5000	11	90,0376	79,5400	84,5783	93,2578
5000	12	92,5488	83,3497	86,8151	96,2949
5000	13	95,0093	86,9528	88,9250	99,3321
5000	14	97,4229	90,3801	90,9242	102,3692
5000	15	99,7929	93,6560	92,8257	105,4064
6000	10	92,1241	79,5718	86,8151	94,9078
6000	11	94,7882	83,8185	89,3333	98,0386
6000	12	97,3958	87,8055	91,6959	101,1695
6000	13	99,9512	91,5743	93,9244	104,3003
6000	14	102,4584	95,1576	96,0359	107,4312
6000	15	104,9207	98,5812	98,0444	110,5620
7000	10	96,2600	83,2080	90,9242	99,0759
7000	11	99,0097	87,6238	93,5615	102,2883
7000	12	101,7016	91,7674	96,0359	105,5006
7000	13	104,3401	95,6826	98,3700	108,7129
7000	14	106,9290	99,4035	100,5814	111,9253
7000	15	109,4719	102,9574	102,6850	115,1376
8000	10	100,0000	86,4982	94,6405	102,8463
8000	11	102,8260	91,0662	97,3856	106,1309
8000	12	105,5929	95,3507	99,9612	109,4155
8000	13	108,3054	99,3974	102,3906	112,7001
8000	14	110,9672	103,2420	104,6925	115,9848
8000	15	113,5820	106,9129	106,8820	119,2694
9000	10	103,4253	89,5133	98,0444	106,3004
9000	11	106,3202	94,2201	100,8883	109,6501
9000	12	109,1550	98,6330	103,5565	112,9998
9000	13	111,9343	102,7995	106,0732	116,3496
9000	14	114,6622	106,7568	108,4579	119,6993
9000	15	117,3420	110,5342	110,7261	123,0491
10000	10	106,5935	92,3034	101,1929	109,4960
10000	11	109,5514	97,1381	104,1281	112,9051
10000	12	112,4483	101,6694	106,8820	116,3142
10000	13	115,2887	105,9463	109,4796	119,7233
10000	14	118,0769	110,0072	111,9408	123,1324
10000	15	120,8162	113,8826	114,2819	126,5415



5.2.2. Breadth

The effects of breadth on techno-eceonomic performance characteristics of a ship can be summarized as follows.

- Increasing breadth will increase the resistance and hence the engine power and operating costs
- Increasing breadth will improve the initial stability characteristics.
- The weight and cost of hull will increase with increasing breadth
- Roll period will reduce with increasing breadth

The breadth of conventional ship types may be estimated based on the length as shown in the following formulae

Ship Type	Formula	Proposed by
Passenger ship	$\frac{L}{9}+6.1$	
General cargo	$\frac{L}{9}+4.27$	
	$0.125L+2.45$	
	$\frac{L}{9}+6 \quad \text{to} \quad 7.5$	(Munro-Smith)
Tanker	$\frac{L}{7.5}+1.98$	
	$0.125L+2.45$	
	$\frac{L}{9}+4.5 \quad \text{to} \quad 6.5$	(Munro-Smith)
VLCC	$\frac{L}{9}+12 \quad \text{to} \quad 15$	
	$\frac{L}{5}-14$	(Munro-Smith)
Bulk carrier	$0.146L-1.04$	
Containership	$0.150L+2.45$	
RoRo	$\frac{L}{10}+8$	
Tug	$0.200L+2.45$	
	$0.220L+1.50$	

The breadth of containerships can be estimated on the basis of the number of containers located transversely in the ship. The standard ISO container has a width of 2.44 m. However, each container requires an allowance for clearence, guides etc. of about 240 mm so that each container requires a width of 2.68 m.

Thus the number n of cells located transversely in the ship require 2.68n metres. Since the width available for containers is about 80 percent of the ship's breadth, then B=3.35n.

5.2.3. Draught

Draught of a ship is less effective on technical and economical performance compared with length or breadth. Therefore the draught is usually selected to satisfy the displacement equation $\nabla = LBTC_B$. The draught may be limited due to the depths of port, harbour and canals. Low draught increases the risk of bow slamming in rough seas.

5.2.4. Depth

Depth of a ship may be estimated as the sum of design draught and the freeboard. The weight and cost of the ship will increase with increasing depth. Classification Societies may impose certain limits on L/D ratio due to the longitudinal strength characteristics. However lower values of L/D may result in buckling problems. The depth will increase the height of centre of gravity which will affect the stability and seakeeping characteristics of the vessel. The following formulae may be suggested for an initial estimate of depth.

Ship Type	Formula	Proposed by
Passenger ship	$D = \frac{B + 0.3}{1.5}$	
Cargo	$D = \frac{B - 2}{1.4}$	
	$D = \frac{B}{1.65}$	Watson (1998)
Tanker	$D = \frac{L}{13.5}$	
	$D = \frac{L}{12.5}$	Watson (1998)
	$D = \frac{B}{1.9}$	Watson (1998)
	$D = \frac{T}{0.78}$	Watson (1998)
Bulk carrier	$D = \frac{B - 3}{1.5}$	Munro-Smith
	$D = \frac{B}{1.9}$	Watson (1998)
	$D = \frac{T}{0.73}$	Watson (1998)
	$D = \frac{L}{11.5}$	Watson (1998)
Containership	$D = \frac{B}{1.7}$	Watson (1998)
Frigate	$D = \frac{T}{0.46}$	Watson (1998)
	$D = \frac{L}{13.3}$	Watson (1998)

L, B, D in meters.

The depth of a container ship is in general controlled by the number of containers to be carried in the hold. Thus

$$D = 2.43n + h$$

where n is the number of tiers of containers in holds and h is the height of double bottom.

5.2.5. Length to Beam Ratio

L/B ratio affects powering and directional stability. A steady decrease in L/B in recent years can be seen in an effort to reduce ship cost and with increased design effort to produce good inflow to the propeller with the greater beam. Watson&Gilfillan (1977) proposes the following values

$$\frac{L}{B} = 6.5 \qquad L \geq 130 \text{ m}$$

$$\frac{L}{B} = 4.0 + 0.025(L - 30) \qquad 30 \leq L \leq 130 \text{ m}$$

$$\frac{L}{B} = 4.0 \qquad L \leq 30 \text{ m}$$

5.2.6. Length to Depth Ratio

L/D ratio is a primary factor in longitudinal strength. Classification Societies, in general, require special consideration L/D>15.

5.2.7. Beam to Depth Ratio

B/D ratio has a major impact on stability.

5.2.8. Beam to Draught Ratio

If this ratio is too small stability may be a problem; too large residuary resistance goes up.

$$\left(\frac{B}{T}\right)\Big|_{\min C_S} = 5.93 - 3.33C_M \qquad \left(\frac{B}{T}\right)_{max} = 9.625 - 7.5C_B$$

Example 5.4. Estimate the dimensions of a dry cargo ship of 13000 tonnes DWT at a maximum draught of 8.0 m and with a service speed of 15 knots. Assume C_D=0.67 and C_B=0.7.

Solution:

Displacement $$\Delta = \frac{DWT}{C_D} = \frac{13000}{0.67} = 19403 \text{ t}$$

Length (Ayre) $$L = \Delta^{1/3}\left(\frac{10}{3} + \frac{5}{3}\frac{V}{\sqrt{L}}\right) \quad \Rightarrow \quad L = 145.25 \text{ m}$$

Length (Posdunine) $$L = C\left(\frac{V}{V+2}\right)^2 \Delta^{1/3} \quad \Rightarrow \quad L = 149.6 \text{ m}$$ with C=7.15

Length (average) $$L = 147.425 \text{ m}$$

Breadth $$B = \frac{L}{9} + 6 = 22.38 \text{ m}$$

Draught $$T = \frac{\nabla}{LBC_B} = \frac{19403/1.025}{147.425 \times 22.38 \times 0.7} = 8.2 \text{ m}$$

Depth $$D = \frac{B-2}{1.4} = 14.56 \text{ m}$$

$$D = \frac{B}{1.65} = 13.56 \text{ m}$$

Depth (average) $$D = 14.06 \text{ m}$$

5.2.5. Freeboard (Load Line)

Safe loading, weight and balance have always been very serious issues for seafarers. In England, Samuel Plimsoll became the moving force to establish safe loading as a rule of law in 1875. Through his efforts, safe loading standards were adopted and given the force of law. The first International Convention on Load Lines, adopted in 1930, was based on the principle of reserve buoyancy, although it was recognized then that the freeboard should also ensure adequate stability and avoid excessive stress on the ship's hull as a result of overloading.

5.2.5.1. International Convention on Load Lines (1966)

In the 1966 Load Lines convention, adopted by IMO, provisions are made determining the freeboard of tankers by subdivision and damage stability calculations. Load line conventions were conceived as instruments to assign the maximum safe draught for ships to operate at sea. At the 1966 Load Line Convention, the uppermost criteria were the following

1. Prevent entry of water into the hull
2. Adequate reserve buoyancy
3. Protection of the crew
4. Adequate hull strength and ability
5. Limitation of deck wetness

The 1988 Protocol
Adoption: 11 November 1988 Entry into force: 3 February 2000

The Protocol was primarily adopted in order to harmonize the Convention's survey and certification requirement with those contained in SOLAS and MARPOL 73/78. All three instruments require the issuing of certificates to show that requirements have been met and this has to be done by means of a survey which can involve the ship being out of service for several days.

Revision of Load Lines Convention
The 1966 Load Lines Convention (as revised by the 1988 Protocol entering into force on 3 February 2000) is currently being revised by IMO's Sub-Committee on Stability, Load lines and Fishing Vessel Safety (SLF). In particular, the revision is focusing on wave loads and permissible strengths of hatch covers for bulk carriers and other ship types.

Article 5 *Exceptions :* These Regulations do not apply to
- (a) ships of less than 24 metres in length
- (b) warships
- (c) fishing vessels
- (d) pleasure yacht;
- (e) ship without means of self-propulsion that is making a voyage

Regulation 3 *Definitions*
Length. The length (L) shall be taken as 96 per cent of the total length on a water line at 85 per cent of the least moulded depth measured from the top of the keel, or as the length from the foreside of the stem to the axis of the rudder stock on that water line, if that is greater.
Perpendiculars. The forward and after perpendiculars shall be taken at the forward and after ends of the length (L). The forward perpendicular shall coincide with the foreside of the stem on the water line on which the length is measured.
Amidships. Amidships is at the middle of the length (L).
Breadth. Unless expressly provided otherwise, the breadth (B) is the maximum breadth of the ship, measured amidships to the moulded line of the frame in a ship with a metal shell and to the outer surface of the hull in a ship with a shell of any other material.
Moulded Depth. The moulded depth is the vertical distance measured from the top of the keel to the top of the freeboard deck beam at side. In wood and composite ships the distance is measured from the lower edge of the keel rabbet.
Depth for Freeboard (D). The depth for freeboard (D) is the moulded depth amidships, plus the thickness of the freeboard deck stringer plate, where fitted, plus $\frac{T(L-S)}{L}$ if the exposed freeboard deck is sheathed, where T is the mean thickness of the exposed sheathing clear of deck openings, and S is the total length of superstructures.

Block Coefficient. The block coefficient (C_b) is given by:

$$C_b = \frac{\nabla}{LBT}$$

∇ is the volume of the moulded displacement of the ship, excluding bossing, in a ship with a metal shell, and is the volume of displacement to the outer surface of the hull in a ship with a shell of any other material, both taken at a moulded draught of T; and where T is 85 per cent of the least moulded depth.

Freeboard. The freeboard assigned is the distance measured vertically downwards amidships from the upper edge of the deck line to the upper edge of the related load line

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.

Superstructure.

(a) A superstructure is a decked structure on the freeboard deck, extending from side to side of the ship or with the side plating not being inboard of the shell plating more than four per cent of the breadth (B). A raised quarter deck is regarded as a superstructure.

(b) The height of a superstructure is the least vertical height measured at side from the top of the superstructure deck beams to the top of the freeboard deck beams.

(c) The length of a superstructure (S) is the mean length of the part of the superstructure which lies within the length (L).

Flush Deck Ship. A flush deck ship is one which has no superstructure on the freeboard deck.

Weathertight. Weathertight means that in any sea conditions water will not penetrate into the ship.

Regulation 4 *Deck Line*

The deck line is a horizontal line 300 mm in length and 23 mm in breadth. It shall be marked amidships on each side of the ship, and its upper edge shall normally pass through the point where the continuation outwards of the upper surface of the freeboard deck intersects the outer surface of the shell (as illustrated in Figure 5.7).

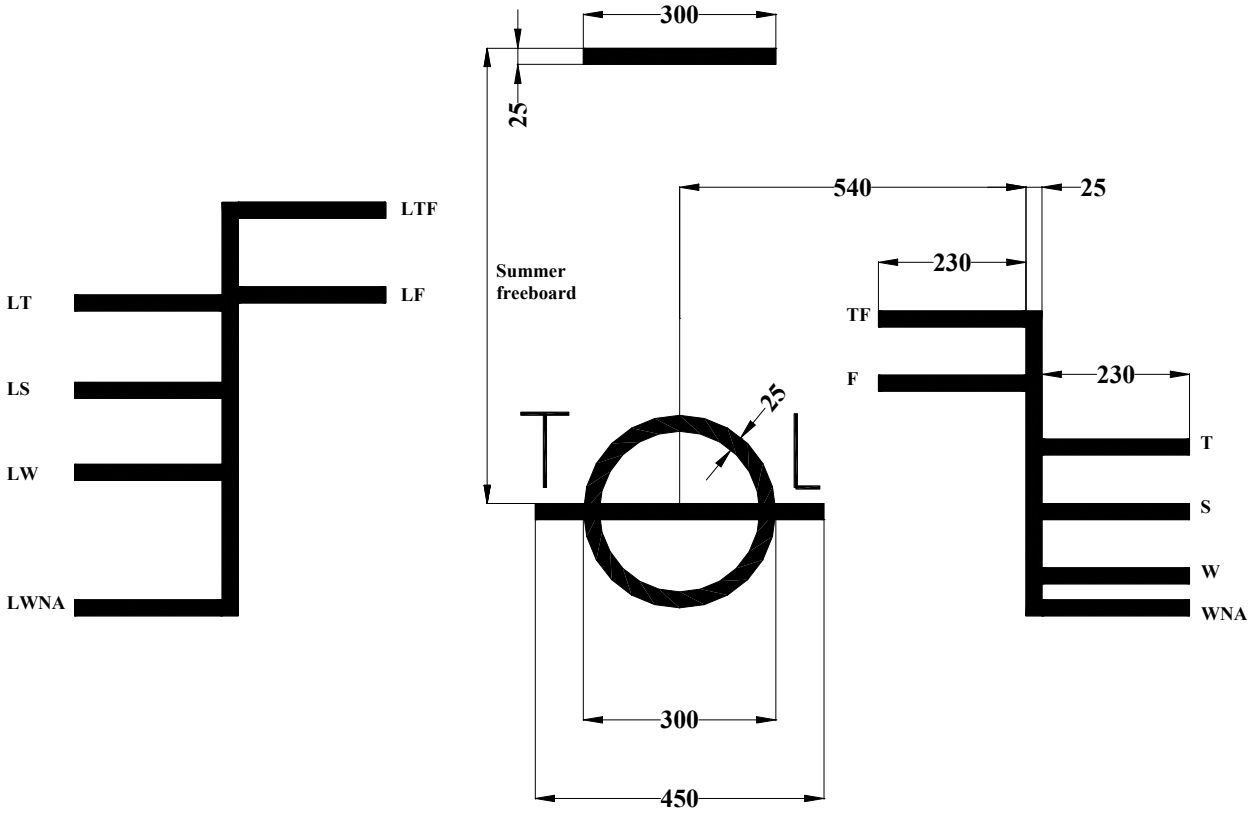


Figure 5.2. Load line mark

Regulation 5 *Load Line Mark*

The Load Line Mark shall consist of a ring 300 mm in outside diameter and 25 mm wide which is intersected by a horizontal line 450 mm in length and 25 mm in breadth, the upper edge of which passes through the centre of the ring. The centre of the ring shall be placed amidships and at a distance equal to the assigned summer freeboard measured vertically below the upper edge of the deck line (as illustrated in Figure 5.7).

Regulation 6 *Lines to be used with the Load Line Mark*

(1) The lines which indicate the load line assigned in accordance with these Regulations shall be horizontal lines 230 mm in length and 25 mm in breadth which extend forward of, unless expressly provided otherwise, and at right angles to, a vertical line 25 mm in breadth marked at a distance 540 mm forward of the centre of the ring (as illustrated in Figure 5.7).

(2) The following load lines shall be used:
   (a) the Summer Load Line indicated by the upper edge of the line which passes through the centre of the ring and also by a line marked S;
   (b) the Winter Load Line indicated by the upper edge of a line marked W;
   (c) the Winter North Atlantic Load Line indicated by the upper edge of a line marked WNA;
   (d) the Tropical Load Line indicated by the upper edge of a line marked T;
   (e) the Fresh Water Load Line in summer indicated by the upper edge of a line marked F. The Fresh Water Load Line in summer is marked abaft the vertical line. The difference between the Fresh Water Load Line in summer and the Summer Load Line is the allowance to be made for loading in fresh water at the other load lines; and
   (f) the Tropical Fresh Water Load Line indicated by the upper edge of a line marked TF, and marked abaft the vertical line.

(3) If timber freeboards are assigned in accordance with these Regulations, the timber load lines shall be marked in addition to ordinary load lines. These lines shall be horizontal lines 230 mm in length and 25 mm in breadth which extend abaft unless expressly provided otherwise, and are at right angles to, a vertical line 25 mm in breadth marked at a distance 540 mm abaft the centre of the ring (as illustrated in Figure 5.7).

(4) The following timber load lines shall be used:
   (a) the Summer Timber Load Line indicated by the upper edge of a line marked LS;
   (b) the Winter Timber Load Line indicated by the upper edge of a line marked LW;
   (c) the Winter North Atlantic Timber Load Line indicated by the upper edge of a line marked LWNA;
   (d) the Tropical Timber Load Line indicated by the upper edge of a line marked LT;
   (e) the Fresh Water Timber Load Line in summer indicated by the upper edge of a line marked LF and marked forward of the vertical line. The difference between the Fresh Water Timber Load Line in summer and the Summer Timber Load Line is the allowance to be made for loading in fresh water at the other timber load lines; and
   (f) the Tropical Fresh Water Timber Load Line indicated by the upper edge of a line marked LTF and marked forward of the vertical line.

Regulation 7 *Mark of Assigning Authority*

The mark of the Authority by whom the load lines are assigned may be indicated alongside the load line ring above the horizontal line which passes through the centre of the ring, or above and below it. This mark shall consist of not more than four initials to identify the Authority's name, each measuring approximately 115 mm in height and 75 mm in width.

Regulation 27 ***Types of Ships***

(1) For the purposes of freeboard computation, ships shall be divided into Type `A' and Type `B'.

Type `A' ships

(2) A Type `A' ship is one which is designed to carry only liquid cargoes in bulk, and in which cargo tanks have only small access openings closed by watertight gasketed covers of steel or equivalent material.

(3) A Type `A' ship shall be assigned a freeboard not less than that based on Table A.

Type `B' ships

(4) All ships which do not come within the provisions regarding Type `A' ships shall be considered as Type `B' ships.

(5) Any Type `B' ships of over 100 m in length may be assigned freeboards less than those required under subsections (6) of this Regulation provided that, in relation to the amount of reduction granted, the Administration is satisfied that:
   (a) the measures provided for the protection of the crew are adequate;
   (b) the freeing arrangements are adequate;
   (c) the covers in positions 1 and 2 comply with the provisions of Regulation 16 and have adequate strength, special care being given to their sealing and securing arrangements;

(d) the ship, when loaded to its summer load water line, will remain afloat in a satisfactory condition of equilibrium after flooding of any single damaged compartment at an assumed permeability of 0.95 excluding the machinery space; and
(e) in such a ship, if over 225 m in length, the machinery space shall be treated as a floodable compartment but with a permeability of 0.85.

The relevant calculations may be based upon the following main assumptions:

- the vertical extent of damage is equal to the depth of the ship;
- the penetration of damage is not more than B/5;
- no main transverse bulkhead is damaged;
- the height of the centre of gravity above the base line is assessed allowing for homogeneous loading of cargo holds, and for 50 per cent of the designed capacity of consumable fluids and stores, etc.

(6) In calculating the freeboards for Type `B' ships which comply with the requirements of subsection (7) of this Regulation, the values from Table B of Regulation 28 shall not be reduced by more than 60 per cent of the difference between the `B' and `A' tabular values for the appropriate ship lengths.
(7) The reduction in tabular freeboard allowed under subsection (8) of this Regulation may be increased up to the total difference between the values in Table A and those in Table B of Regulation 28 on condition that the ship complies with the requirements of Regulations 26(1), (2), (3), (5) and (6), as if it were a Type `A' ship, and further complies with the provisions of paragraphs (7)(a) to (d) inclusive of this Regulation except that the reference in paragraph (d) to the flooding of any single damaged compartment shall be treated as a reference to the flooding of any two adjacent fore and aft compartments, neither of which is the machinery space. Also any such ship of over 225 m in length, when loaded to its summer load water line, shall remain afloat in a satisfactory condition of equilibrium after flooding of the machinery space, taken alone, at an assumed permeability of 0.85.
(8) Type `B' ships, which in position 1 have hatchways fitted with hatch covers which comply with the requirements of Regulation 15, other than subsection (7), shall be assigned freeboards based upon the values given in Table B of Regulation 28 increased by the values given in the following table:

Regulation 29 *Correction to the Freeboard for Ships under100 m in length*

The tabular freeboard for a Type `B' ship of between 24 m and 100 m in length having enclosed superstructures with an effective length of up to 35 per cent of the length of the ship shall be increased by:

$$7.5(100 - L)\left(0.35 - \frac{E}{L}\right) \text{ mm}$$

where L = length of ship in metres,
where E = effective length of superstructure in metres defined in Regulations 35.

Regulation 30 *Correction for Block Coefficient*

Where the block coefficient (C_b) exceeds 0.68, the tabular shall be multiplied by the factor

$$\frac{C_b + 0.68}{1.36}$$

Regulation 31 *Correction for Depth*

(1) Where D exceeds $\frac{L}{15}$ the freeboard shall be increased by $\left(D - \frac{L}{15}\right)R$ millimetres, where R is $\frac{L}{0.48}$ at length less than 120 m and 250 at 120 m length and above.

(2) Where D is less than $\frac{L}{15}$, no reduction shall be made except in a ship with an enclosed superstructure covering at least 0.6 L amidships, with a complete trunk, or combination of detached enclosed superstructures and trunks which extend all fore and aft, where the freeboard shall be reduced at the rate prescribed in paragraph (1) of this Regulation.

(3) Where the height of superstructure or trunk is less than the standard height, the reduction shall be in the ratio of the actual to the standard height as defined in Regulation 33.

Regulation 28 : Table A. Freeboard Tables, Type `A' Ships

L [m]	f [mm]	L [m]	f [mm]	L [m]	f [mm]	L [m]	f [mm]	L [m]	f [mm]	L [m]	f [mm]
24	200	**81**	855	**138**	1770	**195**	2562	**252**	3024	**309**	3295
25	208	**82**	869	**139**	1787	**196**	2572	**253**	3030	**310**	3298
26	217	**83**	883	**140**	1803	**197**	2582	**254**	3036	**311**	3302
27	225	**84**	897	**141**	1820	**198**	2592	**255**	3042	**312**	3305
28	233	**85**	911	**142**	1837	**199**	2602	**256**	3048	**313**	3308
29	242	**86**	926	**143**	1853	**200**	2612	**257**	3054	**314**	3312
30	250	**87**	940	**144**	1870	**201**	2622	**258**	3060	**315**	3315
31	258	**88**	955	**145**	1886	**202**	2632	**259**	3066	**316**	3318
32	267	**89**	969	**146**	1903	**203**	2641	**260**	3072	**317**	3322
33	275	**90**	984	**147**	1919	**204**	2650	**261**	3078	**318**	3325
34	283	**91**	999	**148**	1935	**205**	2659	**262**	3084	**319**	3328
35	292	**92**	1014	**149**	1952	**206**	2669	**263**	3089	**320**	3331
36	300	**93**	1029	**150**	1968	**207**	2678	**264**	3095	**321**	3334
37	308	**94**	1044	**151**	1984	**208**	2687	**265**	3101	**322**	3337
38	316	**95**	1059	**152**	2000	**209**	2696	**266**	3106	**323**	3339
39	325	**96**	1074	**153**	2016	**210**	2705	**267**	3112	**324**	3342
40	334	**97**	1089	**154**	2032	**211**	2714	**268**	3117	**325**	3345
41	344	**98**	1105	**155**	2048	**212**	2723	**269**	3123	**326**	3347
42	354	**99**	1120	**156**	2064	**213**	2732	**270**	3128	**327**	3350
43	364	**100**	1135	**157**	2080	**214**	2741	**271**	3133	**328**	3353
44	374	**101**	1151	**158**	2096	**215**	2749	**272**	3138	**329**	3355
45	385	**102**	1166	**159**	2111	**216**	2758	**273**	3143	**330**	3358
46	396	**103**	1181	**160**	2126	**217**	2767	**274**	3148	**331**	3361
47	408	**104**	1196	**161**	2141	**218**	2775	**275**	3153	**332**	3363
48	420	**105**	1212	**162**	2155	**219**	2784	**276**	3158	**333**	3366
49	432	**106**	1228	**163**	2169	**220**	2792	**277**	3163	**334**	3368
50	443	**107**	1244	**164**	2184	**221**	2801	**278**	3167	**335**	3371
51	455	**108**	1260	**165**	2198	**222**	2809	**279**	3172	**336**	3373
52	467	**109**	1276	**166**	2212	**223**	2817	**280**	3176	**337**	3375
53	478	**110**	1293	**167**	2226	**224**	2825	**281**	3181	**338**	3378
54	490	**111**	1309	**168**	2240	**225**	2833	**282**	3185	**339**	3380
55	503	**112**	1326	**169**	2254	**226**	2841	**283**	3189	**340**	3382
56	516	**113**	1342	**170**	2268	**227**	2849	**284**	3194	**341**	3385
57	530	**114**	1359	**171**	2281	**228**	2857	**285**	3198	**342**	3387
58	544	**115**	1376	**172**	2294	**229**	2865	**286**	3202	**343**	3389
59	559	**116**	1392	**173**	2307	**230**	2872	**287**	3207	**344**	3392
60	573	**117**	1409	**174**	2320	**231**	2880	**288**	3211	**345**	3394
61	587	**118**	1426	**175**	2332	**232**	2888	**289**	3215	**346**	3396
62	600	**119**	1442	**176**	2345	**233**	2895	**290**	3220	**347**	3399
63	613	**120**	1459	**177**	2357	**234**	2903	**291**	3224	**348**	3401
64	626	**121**	1476	**178**	2369	**235**	2910	**292**	3228	**349**	3403
65	639	**122**	1494	**179**	2381	**236**	2918	**293**	3233	**350**	3406
66	653	**123**	1511	**180**	2393	**237**	2925	**294**	3237	**351**	3408
67	666	**124**	1528	**181**	2405	**238**	2932	**295**	3241	**352**	3410
68	680	**125**	1546	**182**	2416	**239**	2939	**296**	3246	**353**	3412
69	693	**126**	1563	**183**	2428	**240**	2946	**297**	3250	**354**	3414
70	706	**127**	1580	**184**	2440	**241**	2953	**298**	3254	**355**	3416
71	720	**128**	1598	**185**	2451	**242**	2959	**299**	3258	**356**	3418
72	733	**129**	1615	**186**	2463	**243**	2966	**300**	3262	**357**	3420
73	746	**130**	1632	**187**	2474	**244**	2973	**301**	3266	**358**	3422
74	760	**131**	1650	**188**	2486	**245**	2979	**302**	3270	**359**	3423
75	773	**132**	1667	**189**	2497	**246**	2986	**303**	3274	**360**	3425
76	786	**133**	1684	**190**	2508	**247**	2993	**304**	3278	**361**	3427
77	800	**134**	1702	**191**	2519	**248**	3000	**305**	3281	**362**	3428
78	814	**135**	1719	**192**	2530	**249**	3006	**306**	3285	**363**	3430
79	828	**136**	1736	**193**	2541	**250**	3012	**307**	3288	**364**	3432
80	841	**137**	1753	**194**	2552	**251**	3018	**308**	3292	**365**	3433

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

Freeboards for type A ships with length of between 365 metres and 400 metres should be determined by the following formula

$$f = 221 + 16.10L - 0.02L^2$$

where f is the freeboard in mm. Freeboards for type A ships with length of 400 metres and above should be the constant value, 3460 mm.

TABLE B. Freeboard Table for Type `B' Ships

L [m]	f [mm]	L [m]	f [mm]	L [m]	f [mm]	L [m]	f [mm]	L [m]	f [mm]	L [m]	f [mm]
24	200	**81**	905	**138**	2065	**195**	3185	**252**	4045	**309**	4726
25	208	**82**	923	**139**	2087	**196**	3202	**253**	4058	**310**	4736
26	217	**83**	942	**140**	2109	**197**	3219	**254**	4072	**311**	4748
27	225	**84**	960	**141**	2130	**198**	3235	**255**	4085	**312**	4757
28	233	**85**	978	**142**	2151	**199**	3249	**256**	4098	**313**	4768
29	242	**86**	996	**143**	2171	**200**	3264	**257**	4112	**314**	4779
30	250	**87**	1015	**144**	2190	**201**	3280	**258**	4125	**315**	4790
31	258	**88**	1034	**145**	2209	**202**	3296	**259**	4139	**316**	4801
32	267	**89**	1054	**146**	2229	**203**	3313	**260**	4152	**317**	4812
33	275	**90**	1075	**147**	2250	**204**	3330	**261**	4165	**318**	4823
34	283	**91**	1096	**148**	2271	**205**	3347	**262**	4177	**319**	4834
35	292	**92**	1116	**149**	2293	**206**	3363	**263**	4189	**320**	4844
36	300	**93**	1135	**150**	2315	**207**	3380	**264**	4201	**321**	4855
37	308	**94**	1154	**151**	2334	**208**	3397	**265**	4214	**322**	4866
38	316	**95**	1172	**152**	2354	**209**	3413	**266**	4227	**323**	4878
39	325	**96**	1190	**153**	2375	**210**	3430	**267**	4240	**324**	4890
40	334	**97**	1209	**154**	2396	**211**	3445	**268**	4252	**325**	4899
41	344	**98**	1229	**155**	2418	**212**	3460	**269**	4264	**326**	4909
42	354	**99**	1250	**156**	2440	**213**	3475	**270**	4276	**327**	4920
43	364	**100**	1271	**157**	2460	**214**	3490	**271**	4289	**328**	4931
44	374	**101**	1293	**158**	2480	**215**	3505	**272**	4302	**329**	4943
45	385	**102**	1315	**159**	2500	**216**	3520	**273**	4315	**330**	4955
46	396	**103**	1337	**160**	2520	**217**	3537	**274**	4327	**331**	4965
47	408	**104**	1359	**161**	2540	**218**	3554	**275**	4339	**332**	4975
48	420	**105**	1380	**162**	2560	**219**	3570	**276**	4350	**333**	4985
49	432	**106**	1401	**163**	2580	**220**	3586	**277**	4362	**334**	4995
50	443	**107**	1421	**164**	2600	**221**	3601	**278**	4373	**335**	5005
51	455	**108**	1440	**165**	2620	**222**	3615	**279**	4385	**336**	5015
52	467	**109**	1459	**166**	2640	**223**	3630	**280**	4397	**337**	5025
53	478	**110**	1479	**167**	2660	**224**	3645	**281**	4408	**338**	5035
54	490	**111**	1500	**168**	2680	**225**	3660	**282**	4420	**339**	5045
55	503	**112**	1521	**169**	2698	**226**	3675	**283**	4432	**340**	5055
56	516	**113**	1543	**170**	2716	**227**	3690	**284**	4443	**341**	5065
57	530	**114**	1565	**171**	2735	**228**	3705	**285**	4455	**342**	5075
58	544	**115**	1587	**172**	2754	**229**	3720	**286**	4467	**343**	5086
59	559	**116**	1609	**173**	2774	**230**	3735	**287**	4478	**344**	5097
60	573	**117**	1630	**174**	2795	**231**	3750	**288**	4490	**345**	5108
61	587	**118**	1651	**175**	2815	**232**	3765	**289**	4502	**346**	5119
62	601	**119**	1671	**176**	2835	**233**	3780	**290**	4513	**347**	5130
63	615	**120**	1690	**177**	2855	**234**	3795	**291**	4525	**348**	5140
64	629	**121**	1709	**178**	2875	**235**	3808	**292**	4537	**349**	5150
65	644	**122**	1729	**179**	2895	**236**	3821	**293**	4548	**350**	5160
66	659	**123**	1750	**180**	2915	**237**	3835	**294**	4560	**351**	5170
67	674	**124**	1771	**181**	2933	**238**	3849	**295**	4572	**352**	5180
68	689	**125**	1793	**182**	2952	**239**	3864	**296**	4583	**353**	5190
69	705	**126**	1815	**183**	2970	**240**	3880	**297**	4595	**354**	5200
70	721	**127**	1837	**184**	2988	**241**	3893	**298**	4607	**355**	5210
71	738	**128**	1859	**185**	3007	**242**	3906	**299**	4618	**356**	5220
72	754	**129**	1880	**186**	3025	**243**	3920	**300**	4630	**357**	5230
73	769	**130**	1901	**187**	3044	**244**	3934	**301**	4642	**358**	5240
74	784	**131**	1921	**188**	3062	**245**	3949	**302**	4654	**359**	5250
75	800	**132**	1940	**189**	3080	**246**	3965	**303**	4665	**360**	5260
76	816	**133**	1959	**190**	3098	**247**	3978	**304**	4676	**361**	5268
77	833	**134**	1979	**191**	3116	**248**	3992	**305**	4686	**362**	5276
78	850	**135**	2000	**192**	3134	**249**	4005	**306**	4695	**363**	5285
79	868	**136**	2021	**193**	3151	**250**	4018	**307**	4704	**364**	5294
80	887	**137**	2043	**194**	3167	**251**	4032	**308**	4714	**365**	5303

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

Freeboards for type A ships with length of between 365 metres and 400 metres should be determined by the following formula

$$f = -587 + 23L - 0.0188L^2$$

where f is the freeboard in mm. Freeboards for type A ships with length of 400 metres and above should be the constant value, 5605 mm.

Regulation 33 ***Standard Height of Superstructure***

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

L (metres)	Standard Height (in metres)	
	Raised Quarter Deck	All other Superstructures
≤ 30	0.90	1.80
75	1.20	1.80
≥ 125	1.80	2.30

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

Regulation 34 *Length of Superstructure*

(1) Except as provided in subsection (2) of this Regulation, the length of a superstructure (S) shall be the mean length of the parts of the superstructure which lie within the length (L).

Regulation 35 *Effective Length of Superstructure*

(1) Except as provided for in subsection (2) of this Regulation, the effective length (E) of an enclosed superstructure of standard height shall be its length.

(2) In all cases where an enclosed superstructure of standard height is set in from the sides of the ship as permitted in subsection 3(10) the effective length is the length modified by the ratio of b/Bs, where
"b" is the breadth of the superstructure at the middle of its length, and
"Bs" is the breadth of the ship at the middle of the length of the superstructure, and
where a superstructure is set in for a part of its length, this modification shall be applied only to the set in part.

(3) Where the height of an enclosed superstructure is less than the standard height, the effective length shall be its length reduced in the ratio of the actual height to the standard height. Where the height exceeds the standard, no increase shall be made to the effective length of the superstructure.

(4) The effective length of a raised quarter deck, if fitted with an intact front bulkhead, shall be its length up to a maximum of 0.6 L. Where the bulkhead is not intact, the raised quarter deck shall be treated as a poop of less than standard height.

(5) Superstructures which are not enclosed shall have no effective length.

Regulation 36 *Trunks*

(1) A trunk or similar structure which does not extend to the sides of the ship shall be regarded as efficient on the following conditions:
   (a) the trunk is at least as strong as a superstructure;
   (b) the hatchways are in the trunk deck, and the hatchway coamings and covers comply with the requirements of Regulations 13 to 16 inclusive and the width of the trunk deck stringer provides a satisfactory gangway and sufficient lateral stiffness. However, small access openings with watertight covers may be permitted in the freeboard deck;
   (c) a permanent working platform fore and aft fitted with guard-rails is provided by the trunk deck, or by detached trunks connected to superstructures by efficient permanent gangways;
   (d) ventilators are protected by the trunk, by watertight covers or by other equivalent means;
   (e) open rails are fitted on the weather parts of the freeboard deck in way of the trunk for at least half their length;
   (f) the machinery casings are protected by the trunk, by a superstructure of at least standard height, or by a deckhouse of the same height and of equivalent strength;
   (g) the breadth of the trunk is at least 60 per cent of the breadth of the ship; and
   (h) where there is no superstructure, the length of the trunk is at least 0.6 L.

(2) The full length of an efficient trunk reduced in the ratio of its mean breadth to B shall be its effective length.

(3) The standard height of a trunk is the standard height of a superstructure other than a raised quarter deck.

(4) Where the height of a trunk is less than the standard height, its effective length shall be reduced in the ratio of the actual to the standard height. Where the height of the hatchway coamings on the trunk deck is less than that required under Regulation 15(1), a reduction from the actual height of trunk shall be made which corresponds to the difference between the actual and the required height of coaming.

Regulation 37 *Deduction for Superstructures and Trunks*

(1) Where the effective length of superstructures and trunks is 1.0 L, the deduction from the freeboard shall be 350 mm at 24 m length of ship, 860 mm at 85 m length, and 1,070 mm at 122 m length and above; deductions at intermediate lengths shall be obtained by linear interpolation.

L [m]	f_e [mm]
24	350
85	860
≥ 122	1070

(2) Where the total effective length of superstructures and trunks is less than 1.0 L the deduction shall be a percentage obtained from one of the following tables:

Percentage of Deduction for Type `A' ships

Total Effective Length of Superstructures and Trunks	0L	0.1L	0.2L	0.3L	0.4L	0.5L	0.6L	0.7L	0.8L	0.9L	1.0L
Percentage of deduction for all types of superstructures	0	7	14	21	31	41	52	63	75.5	87.7	100

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

Percentage of Deduction for Type `B' ships

Total Effective Length of Superstructures and Trunks	0L	0.1L	0.2L	0.3L	0.4L	0.5L	0.6L	0.7L	0.8L	0.9L	1.0L
Ships with forecastle and without detached bridge	0	5	10	15	23.5	32	46	63	75.3	87.7	100
Ships with forecastle and with detached bridge	0	6.3	12.7	19	27.5	36	46	63	75.3	87.7	100

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

(3) For ships of Type `B':

(a) where the effective length of a bridge is less than 0.2 L, the percentages shall be obtained by linear interpolation between lines I and II;
(b) where the effective length of a forecastle is more than 0.4 L, the percentages shall be obtained from line II; and
(c) where the effective length of a forecastle is less than 0.07 L, the above percentages shall be reduced by:

$$5 \times \frac{0.07L - f}{0.07L}$$

where f is the effective length of the forecastle.

Regulation 38 ***Sheer***

(1) The sheer shall be measured from the deck at side to a line of reference drawn parallel to the keel through the sheer line amidships.
(2) In ships designed with a rake of keel, the sheer shall be measured in relation to a reference line drawn parallel to the design load water line.
(3) In flush deck ships and in ships with detached superstructures the sheer shall be measured at the freeboard deck.

(4) In ships with topsides of unusual form in which there is a step or break in the topsides, the sheer shall be considered in relation to the equivalent depth amidships.
(5) In ships with a superstructure of standard height which extends over the whole length of the freeboard deck, the sheer shall be measured at the superstructure deck. Where the height exceeds the standard the least difference (Z) between the actual and standard heights shall be added to each end ordinate. Similarly, the intermediate ordinates at distances of 1/6 L and 1/3 L from each perpendicular shall be increased by 0.444 Z and 0.111 Z respectively.
(6) Where the deck of an enclosed superstructure has at least the same sheer as the exposed freeboard deck, the sheer of the enclosed portion of the freeboard deck shall not be taken into account.
(7) Where an enclosed poop or forecastle is of standard height with greater sheer than that of the freeboard deck, or is of more than standard height, an addition to the sheer of the freeboard deck shall be made as provided in subsection (12) of this Regulation.

Standard Sheer Profile

(8) The ordinates of the standard sheer profile are given in the following table:

Standard Sheer Profile (Where L is in metres)

	Station	Ordinate (in millimetres)	Factor
After Half	After Perpendicular	$25\left(\frac{L}{3}+10\right)$	1
	1/6 L from A.P.	$11.1\left(\frac{L}{3}+10\right)$	3
	1/3 L from A.P.	$2.8\left(\frac{L}{3}+10\right)$	3
	Amidships	0	1
Forward Half	Amidships	0	1
	1/3 L from F.P.	$5.6\left(\frac{L}{3}+10\right)$	3
	1/6 L form F.P.	$22.2\left(\frac{L}{3}+10\right)$	3
	Forward Perpendicular	$50\left(\frac{L}{3}+10\right)$	1

Measurement of Variation from Standard Sheer Profile

(9) Where the sheer profile differs from the standard, the four ordinates of each profile in the forward or after half shall be multiplied by the appropriate factors given in the table of ordinates. The difference between the sums of the respective products and those of the standard divided by eight measures the deficiency or excess of sheer in the forward or after half. The arithmetical mean of the excess or deficiency in the forward and after halves measures the excess or deficiency of sheer.
(10) Where the after half of the sheer profile is greater than the standard and the forward half is less than the standard, no credit shall be allowed for the part in excess and deficiency only shall be measured.
(11) Where the forward half of the sheer profile exceeds the standard, and the after portion of the sheer profile is not less than 75 per cent of the standard, credit shall be allowed for the part in excess; where the after part is less than 50 per cent of the standard, no credit shall be given for the excess sheer forward. Where the after sheer is between 50 per cent and 75 per cent of the standard, intermediate allowances may be granted for excess sheer forward.
(12) Where sheer credit is given for a poop or forecastle the following formula shall be used:

$$s = \frac{y}{3}\frac{L'}{L}$$

where s = sheer credit, to be deducted from the deficiency or added to the excess of sheer,
y = difference between actual and standard height of superstructure at the end of sheer,
L' = mean enclosed length of poop or forecastle up to a maximum length of 0.5 L,
L = length of ship

The above formula provides a curve in the form of a parabola tangent to the actual sheer curve at the freeboard deck and intersecting the end ordinate at a point below the superstructure deck a distance equal to the standard height of a superstructure. The superstructure deck shall not be less than standard height above this curve at any point. This curve shall be used in determining the sheer profile for forward and after halves of the ship.

Correction for Variations from Standard Sheer Profile

(13) The correction for sheer shall be the deficiency or excess of sheer (see subsections (9) to (11) inclusive of this Regulation), multiplied by

$$0.75 - \frac{S}{2L}$$

where S is the total length of enclosed superstructures.

Addition for Deficiency in Sheer

(14) Where the sheer is less than the standard, the correction for deficiency in sheer (see subsection (13) of this Regulation) shall be added to the freeboard.

Deduction for Excess Sheer

(15) In ships where an enclosed superstructure covers 0.1 L before and 0.1 L abaft amidships, the correction for excess of sheer as calculated under the provisions of subsection (13) of this Regulation shall be deducted from the freeboard; in ships where no enclosed superstructure covers amidships, no deduction shall be made from the freeboard; where an enclosed superstructure covers less than 0.1 L before and 0.1 L abaft amidships, the deduction shall be obtained by linear interpolation. The maximum deduction for excess sheer shall be at the rate of 125 mm per 100 m of length.

Regulation 39. M*inimum Bow Height*

(1) The bow height defined as the vertical distance at the forward perpendicular between the water line corresponding to the assigned summer freeboard and the designed trim and the top of the exposed deck at side shall be not less than:

for ships below 250 m in length,

$$56L\left(1 - \frac{L}{500}\right)\frac{1.36}{C_b + 0.68}\ \text{mm}$$

for ships of 250 m and above in length,

$$7000\frac{1.36}{C_b + 0.68}\ \text{mm}$$

where L is the length of the ship in metres, Cb is the block coefficient which is to be taken as not less than 0.68.

(2) Where the bow height required in subsection (1) of this Regulation is obtained by sheer, the sheer shall extend for at least 15 per cent of the length of the ship measured from the forward perpendicular. Where it is obtained by fitting a superstructure, such superstructure shall extend from the stem to a point at least 0.07 L abaft the forward perpendicular, and it shall comply with the following requirements:

(a) for ships not over 100 m in length it shall be enclosed as defined in Regulation 3(10); and
(b) for ships over 100 m in length it shall be fitted with satisfactory closing appliances.

(3) Ships which, to suit exceptional operational requirements, cannot meet the requirements of subsections (1) and (2) of this Regulation may be given special consideration by the Administration.

Regulation 40 *Minimum Freeboards*

Summer Freeboard
The minimum freeboard in summer shall be the freeboard derived from the tables as modified by the corrections

Tropical Freeboard
The minimum freeboard in the Tropical Zone shall be the freeboard obtained by a deduction from the summer freeboard of 1/48th of the summer draught measured from the top of the keel to the centre of the ring of the load line mark.

$$f_T = f_S - \frac{T}{48}$$

Winter Freeboard
The minimum freeboard in winter shall be the freeboard obtained by an addition to the summer freeboard of 1/48th of summer draught, measured from the top of the keel to the centre of the ring of the load line mark.

$$f_W = f_S + \frac{T}{48}$$

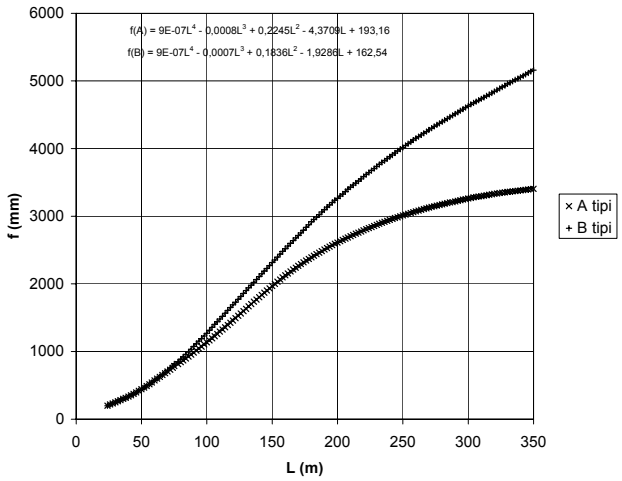
Winter North Atlantic Freeboard
The minimum freeboard for ships of not more than 100 m in length that enter any part of the North Atlantic defined in section 7 of Schedule II during the winter seasonal period shall be the winter freeboard plus 50 mm. For other ships, the Winter North Atlantic Freeboard shall be the winter freeboard.

$$f_{WNA} = f_W + 50$$

Fresh Water Freeboard
The minimum freeboard in fresh water of unit density shall be obtained by deducting from the minimum freeboard in salt water:

$$f_F = f_S - \frac{\Delta}{40T_1} \qquad f_{TF} = f_F - \frac{T}{48}$$

where Δ = displacement in salt water in tonnes at the summer load water line,
T = tonnes per centimetre immersion in salt water at the summer load water line.



Certificate No.: **060596-1**

TÜRK LOYDU

INTERNATIONAL LOAD LINE CERTIFICATE (1966)
OF COMPLIANCE

Issued under the provisions of the International Convention on Load Lines, 1966,
under the authority of the Government of **THE REPUBLIC OF TURKEY**
by TÜRK LOYDU

Name of Ship	Distinctive Number or Letters	Port of Registry	Length (L) as defined in Article 2(8)
YARBAY KUDRED GÜNGÖR	-	GÖLCÜK-KOCAELİ	133.01

Freeboard assigned as * A new ship / ~~An existing ship~~

Type of ship * Type A / ~~Type B~~ / ~~Type B with reduced freeboard~~ / ~~Type B with increased freeboard~~

Freeboard from deck line			Load Line	
Tropical	-	mm (Y)	-	mm above (S)
Summer	*1965.5	mm (S)	Upper edge of line through centre of ring	
Winter	-	mm (W)	-	mm below (S)
Winter North Atlantic	-	mm (WNA)	-	mm below (S)
Timber Tropical		mm (LT)		mm above (LS)
Timber Summer		mm (LS)		mm above (S)
Timber Winter		mm (LW)		mm below (LS)
Timber Winter North Atlantic		mm (LWNA)		mm (below (LS)

*** According to LLC 66, Reg. 6(6) FREEBOARD assigned as per scatling draft from The Classification Rules.**

Note: Freeboards and load lines which are not applicable need not be entered on the certificate.

Allowance for fresh water for all freeboards other than timber 179* mm. For timber freeboards - mm.
The upper edge of the deck line from which these freeboards are measured is 450 mm.

lower from the main deck at side.

Date of Initial or Periodical Survey

May. 1996

This is to certify that this ship has been surveyed and that the freeboards have been assigned and load lines shown above have been marked in accordance with the International Convention on Load Lines, 1966.

This certificate is valid until - subject to periodical inspections in accordance with Article 14(1)(c) of the Convention.

ISTANBUL
Issued at

06.05.1996
Date of issue

Fuat ÇAKMAK
Signature

* Delete whatever is inapplicable

Form No :TL 12A/94

Freeboard Calculation according to International Convention on Load Line 1

1 - Principle Dimentions

L.O.A.	=	143.100	m
L.B.P.	=	134.000	m
B.	=	22.800	m
D.	=	10.000	m
T.	=		m

2 - Determination of the length

* d1 = 8.500 m

Length on waterline at 8.500 m draught

L1 = 136.310 m
L' = 130.858 m

* Length on waterline at 8.500 m draught measured from the forward edge of the steam to the rudder head 's

L'' = 133.010 m

L'' > L'

L = 133.010 m

3 - Block Coefficient

Volume of Displ. at 8.500 m draught

Volume = 21524.000 m3
Cb = 0.835

4 - Tabular Freeboard

Length	Type A	Type B
133.000	1684.000	
134.000	1702.000	
133.010	1684.180	

5 - Correction for Block Coefficient

Cb = 0.835 > 0.680

K 1	=	1.114

6 - Correction for depth

D = 10.000 + 0.016 = 10.016 m

L / 15 = 8.867

D > (L / 15)

K2 = 287.042 mm

7 - Correction for Superstructure

Effective Length of Superstructure 44.860 m

E / L = 0.337

Deduction from the Freeboard = 1070.000

0.300 L	21.000 %
0.400 L	31.000 %
0.337 L	24.727 %

K 3 = 264.577 mm

8 - Sheer Correction

Station	Standard ordinate	Factor	Pruduct	Actuel ordinate	Factor	Pruduct
A.P.	1358.417	1.000	1358.417	231.000	1.000	231.000
1/6 L fr A.P.	603.137	3.000	1809.411	6.000	3.000	18.000
1/3 L fr A.P.	152.143	3.000	456.428	0.000	3.000	0.000
Amidship	0.000	1.000	0.000	0.000	1.000	0.000
			3624.256			249.000
Amidship	0.000	1.000	0.000	0.000	1.000	0.000
1/3 L fr F.P.	304.285	3.000	912.856	0.000	3.000	0.000
1/6 L fr F.P.	1206.274	3.000	3618.822	27.000	3.000	81.000
F.P.	2716.833	1.000	2716.833	520.000	1.000	520.000
			7248.511			601.000

Deficiency of the Sheer SUM/8= 106.250

in the after half 453.032
in the forward half 906.064

Sheer Credit for Forecastle L f = 11.610 m

y = 2560.000 - 2300.000 = 260.000

s = 7.565 mm

Deficiency of the sheer in the forward half 906.064

Sheer Credit for Poopdeck L p = 33.250 m

y = 2680.000 - 2300.000 = 380.000

s = 31.664 mm

Deficiency of the sheer in the aft half 453.032

The Aritmatical mean of the deficiency 587.194

Actual length of the superstructure E = 44.860

Ccr = 0.581

K 4 = 341.375 mm

9 - Summary

		+	-
Correction for depth	K 2	287.042	
Correction for superstr.	K 3		264.577
Correction for Sheer	K4	341.375	
		628.416	264.577

Correction Sum 363.840 mm

10 - Summer Freeboard

Tabular freeboard for type	A	1684.180
Tabular freeboard for type	B	0.000
		1684.180
Summer		2239.97
Correction for deckline		-450.000
SUMMER FREEBOARD		1790.0
Height to the freeboard deck		10.016 m
Draft to the summer freeboard		7775.53 mm
TROPICAL FREEBOARD (S.F-)		-161.99
WINTER FREEBOARD (S.F+)		161.99

FRESH WATER FREE. (S.F-) -183.76

Displacement at 7775.53

D = 20169.5 ton
TP1 = 27.44 ton/cm
dF = 183.76

TROPICAL F.WATER FR. (F.W.F-) -183.76

11. Minimum Bow Height

H min = 4907.754

12. Effective Bow Height

H eff = 5194

H eff > H min

Example 5.5. Calculate the minimum freeboard requirements for the following ship in accordance with ICLL 66 regulations

Main particulars

Ship type : Dry cargo (B)
L_{BP} : 120.00 m
B : 19.50 m
D : 10.00 m
L_{WL} at 0.85 D : 126.00 m
Thickness of deck plating (t) : 25 mm
Block coefficent at 0.85D : 0.722
T_1 : 9

Superstructure

	Length	Height
Poop	23.16	2.60
Raised Quarter Deck	21.40	1.50
Forecastle	13.00	2.80

The ship's sheer profile is as follows

AP	L/6	L/3	L/2	2L/3	5L/6	FP
750	340	85	0	300	1200	2500

Solution

Freeboard Length

$$\left.\begin{aligned} L_{BP} &= 120.00 \\ 0.96L_{WL} &= 0.96\times 126 = 120.96 \end{aligned}\right\} \quad L = 120.96\text{m}$$

Freeboard depth

D_f = D + t = 10.00+0.025 = 10.025 m

Tabular freeboard value

From the Table B

Ship length (m)	Freeboard (mm)
120	1690
120.96	f_T
122	1729

The tabular value of freeboard can be calculated by linear interpolation

$$f_T = 1690 + (1729 - 1690)\frac{120.96 - 120}{122 - 120} = 1708.72\text{mm}$$

Correction for length

The tabular freeboard for a Type `B' ship of between 24 m and 100 m in length having enclosed superstructures with an effective length of up to 35 per cent of the length of the ship shall be increased by:

$$7.5(100 - L)\left(0.35 - \frac{E}{L}\right)\ \text{mm}$$

where L = length of ship in metres,

where E = effective length of superstructure in metres defined in Regulations 35.

Since the ship is greater than 100 m there is no need for correction

$$f_1 = f_T = 1708.72\,\text{mm}$$

Correction for Block Coefficient

Where the block coefficient (C_b) exceeds 0.68, the freeboard shall be multiplied by the factor

$$\frac{C_b + 0.68}{1.36}$$

The ship's block coefficient is 0.722>0.68 hence the corrected freeboard is

$$f_2 = f_1 \times \frac{C_B + 0.68}{1.36} = 1708.72 \times \frac{0.722 + 0.68}{1.36} = 1761.5\ \text{mm}$$

Correction for Depth

(4) Where D exceeds $\frac{L}{15}$ the freeboard shall be increased by $\left(D - \frac{L}{15}\right)R$ millimetres, where R is $\frac{L}{0.48}$ at length less than 120 m and 250 at 120 m length and above.

(5) Where D is less than $\frac{L}{15}$, no reduction shall be made.

Since D=10.025 m and $\frac{L}{15} = \frac{120.96}{15} = 8.064$ a depth correction is required

$$f_3 = f_2 + (D - \frac{L}{15})R = 1761.5 + (10.025 - 8.064)250 = 2251.8\ \text{mm}$$

Correction for Superstructures

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

L (metres)	Standard Height (in metres)	
	Raised Quarter Deck	All other Superstructures
≤ 30	0.90	1.80
75	1.20	1.80
≥ 125	1.80	2.30

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

Since the length of the ship is 120.96 m the standard height for the superstructures are as follows.

Raised quarter deck

$$1.20 + (1.80 - 1.20)\frac{120.96 - 75}{125 - 75} = 1.75\text{m}$$

Other superstructures

$$1.80 + (2.30 - 1.80)\frac{120.96 - 75}{125 - 75} = 2.26\text{m}$$

The effective length is the length modified by the ratio of b/Bs and h/Hs, where

b is the breadth of the superstructure at the middle of its length, and
B is the breadth of the ship at the middle of the length of the superstructure, and
h is the height of superstructure

H is the standard height

Poop

Enclosed length(S) : 23.16 m

Effective length (E) : $\ell \frac{b}{B}\frac{h}{H} = 23.16$ m (h/H is taken 1)

Raised Quarterdeck

Enclosed length (S) : 21.40 m

Effective length (E) : $\ell \frac{b}{B}\frac{h}{H} = 21.40\frac{1.5}{1.75} = 18.34$ m

Forecastle :

Enclosed length (S) : 13.00 m

Effective length (E) : $\ell \frac{b}{B}\frac{h}{H} = 13.00$ m (h/H is taken 1)

	Enclosed length (m)	Effective length (m)
Poop	23.16	23.16
Raised quarter deck	21.40	18.34
Forecastle	13.00	13.00
Total	57.56	54.50

Deduction for Superstructures and Trunks

(4) Where the effective length of superstructures and trunks is 1.0 L, the deduction from the freeboard shall be 350 mm at 24 m length of ship, 860 mm at 85 m length, and 1,070 mm at 122 m length and above; deductions at intermediate lengths shall be obtained by linear interpolation.

L [m]	f_e [mm]
24	350
85	860
≥ 122	1070

The length of ship is 120.96 m, thus

$$f_e = 860 + (1070 - 860)\frac{120.96 - 85}{122 - 85} = 1064.1\text{mm}$$

the ratio of effective length to ship length is 54.5/120.96=0.45. Thus from the following table the percentage of deduction is 0.2775.

Total Effective Length of Superstructures and Trunks	0L	0.1L	0.2L	0.3L	0.4L	0.5L	0.6L	0.7L	0.8L	0.9L	1.0L
Ships with forecastle and without detached bridge	0	5	10	15	23.5	32	46	63	75.3	87.7	100
Ships with forecastle and with detached bridge	0	6.3	12.7	19	27.5	36	46	63	75.3	87.7	100

(d) where the effective length of a bridge is less than 0.2 L, the percentages shall be obtained by linear interpolation between lines I and II;

(e) where the effective length of a forecastle is more than 0.4 L, the percentages shall be obtained from line II; and

(f) where the effective length of a forecastle is less than 0.07 L, the above percentages shall be reduced by:

$$5 \times \frac{0.07L - f}{0.07L}$$

where f is the effective length of the forecastle.

The freeboard following the superstructure correction is

$$f_4 = f_3 - 0.2775 f_e = 2251.8 - 0.2775 \times 1064.1 = 1956.5 \text{ mm}$$

Correction for Sheer

Where the sheer profile differs from the standard, the four ordinates of each profile in the forward or after half shall be multiplied by the appropriate factors given in the table of ordinates. The difference between the sums of the respective products and those of the standard divided by eight measures the deficiency or excess of sheer in the forward or after half.

Station	Standard	Factor	Product	Current	Factor	Product
AP	$25\left(\frac{L}{3}+10\right)$	1	1258	750	1	750
1/ 6 L	$11.1\left(\frac{L}{3}+10\right)$	3	1675.656	340	3	1020
1/3 L	$2.8\left(\frac{L}{3}+10\right)$	3	422.688	85	3	255
1/2 L	0	1	0	0	1	0
TOTAL		**Σ_1=**	**3356.344**		**Σ_3=**	**2025**
1/2 L	0	1	0	0	1	0
2/3 L	$5.6\left(\frac{L}{3}+10\right)$	3	845.376	300	3	900
5/6 L	$22.2\left(\frac{L}{3}+10\right)$	3	3351.312	1200	3	3600
FP	$50\left(\frac{L}{3}+10\right)$	1	2516	2500	1	2500
TOTAL		**Σ_2=**	**6712.688**		**Σ_4=**	**7000**

$$\delta S_A = \frac{\Sigma_1 - \Sigma_3}{8} = \frac{3356.344 - 2025}{8} = 166.418$$

$$\delta S_F = \frac{\Sigma_2 - \Sigma_4}{8} = \frac{6712.688 - 7000}{8} = -35.914$$

Where an enclosed poop or forecastle is of standard height with greater sheer than that of the freeboard deck, or is of more than standard height, an addition to the sheer of the freeboard deck shall be made in accordance with the following formula

$$s = \frac{y}{3}\frac{L'}{L}$$

where s = sheer credit, to be deducted from the deficiency or added to the excess of sheer,
y = difference between actual and standard height of superstructure at the end of sheer,
L' = mean enclosed length of poop or forecastle up to a maximum length of 0.5 L,
L = length of ship as defined in Regulation 3(1).

s values for the poop and forecastle are calculated in the following table

	Actual height	Standard height	Difference	s
Poop	2600	2260	340	$\frac{340}{3}\frac{23.16}{120.96} = 21.7$

Forecastle	2800	2260	540	$\frac{540}{3}\frac{13.00}{120.96}=19.3$

Than the modifed forward and aft sheers are

$$\delta S_A = 166.418 - 21.7 = 144.718 \text{ mm}$$
$$\delta S_F = -35.914 - 19.3 = -55.214 \text{ mm}$$

The excess/deficiancy of sheer is

$$\delta S = \frac{\delta S_A + \delta S_F}{2} = \frac{144.718 - 55.214}{2} = 44.752 \text{ mm}$$

Where the forward half of the sheer profile exceeds the standard and the after sheer is between 50 per cent and 75 per cent of the standard, intermediate allowances may be granted for excess sheer forward. In this example the excess ratio of the after portion of sheer is

$$\frac{2025}{3356.5} = 0.60$$

Hence the deficiency is

$$\left[\delta S \times \frac{0.60 - 0.50}{0.75 - 0.50}\right] = 44.752 \times 0.4 = 30.3864 \text{ mm}$$

The correction for sheer shall be the deficiency or excess of multiplied by

$$0.75 - \frac{S}{2L}$$

where S is the total length of enclosed superstructures. The increase in freeboard due to the excess of sheer is

$$\left(0.75 - \frac{57.56}{2 \times 120.96}\right) \times 30.3864 = 15.56 \text{ mm}$$

The freeboard following the sheer correction is

$$f_5 = f_4 + 15.56 = 1956.5 + 15.56 = 1972.06 \text{ mm}$$

Then the maximum draught in summer is $T = D - f = 10.025 - 1972.06 = 8.098$ m

Minimum Bow Height

The bow height defined as the vertical distance at the forward perpendicular between the water line corresponding to the assigned summer freeboard and the designed trim and the top of the exposed deck at side shall be not less than:

for ships below 250 m in length,

$$56L\left(1 - \frac{L}{500}\right)\frac{1.36}{C_b + 0.68} \text{ mm}$$

for ships of 250 m and above in length,

$$7000\frac{1.36}{C_b + 0.68} \text{ mm}$$

where L is the length of the ship in metres, Cb is the block coefficient which is to be taken as not less than 0.68. For this example the minimum bow height is

$$56 \times 120.96 \times \left(1 - \frac{120.96}{500}\right) \frac{1.36}{0.722 + 0.68} = 4981 \text{mm}.$$

Minimum Freeboards

Summer Freeboard

$$f_S = 1972.06 \text{ mm}$$

Tropical Freeboard

$$f_T = f_S - \frac{T}{48} = 1972.06 - \frac{8098}{48} = 1803 \text{ mm}$$

Winter Freeboard

$$f_W = f_S + \frac{T}{48} = 1972.06 + \frac{8098}{48} = 2141 \text{ mm}$$

Winter North Atlantic Freeboard

$$f_{WNA} = f_W + 50 = 2191 \text{ mm}$$

Fresh Water Freeboard

$$f_F = f_S - \frac{\Delta}{40T_1} = 1972.06 - \frac{120 \times 19.5 \times 6 \times 0.722 \times 1.025}{40 \times 9} = 1942.97 \text{ mm}$$

Example 5.6. (Baxter) A type B ship has a freeboard length of 145 m measured on a waterline at 85% of the moulded depth of 12 m and a beam of 21 m. There is no bridge amidships and the forecastle and poop have mean covered lengths of 30 m and 15 m and heights of 2.6 m, respectively

The sheer of the freeboard deck in milimeters is as follows

AP	L/6	L/3	L/2	2L/3	5L/6	FP
2730	320	0	0	0	1630	4060

The displacement at a moulded draught of 85% of the moulded depth is 22700 m^3 and the displacement in seawater at the summer LWL is 19420 tonnes wşth a corresponding tonnes immersion per cm of 25. Determine the freeboards.

Solution

Freeboard Length L = 145 m

Freeboard depth $D_f = D + t = 12.00+0.02 = 12.02$ m

Tabular freeboard value : From the Table B

Ship length (m)	Freeboard (mm)
144	2190
145	f_T
146	2229

The tabular value of freeboard can be calculated by linear interpolation

$$f_T = 2190 + (2229 - 2190)\frac{145-144}{146-144} = 2209.5 \text{ mm}$$

Correction for length: Since the ship is greater than 100 m there is no need for correction

$$f_1 = f_T = 2209.5 \text{ mm}$$

Correction for Block Coefficient: Where the block coefficient (C_b) exceeds 0.68, the freeboard shall be multiplied by the factor

$$\frac{C_B + 0.68}{1.36}$$

The ship's block coefficient is

$$C_B = \frac{\nabla}{LBT} = \frac{22700}{145 \times 21 \times 12 \times 0.85} = 0.731$$

0.731>0.68 hence the corrected freeboard is

$$f_2 = f_1 \times \frac{C_B + 0.68}{1.36} = 12209.5 \times \frac{0.731 + 0.68}{1.36} = 2292.3 \text{ mm}$$

Correction for Depth

Where D exceeds $\frac{L}{15}$ the freeboard shall be increased by $\left(D - \frac{L}{15}\right)R$ millimetres, where R is $\frac{L}{0.48}$ at length less than 120 m and 250 at 120 m length and above.

Since D=12.02 m and $\frac{L}{15} = \frac{145}{15} = 9.667$ a depth correction is required

$$f_3 = f_2 + (D - \frac{L}{15})R = 2292.3 + (12.02 - 9.667) \times 250 = 2880.6 \text{ mm}$$

Correction for Superstructures

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

L (metres)	Standard Height (in metres)	
	Raised Quarter Deck	All other Superstructures
≤ 30	0.90	1.80
75	1.20	1.80
≥ 125	1.80	2.30

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

Since the length of the ship is 145 m the standard height for the superstructures ais 2.30 m.

The effective length is the length modified by the ratio of b/Bs and h/Hs, where

b is the breadth of the superstructure at the middle of its length, and
B is the breadth of the ship at the middle of the length of the superstructure, and
h is the height of superstructure
H is the standard height

Poop

Enclosed length(S) : 15 m

Effective length (E) : $\ell \frac{b}{B} \frac{h}{H} = 15$ m (h/H is taken 1)

Forecastle :

Enclosed length (S) : 30 m

Effective length (E) : $\ell \frac{b}{B} \frac{h}{H} = 30$ m (h/H is taken 1)

	Enclosed length (m)	Effective length (m)
Poop	15	15
Forecastle	30	30
Total	45	45

Deduction for Superstructures and Trunks

(5) Where the effective length of superstructures and trunks is 1.0 L, the deduction from the freeboard shall be 350 mm at 24 m length of ship, 860 mm at 85 m length, and 1,070 mm at 122 m length and above; deductions at intermediate lengths shall be obtained by linear interpolation.

L [m]	f_e [mm]
24	350
85	860
≥ 122	1070

The length of ship is 145 m, thus f_e=1070 mm. The ratio of effective length to ship length is 45/145=0.31. Thus from the following table the percentage of deduction is 0.1585.

Total Effective Length of Superstructures and Trunks	0L	0.1L	0.2L	0.3L	0.4L	0.5L	0.6L	0.7L	0.8L	0.9L	1.0L
Ships with forecastle and without detached bridge	0	5	10	15	23.5	32	46	63	75.3	87.7	100
Ships with forecastle and with detached bridge	0	6.3	12.7	19	27.5	36	46	63	75.3	87.7	100

(g) where the effective length of a bridge is less than 0.2 L, the percentages shall be obtained by linear interpolation between lines I and II;
(h) where the effective length of a forecastle is more than 0.4 L, the percentages shall be obtained from line II; and
(i) where the effective length of a forecastle is less than 0.07 L, the above percentages shall be reduced by:

$$5 \times \frac{0.07L - f}{0.07L}$$

where f is the effective length of the forecastle.

The freeboard following the superstructure correction is

$$f_4 = f_3 - 0.1585 f_e = 2880.6 - 0.1585 \times 1070 = 2711 \text{ mm}$$

Correction for Sheer

Where the sheer profile differs from the standard, the four ordinates of each profile in the forward or after half shall be multiplied by the appropriate factors given in the table of ordinates. The difference between the sums of the respective products and those of the standard divided by eight measures the deficiency or excess of sheer in the forward or after half.

Station	Standard	Factor	Product	Current	Factor	Product
AP	$25\left(\frac{L}{3}+10\right)$	1	1458	2730	1	2730
1/ 6 L	$11.1\left(\frac{L}{3}+10\right)$	3	1942.5	320	3	960
1/3 L	$2.8\left(\frac{L}{3}+10\right)$	3	490	0	3	0
1/2 L	0	1	0	0	1	0
TOTAL		**Σ_1=**	**3890.833**		**Σ_3=**	**3690**
1/2 L	0	1	0	0	1	0
2/3 L	$5.6\left(\frac{L}{3}+10\right)$	3	845.376	0	3	0
5/6 L	$22.2\left(\frac{L}{3}+10\right)$	3	3351.312	1630	3	4890
FP	$50\left(\frac{L}{3}+10\right)$	1	2516	4060	1	4060
TOTAL		**Σ_2=**	**7781.667**		**Σ_4=**	**8950**

$$\delta S_A = \frac{\Sigma_1 - \Sigma_3}{8} = \frac{3890.833 - 3690}{8} = 25.104 \text{ mm}$$

$$\delta S_F = \frac{\Sigma_2 - \Sigma_4}{8} = \frac{7781.667 - 8950}{8} = -146.042 \text{ mm}$$

Where an enclosed poop or forecastle is of standard height with greater sheer than that of the freeboard deck, or is of more than standard height, an addition to the sheer of the freeboard deck shall be made in accordance with the following formula

$$s = \frac{y}{3}\frac{L'}{L}$$

where s = sheer credit, to be deducted from the deficiency or added to the excess of sheer,
y = difference between actual and standard height of superstructure at the end of sheer,
L' = mean enclosed length of poop or forecastle up to a maximum length of 0.5 L,
L = length of ship

s values for the poop and forecastle are calculated in the following table

	Actual height	Standard height	Difference	s
Poop	2600	2300	300	$\frac{300}{3}\frac{15}{145}=10.345$
Forecastle	2600	2300	300	$\frac{300}{3}\frac{30}{145}=20.690$

Than the modifed forward and aft sheers are

$$\delta S_A = 25.104 - 10.345 = 14.759 \text{ mm}$$
$$\delta S_F = -146.042 - 20.690 = -166.732 \text{ mm}$$

The excess/deficiancy of sheer is

$$\delta S = \frac{\delta S_A + \delta S_F}{2} = \frac{14.759 - 166.732}{2} = -90.75 \text{ mm}$$

Where the forward half of the sheer profile exceeds the standard and the after portion of the sheer profile is no less than 75 per cent of the standard, credit shall be allowed for the part in excess.

$$\frac{3690}{3890.833} = 0.95$$

The correction for sheer shall be the deficiency or excess of multiplied by

$$0.75 - \frac{S}{2L}$$

where S is the total length of enclosed superstructures. The increase in freeboard due to the excess of sheer is

$$\left(0.75 - \frac{45}{2 \times 145}\right) \times (-90.75) = -54 \text{ mm}$$

The freeboard following the sheer correction is

$$f_5 = 2711 - 54 = 2657 \text{ mm}$$

Then the maximum summer freeboard is $T = D - f = 12.02 - 2.657 = 9.363$ m

Minimum Bow Height

For ships below 250 m in length the bow height shall be not less than:

$$56L\left(1 - \frac{L}{500}\right)\frac{1.36}{C_b + 0.68} \text{ mm}$$

where L is the length of the ship in metres, Cb is the block coefficient which is to be taken as not less than 0.68. For this example the minimum bow height is

$$56 \times 145 \times \left(1 - \frac{145}{500}\right)\frac{1.36}{0.731 + 0.68} = 5557 \text{ mm}.$$

Minimum Freeboards

Summer Freeboard $f_S = 2657$ mm

Tropical Freeboard $f_T = f_S - \frac{T}{48} = 2657 - \frac{9363}{48} = 2462$ mm

Winter Freeboard $f_W = f_S + \frac{T}{48} = 2657 + \frac{9363}{48} = 2852$ mm

Winter North Atlantic Freeboard $f_{WNA} = f_W + 50 = 2902$ mm

Fresh Water Freeboard $f_F = f_S - \frac{\Delta}{40T_1} = 2657 - \frac{19420}{40 \times 25} = 2638$ mm