Aalto University
School of Engineering

MEC-E1004 Principles of Naval Architecture

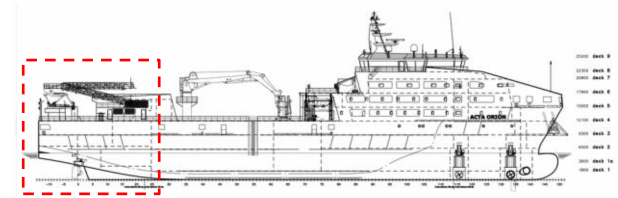
Tutorial 6 – General Arrangement

General arrangement

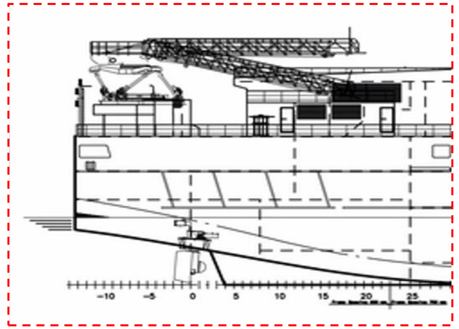
Question: How can we efficiently design a ship's general arrangement ? … a step by step guide.

Introduction

- There is no specific procedure with rules stated for the same.



- Different ship types have different innovative characteristics



- A naval architect needs to know the basic process to follow in order to come down to an optimum design.

Image credit poland@sea

Introduction

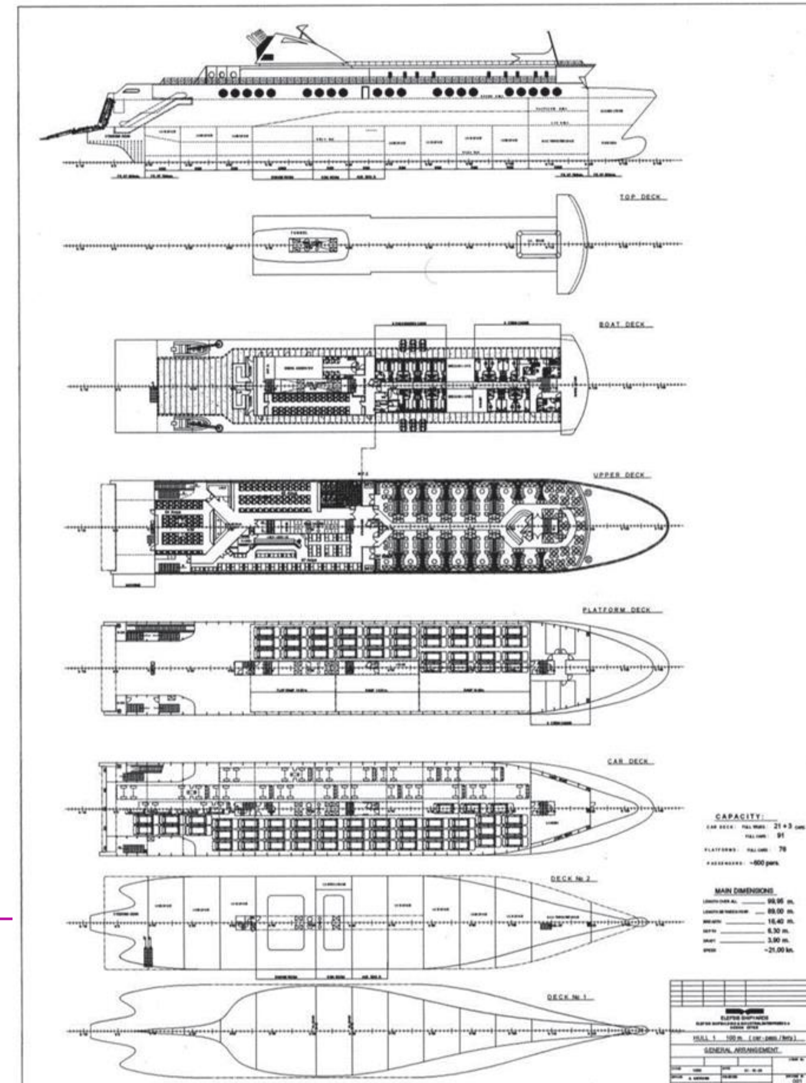
A GA of any ship will consist of the drawings of the following views:

- Profile View (generally looking from starboard side)
- Midship sections (looking from aft, and looking from forward)
- Main deck plan (also shows the accommodation layout)
- Navigation deck plan.
- Forecastle deck plan
- Tank top plan
- Tank plan

It should also be noted that a the process of developing the general arrangement drawing is slightly different for various design firms, depending on their procedures and practices.

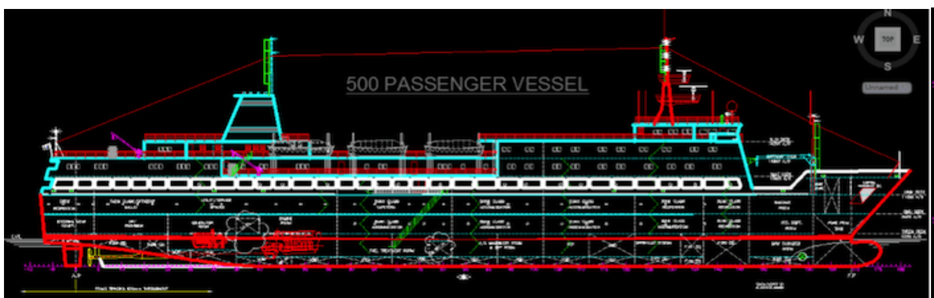
However, the underlying principle always remains the same. It is an iterative process, and the final GA is derived after repeated approvals by the classification society and the owners party.

General arrangement of a RoPax ship

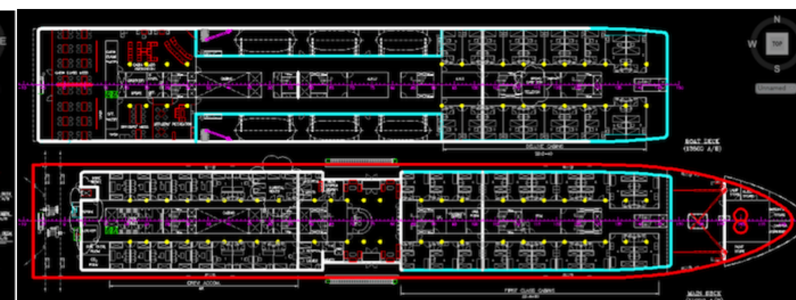


Step 1 - Clarification

- To have a visual approximation of the ship dimensions, draw
  - *an outline of the profile view,*
  - *main deck or uppermost deck that contributes to longitudinal strength,*
  - *the forecastle deck.*
- In some ships, the upper deck is stepped, i.e. it has a poop deck at the aft. Make sure you show that in the profile view and the deck outline view.



Profile view of a 500 Pax ship



Main deck and Boat deck plans

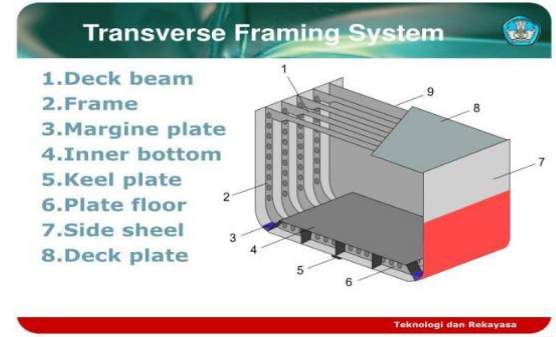
Step 1 - Clarification

The reasons behind deciding the particulars (Especially height) of the forecastle deck at this stage are :

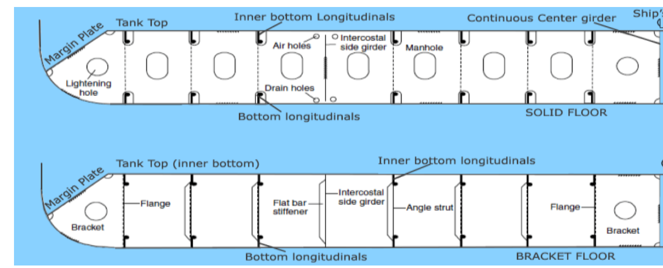
- Minimum bow height has to be attained (according to ILLC Regulations) in order to reduce the deck wetness
- To provide forecastle deck area for anchoring and mooring equipment
- Adequate volume underneath for storage and chain locker, etc.
- To provide additional cargo space (in lower decks) in case of certain ships

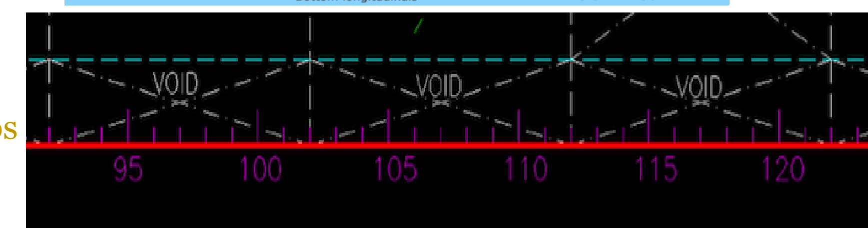
Step 2

- After having drawn the profile plan, the first thing a designer should do is decide on the framing and frame spacing of the ship.
- The framing, whether longitudinal or transverse is decided on the basis of the length of the vessel.
- Generally, all ships longer than 120 m are longitudinally strengthened.
- Frame spacing is the basic module length. Frame location is defined by frame number
- The frame spacing is then calculated by the formula specified in the rule book of the authorized classification society. The value obtained from the formula is generally rounded off to the nearest hundreds or fifties, so as to attain ease of production and design.
- For the estimation of the frame spacing around amidships the directive of the Norwegian Classification Society, DNV, can be used: s[mm] = 2(240 + L[m])
- Web frame spacing S = n * s; n = 3,4



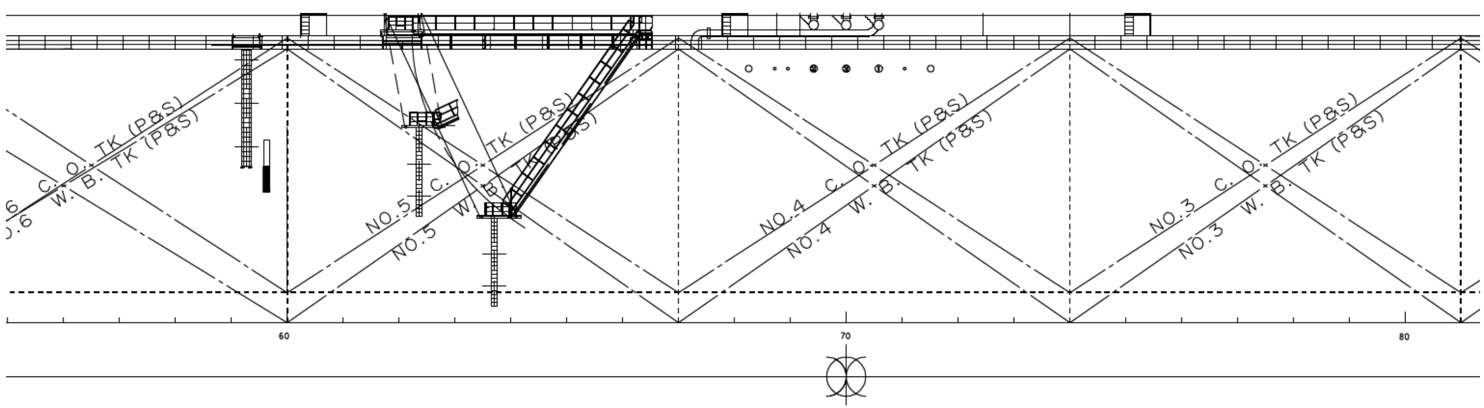
Longitudinal framing system





Step 3

- Next is to mark the decided frame spacing of the drawing. This frame spacing will now act as scale on the drawing, helping you to locate every point on the ship.



Step 4 watertight bulkheads

You must now divide the ship into certain number of watertight compartments, which is decided by the subdivision rules prescribed by the classification society.

The rules specify the total number of watertight transverse bulkheads that are necessary to maintain watertight integrity of the ship. A ship generally has four types of transverse bulkheads:

- ❑ A fore peak collision bulkhead
- ❑ An aft-peak bulkhead
- ❑ A bulkhead at each end of machinery space
- ❑ Transverse bulkheads in cargo hold regions

How to decide the position of the fore peak collision bulkhead?

The distance of the forepeak collision bulkhead from the forward perpendicular is decided based on formulae prescribed by the authorised classification society. Generally, the class society would provide you with two formulae.

One, to specify the minimum distance of the forepeak bulkhead aft of the forward perpendicular. Other, to specify the maximum distance of the forepeak bulkhead aft of the forward perpendicular

It is up to you, as a designer, to provide the forepeak collision bulkheads within the above limits, depending on the dimensions of the forepeak ballast tank, anchor equipment, and chain locker dimensions

How to decide the position of the fore peak collision bulkhead?

In DNVGL classification rules for ships with length 100 m and above, the collision bulkhead shall be taken between the following limits:

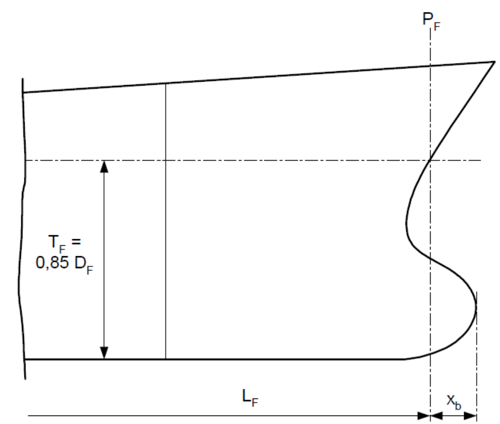
$$x_c\ (\text{minimum}) = 0.05\,L_F - x_r \quad (\text{m})\ \text{for}\ L_F < 200\ \text{m}$$
$$= 10 - x_r \quad (\text{m})\ \text{for}\ L_F \geq 200\ \text{m}$$

$$x_c\ (\text{maximum}) = 0.08\,L_F - x_r \quad (\text{m})$$

where $x_r = 0$ for ships with ordinary bow shape, while for ships with bulbous bow.

$$x_r = 0.5\,x_b \quad (\text{m})$$
$$x_r = 0.015\,L_F \quad (\text{m})$$
$$x_r = 3.0 \quad (\text{m})$$

x_b = distance from P_F to the forward end of the bulbous bow



L_F = 96 percent of the total length on a waterline at 85 per cent of the least moulded depth.

DNVGL rules “Hull Structural Design, Ships with Length 100 meters and above” section 3 DESIGN PRINCIPLES http://rules.dnvgl.com/docs/pdf/dnv/rulesship/2016-01/ts301.pdf

How to decide the position of the aft peak / engine room aft bulkhead?

1. The position of the engine room forward bulkhead is fixed according the position and length of the holds.

2. Once the above is done, about four frame spaces need to be left out before placing the main engine aft of the engine room forward bulkhead. That is to leave space for maintenance and crew operations.

3. Aft of the empty space, the length of the engine room is to be decided depending upon the length of the main engine, and the length of the intermediate shaft.

How to decide the position of the aft peak / engine room aft bulkhead?

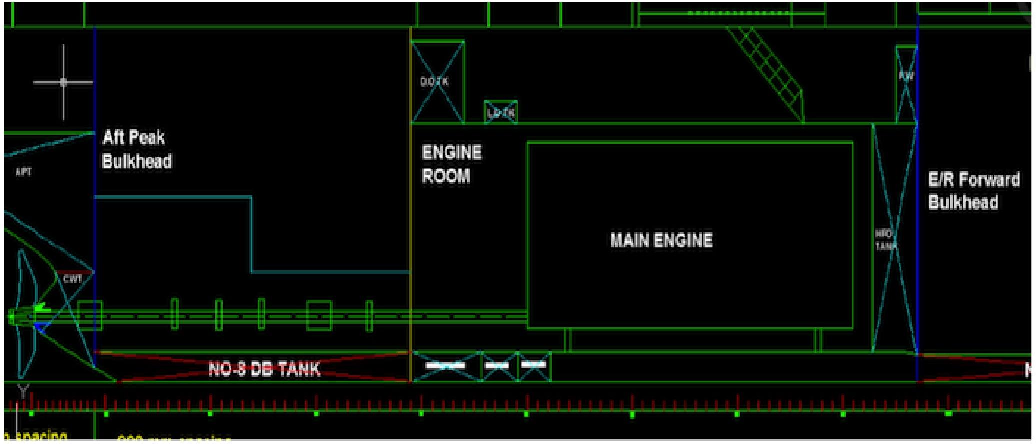
4. The intermediate shaft is coupled with the propeller shaft by a flanged connection. The coupling flange between the intermediate shaft and the propeller shaft is to be housed within the engine room itself. It is just aft of the coupling flange that the engine room aft bulkhead is positioned.

5. The propeller shaft runs from aft of the engine room bulkhead connecting to the propeller through the stern tube.

6. In many cases, the position of the engine rom aft bulkhead is also governed by the decided capacity of the aft peak ballast tank, which is always aft of the aft peak bulkhead.

7. The capacity of the tank is estimated by trim and stability calculations, which is a very preliminary stage of design.

8. But the engine and shaft lengths are decided at a comparatively later stage. This should give you an idea of how iterative the ship design process is



Aft peak bulkhead position

How to decide the number and the position of the transverse watertight bulkheads?

Number and position of the transverse BKHD depend on:

- The desired number of cargo holds (next slide), engine rooms etc.,
- The position of bulkheads is determined by the dimensions of the carried cargo (e.g. containerships), and also the requirements regarding minimum distances between bulkheads.
- DNV GL requires minimum number of watertight transverse BKHDs as shown in the table.

Number of transverse bulkheads		
Ship length in m	*Engine room*	
	Aft	*Elsewhere*
$85 < L \leq 105$	4	5
$105 < L \leq 125$	5	6
$125 < L \leq 145$	6	7
$145 < L \leq 165$	7	8
$165 < L \leq 190$	8	9
$190 < L \leq 225$	9	10
$L > 225$	specially considered	

For ships without longitudinal bulkheads in the cargo region.

Passenger ships watertight bulkheads and fire zones.

Passenger and Ro-Ro-Passenger (RoPax) ships:

- There are no typical values for the number of watertight compartments. The watertight subdivision of passenger ships can be accomplished by fitting of both transverse and longitudinal bulkheads and combinations of both. The density of the watertight subdivision is determined by the damage stability regulations of SOLAS.
- In passenger ships, the main vertical fire safety zones should be shown; typically, they are extensions of the watertight bulkheads extending below the main deck. The distance of these fire zones should not exceed **40** m (according to the SOLAS regulations), and any exceedance of this limit must be justified by dedicated studies and approved by competent authorities.

Step 5 How to arrange cargo spaces?

- The entire cargo space needs to be divided into cargo holds by placing the specified number of transverse watertight bulkheads. The longitudinal position of the bulkheads may be decided according to the following :

  - ✓ Holds should be kept of equal lengths wherever possible

  - ✓ In some cases where necessary, alternate large and small holds are designed to meet the cargo requirements for different voyage and cargo conditions. This is normally done for bulk carriers, product tankers, and some container ships

  - ✓ In cases of oil tankers and container ships, decisions on longitudinal bulkheads should ensure proper cargo distribution and handling characteristics.

Step 5 How to arrange cargo spaces?

- The stowage factor (SF), which corresponds to the required hold volume per ton of cargo, can be used to determine the required volume to hold the intended cargo weight.

Examples (Capacity factor)

General cargo ship	1.6–2.0 m^3/t (55–72 ft^3/t)
Small–medium tanker (< 100,000 t DWT)	1.3–1.4 m^3/t (45–49 ft^3/t)
Large tanker (> 100,000 t DWT)	1.2–1.25 m^3/t (43–44 ft^3/t)

Examples (SF)

Light cargoes $SF \geq 2.0\ m^3/t$

Citrus and other fruits	2.0–2.5 m^3/t
Cotton goods	2.2–2.8 m^3/t
Coking coal	1.95–2.78 m^3/t
Tobacco	3.00–5.00 m^3/t
Bananas (in boxes)	3.25 m^3/t

Semiheavy cargoes $1.25 \leq SF \leq 2.0\ m^3/t$

Grains	1.2–1.8 m^3/t
Sugar (in sacks)	1.29–1.34 m^3/t
Coal	1.18–1.33 m^3/t
Coffee	1.61–1.75 m^3/t
Wines	1.39–1.53 m^3/t

Heavy cargoes $SF \leq 1.25\ m^3/t$

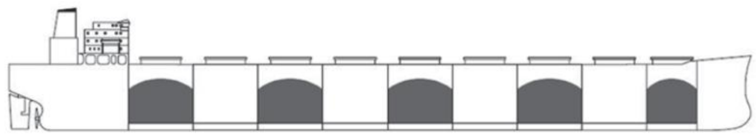
Cements	0.64–0.78 m^3/t
Ores	0.34–0.50 m^3/t
Crude oil	0.91–1.00 m^3/t
Steel panels	0.60 m^3/t
Electrical cables	0.85–1.12 m^3/t

Typical Ship Design Stowage Factors

Ship Type	*Stowage Factor Range* m^3/t *DWT*
Bulk Carrier	1.24
Car Carrier	0.35 car/t DWT
Container Ship	0.8 TEU/t DWT
Crude Oil Tanker	1.22
Cruise	0.7 – 0.3 pass/t DWT
Cruise Ferry	0.45 – 0.37 lane m/t DWT
LNG Carrier	2.02
Ore Carrier	0.54
Orange Juice Carrier	0.74
Multipurpose Cargo	1.70
Product Tanker	1.35
Reefer	1.35
RO/RO	0.33 – 0.25 lane m/t DWT

How to arrange cargo spaces?

- The number of holds should be an odd number (3, 5, 7, 9), Especially for bulk cargo carriers , so that it is possible to arrange an “alternate hold loading” due to strength and stability considerations, see figure below.



- Ships carrying standardized large cargo units (unitized cargo), such as standard containers (ISO-Containers), barges, trailers, vehicles, and trains, namely containerships, LASH, Ro/Ro, car carriers/ train carriers, the relationship of the cargo hold length should be a multiple of the individual standard cargo length with little freedom to balance any differences

Step 6 Cargo handling

- The cargo handling equipment depends mainly on the vessel type. It may include the following items:
  - Derricks;
  - Winches;
  - Deck cranes;
  - Hatch cover;
  - lashing units of containers;
  - Planking of holds; planking of the sides of hold spaces with wooden planks;
  - Derrick's mast;
  - For Ro-Ro ships, all the ramps, external or internal;
  - Doors Bow, side and stern doors;
  - Pumping: transfer of liquid cargo to and from tanks by pumping;
  - Mooring equipment.

How about bottom & twin deck heights?

1. The double bottom height needs to be shown clearly, so as to ensure proper estimation and representation of the tank plan. Therefore the designer is required to estimate the height of the double bottom using the corresponding formula specified in the rules of the authorised class society.

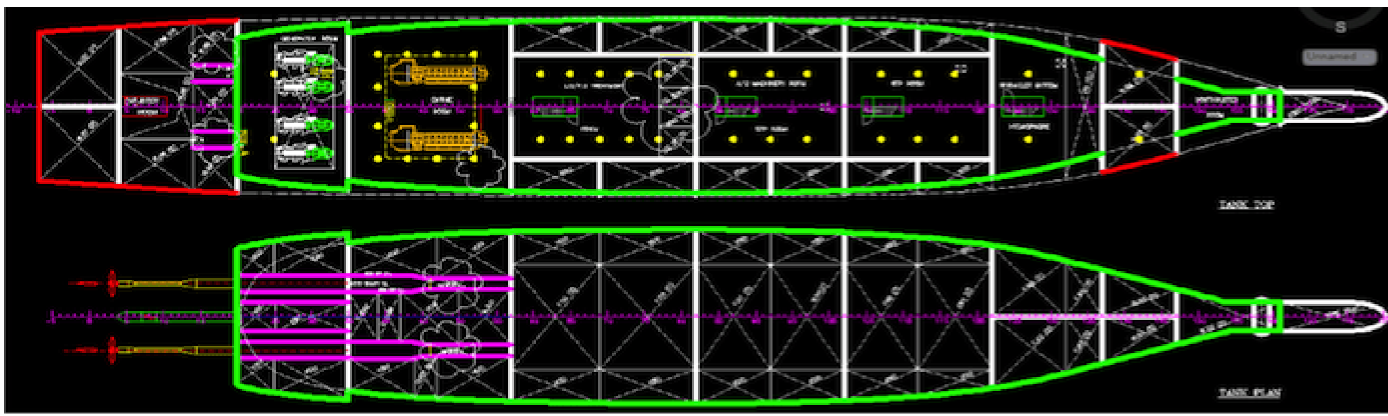
2. Ships that carry packed cargo and cars, require more deck space to attain maximum stowage capacity. In order to increase the overall deck area, these ships are provided with a number of tween decks. The height of each tween deck should be sufficient to accommodate the cargo that is to be stowed on it.

3. This consideration of tween deck is however not required for volume based cargo carrier, like oil tankers, chemical carriers and bulk carriers. And in case of container ships, the top of each container serves as the floor for the next container to be stowed above it, hence container ships do not require tween decks for cargo stowage.

How about bottom & twin deck heights?

1. Ballast capacity should be such that full propeller immersion is obtained at the aft end and forward draught is not too low to avoid the harmful effects of slamming.

2. Ballast distribution should be such that excessive hogging moment is avoided in this condition. So a designer should always ensure to segregate the ballast water tank from any other liquid tank



How about bottom & twin deck heights?

- The minimum height of the double bottom is determined by relevant regulations of recognized classification societies as a function of ship's beam B and draft T; regulations differs (slightly) among different class societies.
  - ✓ Det Norske Veritas, DNV [mm]: 250 + 20 B[m] + 50 T[m], with minimum height 650 mm.
  - ✓ Lloyd's Register, LR [mm]: 28 B[m] + 205 $T^{1/2}$ [m], also with minimum height 650 mm
  - ✓ American Bureau of Shipping, ABS [mm]: 32 B[m] + 190 $T^{1/2}$[m], for ships with L ≤ 427 m.
- The height of the double bottom can be increased in the engine room compartments and at the bow for operational and constructional reasons (size of double bottom tanks, accessibility, and strength).

Step 7 Fire zones

- SOLAS regulations require subdividing the ship by thermal and structural boundaries.
- The purpose of this regulation is to contain a fire in the space of origin.
- "'A' class divisions" are those divisions formed by bulkheads and decks which comply with the following:
  - They shall be constructed of steel or other equivalent material and suitably stiffened;
  - preventing the passage of smoke and flame to the end of the one-hour standard fire test;
  - shall be insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140 ° C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180 ° C above the original temperature, within the time listed below:
    - class A-60 60 minutes
    - class A-30 30 minutes
    - class A-15 15 minutes
    - class A-0 0 minutes

DNVGL OFFSHORE STANDARD DNVGL-OS-D301, Fire protection
https://rules.dnvgl.com/docs/pdf/DNVGL/OS/2017-01/DNVGL-OS-D301.pdf

Step 7 Firezones

"'B' class divisions" are those divisions formed by bulkheads, decks, ceilings or linings which comply with the following:

- they shall be so constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test;
- they shall have an insulation value such that the average temperature of the unexposed side will not rise more than 140 °C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225 °C above the original temperature within the time listed below:
  - class B-15 15 min
  - class B-0 0 min

"'C' class divisions" are divisions constructed of approved non-combustible materials. They need meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise.

Step 7 Fire zones

For passenger ship, ships carrying more than 36 passengers, the following division classes are applied between the adjacent spaces. Refer to SOLAS regulation for more details.

Fire integrity of bulkheads separating adjacent spaces

Spaces	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*	*(10)*	*(11)*
Control stations (1)	A-0(d)	A-0	A-60	A-0	A-15	A-60	A-15	A-60[e]	A-60	*)	A-0
Corridors (2)		C	B-0	B-0 A-0(b)	B-0	A-60	A-0	A-0[e]	A-0	*)	B-0
Accommodation spaces (3)			C	B-0 A-0(b)	B-0	A-60	A-0	A-0[e]	A-0	*)	C
Stairways (4)				B-0 A-0(b)	B-0 A-0(b)	A-60	A-0	A-0[e]	A-0	*)	B-0 A-0(b)
Service spaces (low risk) (5)					C	A-60	A-0	A-0	A-0	*)	B-0
Machinery spaces of category A (6)						*)(a)	A-0(a)	A-60	A-60	*)	A-0
Other machinery spaces (7)							A-0(a) (c)	A-0	A-0	*)	A-0
Hazardous areas (8)								-	A-0	-	A-0
Service spaces (high risk) (9)									A-0(c)	*)	A-0
Open decks (10)										-	*)
Sanitary and similar spaces (11)											C

Fire integrity of decks separating adjacent spaces

Space - above below	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Control stations (1)	A-0	A-0	A-0	A-0	A-0	A-60	A-0	A-0(e)	A-0	*)	A-0
Corridors (2)	A-0	*)	*)	A-0	*)	A-60	A-0	A-0(e)	A-0	*)	*)
Accommodation spaces (3)	A-60	A-0	*)	A-0	*)	A-60	A-0	A-0(e)	A-0	*)	*)
Stairways (4)	A-0	A-0	A-0	*)	A-0	A-60	A-0	A-0(e)	A-0	*)	A-0
Service spaces (low risk) (5)	A-15	A-0	A-0	A-0	*)	A-60	A-0	A-0	A-0	*)	A-0
Machinery spaces of category A (6)	A-60	A-60	A-60	A-60	A-60	*) (a)	A-60	A-60	A-60	*)	A-0
Other machinery spaces (7)	A15	A-0	A-0	A-0	A-0	A-0 (a)	*) (a)	A-0	A-0	*)	A-0
Hazardous areas (8)	A-60(e)	A-0(e)	A-0(e)	A-0(e)	A-0	A-60	A-0	-	A-0	-	A-0
Service spaces (high risk) (9)	A-60	A-0	A-0	A-0	A-0	A-0	A-0	A-0	A-0 (c)	*)	A-0
Open decks (10)	*)	*)	*)	*)	*)	*)	*)	-	*)	-	*)
Sanitary and similar spaces (11)	A-0	A-0	*)	A-0	*)	A-0	A-0	A-0	A-0	*)	*)

Notes: To be applied to Table 3 and Table 4, as appropriate.

The required fire integrity should be qualified through the conditions for the dimensioning accidental load that applies. Areas where the dimensioning fire load exceeds 100 kW/m^2, H-rated divisions shall be applied. See DNVGL-OS-A101 Sec.2.

(a) Where the space contains an emergency power source or components of an emergency power source adjoining a space containing a ship's service generator or the components of a ship's service generator, the boundary bulkhead or deck be-tween those spaces shall be an "A-60" class division.

(b) For clarification as to which note applies see [3.3.3] and [3.3.5].

(c) Where spaces are of the same numerical category and superscript "c" appears, a bulkhead or deck of the rating shown in the tables is only required when the adjacent spaces are for a different purpose, e.g. in category (9). A galley next to a galley does not require a bulkhead but a galley next to a paint room requires an "A-0" bulkhead.

(d) Bulkheads separating the navigating bridge, chartroom and radio room from each other may be "B-0" rating.

(e) An engineering evaluation shall be conducted in accordance with [3.3.1]. In no case shall the bulkhead or deck rating be less than the value indicated in the tables.

*) Where an asterisk appears in the tables, the division shall be of steel or equivalent material, but need not be of "A" class standard. However, where a deck is penetrated for the passage of electric cables, pipes and vent ducts, such penetrations shall be made tight to prevent the passage of flame and smoke.

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Thank you

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