# Bulk Carriers

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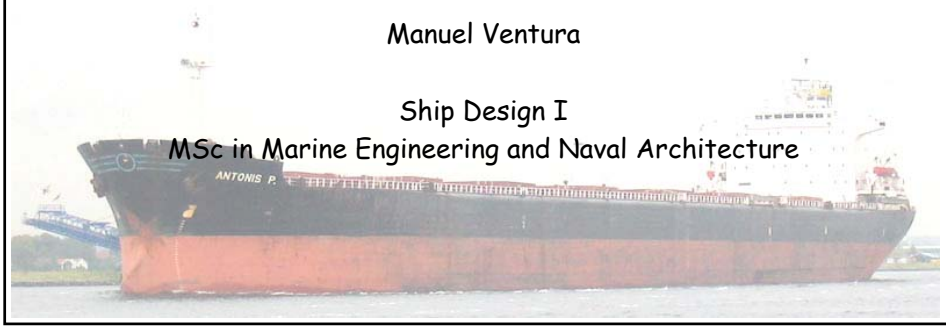
Ship Design I
MSc in Marine Engineering and Naval Architecture




## Summary

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## Bulk Carriers

**Definition**

- Ships for the carriage of homogeneous cargo, in bulk (not unitized), with vertical loading/unloading through hatches with large dimensions.
- Bulkcarriers were remotely originated in the ships for bulk cargo that appeared in Great Lakes of the EUA for the carriage of iron ore. Even in 1900 these ships attained lengths of about 150 m.
- The current configuration dates from the years 1960s.



## Types of Bulk Carriers

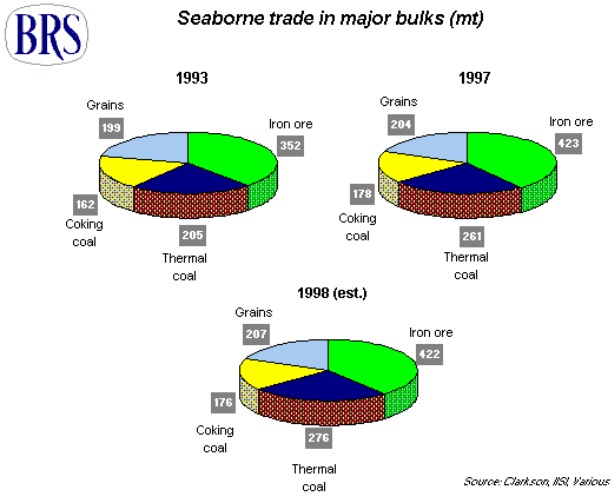
- **Bulk Carrier** *(Graneleiro)* – with/without equipment for self loading/unloading
- **Ore Carrier** (*Mineraleiro*) – with stowage factors of about 0.34 – 0.51 m3/t
- **Cement Carrier** (*Cimenteiro*) - with stowage factors of about 0.79 – 0.83 m3/t
- **Great Lakes** – ships that operate in the region of the Great Lakes, between the EUA and Canada, that are limited by the maximum width of the St. Lawrence Canal (22.80 m); characterized by being self-unloaders (buckets/conveyors), having a large number of cargo holds and hatches and with a deadweight ranging about 26,000 – 38,000 t

## Combined Carriers

- **OBO Ships** (*ore/bulk/oil*), for the carriage of solid and liquid bulk cargo
- **ConBulkers** (*container/bulk*), for the carriage of containers and bulk cargo, generally provided with wide hatches and lifting equipment



## Distribution of the Types of Cargo



## Typical Sizes

- **Small** – DW < 10,000 t
- **Handysize** – 10,000 t < DW < 35,000 t
- **Handymax** – 35,000 t < DW < 50,000 t
- **Supramax** – 50,000 t ≤ DW < 60,000 t
- **Panamax** – B ≤ 32.24 m, 60,000 < DW < 80,000 t
- **Capesize** – ships larger than Panamax or Suezmax (they can not cross the canals), and that use the route of Cape Horn or the route of the Cape of Good Hope to sail between oceans, with 80,000 t < DW < 200,000 t
- **Very Large Bulk Carrier** – DW > 200,000 t



## Special Sub-Classes

- **Kamsarmax**: ~82,000 dwt Panamax with increased LOA = 229 m (for Port Kamsar in Equatorial Guinea)
- **Dunkirkmax**: ~175,000 dwt large Capesize with max LOA = 289 m and max. B = 45 m (for the French port's eastern harbour lock at Dunkirk)
- **Newcastlemax**: ~185,000 dwt large Capesize with max. beam B = 47 m (for use of the Australian port of Newcastle)
- **Setouchmax**: ~205,000 dwt large Capesize (VLBC) with a low design draught of 16.10 m and max. LOA = 299.9 m (for ports in Setouch Sea in Japan)

# Analysis of the Fleet

## Dry bulk and combined carrier fleet

| | End 1993 | | January 1998 | |
|---|---|---|---|---|
| | Number | Dwt | Number | Dwt |
| Handy | 2542 | 61.2 | 2590 | 63.4 |
| Handymax | 1000 | 40.2 | 1276 | 53.4 |
| Panamax | 814 | 51.5 | 979 | 64.8 |
| Capes | 409 | 60.2 | 540 | 82.3 |
| Total Bulk | 4765 | 213.1 | 5385 | 263.9 |
| Combis | 266 | 29.7 | 174 | 18.2 |

Source: Various



# Ships on Order (2010)

**Dry Bulk Orderbook 24/09/2010** Number of ships

| | 2010 (deliv.) | 2010 | 2011 | 2012 | 2013 | 2014 | 2015+ | Total on order |
|---|---|---|---|---|---|---|---|---|
| VLOC | 13 | 11 | 42 | 39 | 11 | 1 | 0 | **104** |
| Cape | 128 | 85 | 235 | 95 | 34 | 3 | 1 | **453** |
| Small Cape | 58 | 52 | 167 | 62 | 13 | 0 | 0 | **294** |
| Panamax | 64 | 96 | 249 | 253 | 66 | 9 | 0 | **673** |
| Supramax | 213 | 196 | 341 | 201 | 38 | 1 | 0 | **777** |
| Handysize | 159 | 157 | 295 | 147 | 30 | 6 | 0 | **635** |
| **Total** | **635** | **597** | **1329** | **797** | **192** | **20** | **1** | **2936** |

(Source: BRS)

## Typical Prices of New Ships

| | Price [Million US$] |
|---|---|
| Handysize | |
| Handymax | 18.5 (*) |
| Supramax | |
| Panamax | 21.0 (*) |
| Capesize | 35.0 (*) |

Sources: (*) Fearnleys Nov. 2002



## Types and Properties of Grain Cargo

| **Cereals** | **Spec.Weight [t/m$^3$]** | **Angle of Rest [graus]** |
|---|---|---|
| Cevada (*barley*) | 0.645 | 46 |
| Milho (*corn*) | 0.710 | 21 |
| Linhaça (*linseed*) | 0.645 | 21 |
| Aveia (*oats*) | 0.516 | 21 |
| Arroz (*rice*) | 0.773 | 20 |
| Centeio (*rye*) | 0.750 | 32 |
| Sem. de Açafrão (*safflower seed*) | 0.530 | 28 |
| Sorgo (*sorghum*) | 0.735 | 31 |
| Soja (*soybeams*) | 0.722 | 22 |
| Trigo (*wheat*) | 0.800 | 23 |

## Types of Ore

| | Spec.Weight [t/m$^3$] | Stowage Factor [ft$^3$/LT] |
|---|---|---|
| Minério de ferro (*iron ore*) | 2.392-2.990 | 12-15 |
| Grenalha de ferro | 0.598-2.392 | 15-60 |
| Carvão (*coal*) | 0.747-0.854 | 42-48 |
| Carvão mineral (*anthracite*) | 1.554 | |
| Fosfatos (*phosphates*) | 1.055-1.121 | 32-34 |
| Bauxite (*bauxite*) | 1.025-1.281 | 28-35 |
| | | |

**Notes:**
1 LT (long ton) = 2240 lb = 1.016 t  1 T (short ton) = 2000 lb = 0.907 t
1 lb (pound) = 0.454 kg



## Hull Structures – Class Notations

**Harmonized Notation from IACS (Jan. 2002)**

Recognizes three categories of bulk carriers:

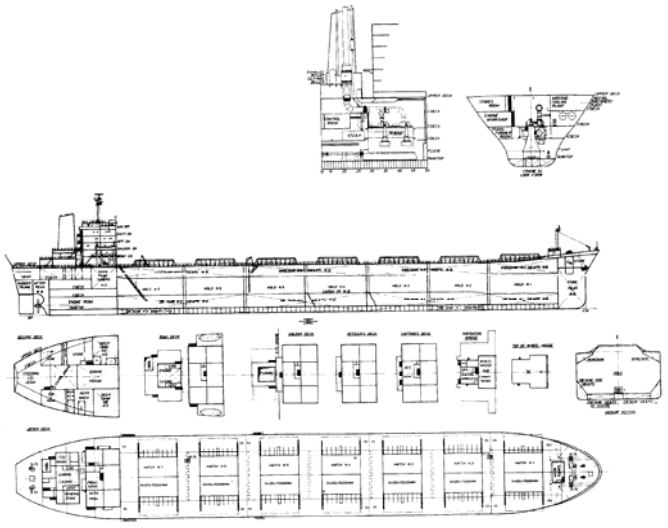
- **BC-I**: bulk carriers designed to carry dry bulk cargoes with a density < 1.0 ton/m3.
- **BC-II**: **BC-I**, plus carriage of cargoes with density ≥ 1.0 ton/m3 (with all cargo holds loaded).
- **BC-III**: **BC-II**, plus carriage of cargoes with density ≥ 1.0 ton/m3 (with specified holds empty at full draught).

## IACS Joint Bulker Project (JBP)

- BV, CCS, GL, KR, NK, RINA, RS
- Complete set of rules about structures of bulk carriers for SSS (*Short Sea Shipping*) and DSS (*Deep Sea Shipping*)
- Applicable to ships with:
  - Length ≥ 90 m
  - Single hull and double hull
- Entry into force on 1st January 2006
- Ref. Annex A



## Typical General Arrangement



# Bulk Carriers

Ships Gear less

Ships Geared

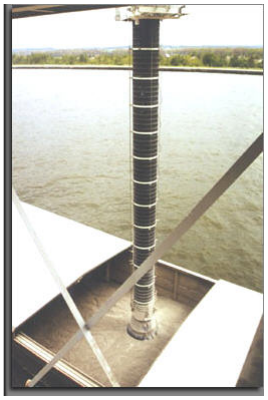


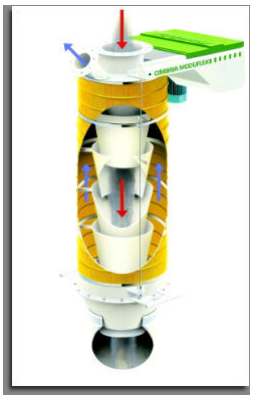
# Cement Carriers (1)

- The modern cement carriers are specialized ships that carry only this type of cargo
- Although still classified as bulk carriers, in their current configuration they ate ships totally closed, more similar to tankers

## Cement Carriers (2)

- They have complex cargo handling systems composed by:
  - A pneumatic system,
  - A system of conveyors and very often,
  - a tower on the main deck FWD



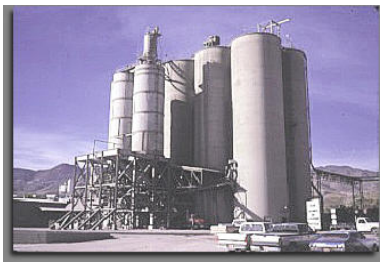




## Cement Carriers (3)

- Can be classified in *deep sea* and *short sea* (3,000 – 5,000 tdw)
- The ocean going ships have DW ~ 20,000 t, a size imposed
  - By the cargo loading ports
  - By the storage facilities available at the discharge terminals





## Cement Carriers (4)

- The cargo, although reasonably inert, is quite demanding and require conditions of absolute dryness inside the holds, which are totally enclosed
- Stability must be taking into consideration because the cargo behaves almost as a liquid, sliding to one side with the heeling of the ship.
- The cement powder is a serious problem that requires a cautious handling to avoid the passage of the cement in the air. The air exiting the cargo holds during loading is filtered and recirculated



## Cement Carriers (5)

- Mechanical systems are used to distribute the cargo inside the holds to guarantee that they can be completely filled
- Mechanical conveyors are one possible alternative to pneumatic blowers.
- Some systems have the capacity to load a ship at a rate of 1,500 t/h and of unloading it with a slightly lower rate.
- The ships are totally closed and capable of loading/unloading in any weather conditions

## Great Lakes and St. Lawrence Seaway




## Ships for the Great Lakes (1)

Typical Characteristics:

- Generally Self-Unloaders
- High number of cargo holds (11 ~ 15)

B < 22.80 m (St. Lawrence Seaway )

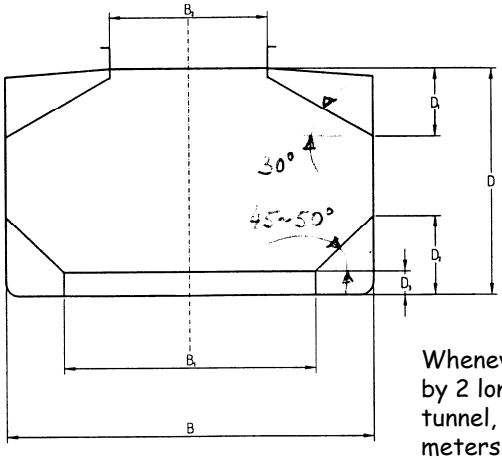
## Ships for the Great Lakes (2)

Typical characteristics:

- Second superstructure forward
- Very simplified hull forms
- Almost round bow, no bulb



## Typical Geometry of the Midship Section

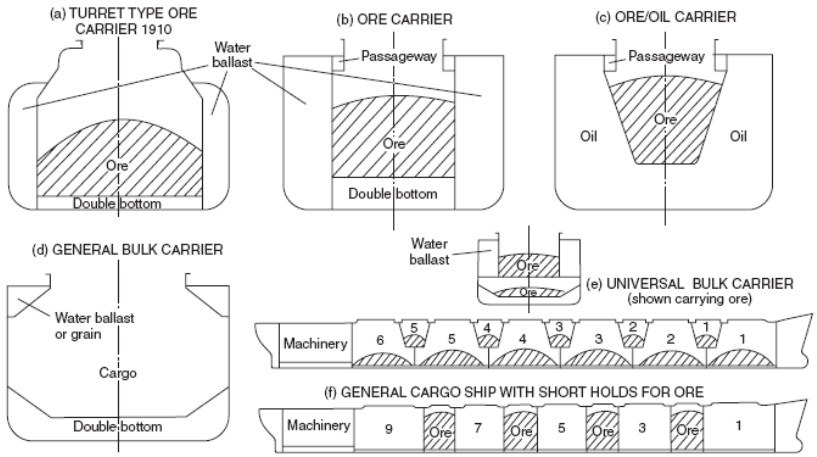



**Notes:**

- Breadth of the hatches ≅ 50% - 70% Breadth of the ship
- Angle of the *wing-tank* with the horizontal ≅ 30° > angle of rest of the cargo
- Central or asymmetric tunnel, for the passage of piping

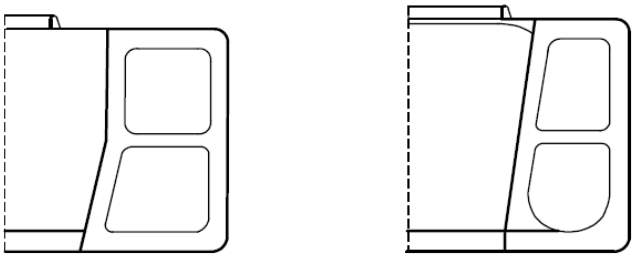
Whenever the vertical keel is replaced by 2 longitudinal girders to create a tunnel, these shall not be more than 3 meters apart (IACS)

# Cargo Zone - Typical Sections






# Typical Sections of Ore Carriers



- Notes:
  - Increased height of double-bottom in comparison to bulk carriers
  - Section of the cargo hold
- Objective:
  - Raise the position of the centre of gravity of the cargo

## Hold/Ballast Tank for Emergency Ballast

- The central cargo hold of bulk carriers can be used to carry additional ballast, in bad weather conditions
- This double functionality has implications at the level of the structural dimensioning of the:
  - Double-bottom
  - Bulkheads (AFT and FWD)
  - Hatch covers



## Hatch Covers Side-Rolling Type

- Bulk carriers and combined ships
- Hatch opening totally accessible
- Small interval between cargo hatches
- Hydraulic drive

## Loading/Unloading Equipment



## Accidents with Bulk Carriers (1)

- The question of the safety of bulk carriers was raised after the recognition of an unacceptable number of losses of lives, ships and cargoes that attained a peak during the years 1990/91:
  - during 1990, 20 ships and 94 lives were lost
  - during 1991, 24 ships and 154 lives were lost.
- The accident data base from IACS shows that:
  - from 1983 until June 1997 inclusive, 73 bulk carriers were lost due to known or probable structural failure.
  - at least more than 40 ships suffered severe damages.

## Accidents with Bulk Carriers (2)

- The investigation carried out by IACS shows that 70% of the total losses had **3 common factors**:
  - Ship with age > 18 years
  - Carrying heavy ore cargoes
  - Suffered water flooding of the cargo hold during bad weather conditions.



## Accidents with Bulk Carriers (3)

- The **main factors** that have contributed for the accidents were:
  - Corrosion
  - Existence of structural cracks in the cargo holds
- **Other factors** that may have contributed to the structural failure:
  - Occurrence of tensions above the admissible value due to incorrect loading
  - Physical damage of the shell structures due to unloading operations

## Accident of the MV "Derbyshire"

- The MV DERBYSHIRE, British flagged, owned and crewed, disappeared virtually without trace when the vessel was in the Typhoon Orchid, south of Japan, or about 9 September 1980.
- All on board – 42 crew members and two wives were lost.
- The DERBYSHIRE was a modern (built 1976), fully equipped and well managed ore-bulk-oil (OBO) combination carrier.
- At over 90,000 gross tons she was, and remains, the largest UK ship ever to have been lost at sea.

Source: http://www.mv-derbyshire.org.uk/press.htm

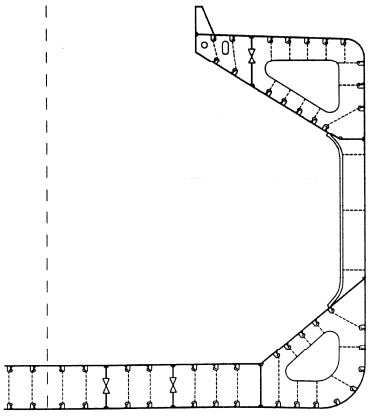


## Bibliography


- ISO 15401:2000 - Ships and marine technology – Bulk carriers – Construction quality of hull structure
- ISO 15402:2000 - Ships and marine technology – Bulk carriers – Repair quality of hull structure.
- BIMCO/MARTECMA Bulk Carrier Newbuilding Specification Guide

# Annex A. IACS Common Structural Rules for Bulk Carriers

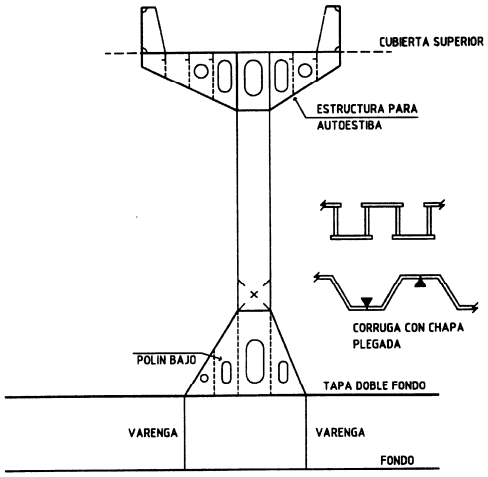
## Typical Midship Section



**Notes:**

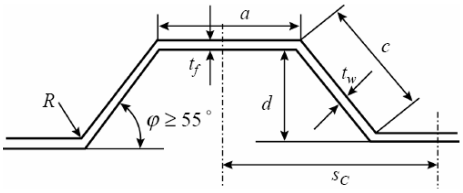
- Additional thickness in the top of double-bottom plates for cargoes unloaded by mechanical grabs.
- Double bottom structure with a web frame spacing (S)
  S < 3.5 m or S < 4s
- Classification HC (*heavy cargo*) for heavier cargo in alternate holds

# Typical Corrugated Bulkhead






# Scantlings of the Corrugated Plate (1)




The plates of the corrugated bulkheads are computed as a stiffened panel where the stiffener spacing, s, is determined from the geometry of the corrugation, by the expression:

s = MAX(a,c)

$$t = 28(s+0.7)\frac{(BT)^{0.25}}{\sqrt{R_{eH}}}$$

## Scantlings of the Corrugated Plate (2)

The inertia of the corrugation, in [cm3], is computed by the expression:

$$w = \left[\frac{d(3at_f + ct_w)}{6}\right] 10^{-3}$$

where:

$t_f$, $t_w$ : Net thickness of the plating of the corrugation, in mm, shown in Fig 28

$d$, $a$, $c$ : Dimensions of the corrugation, in mm, shown in Fig 28.

The net thickness of the web of ordinary stiffeners, in mm, is to be not less than the greater of:

- $t = 3.0 + 0.015L_2$
- 40% of the net offered thickness of the attached plating

and is to be less than 2 times the net offered thickness of the attached plating



## Scantlings of the Corrugated Plate (3)

The inertia of the corrugated plates, in [cm3], shall not be less than :

$$w = \frac{p_F s \ell^2}{16 \alpha \lambda_S R_Y} 10^3$$

- The values of the span (l) used to compute the corrugation are represented in the figure

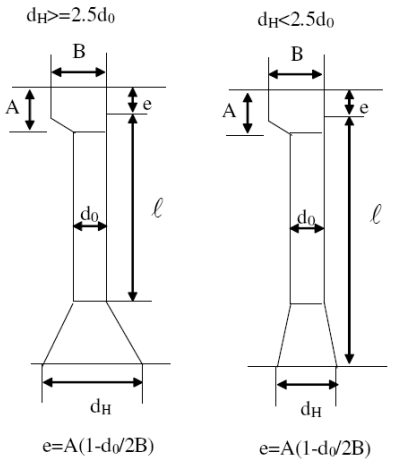



Figure 6: Measurement of $\ell$

## Number of Watertight Transv. Bulkheads

- All ships shall have at least the following transverse bulkheads:
  - Collision
  - Aft peak
  - Two bulkheads defining the boundaries of the engine room, in ships with engine room amidships
  - A bulkheads forward of the engine room when this is aft
  - In ships with an electric propulsion system, both the generators room and the engine room shall be bounded by watertight transverse bulkheads



## Additional Bulkheads

- In ships that do not have to comply with specific compartment rules, there shall be a number of transverse bulkheads not less than the values of the following table:

**Table 1: Number of bulkheads**

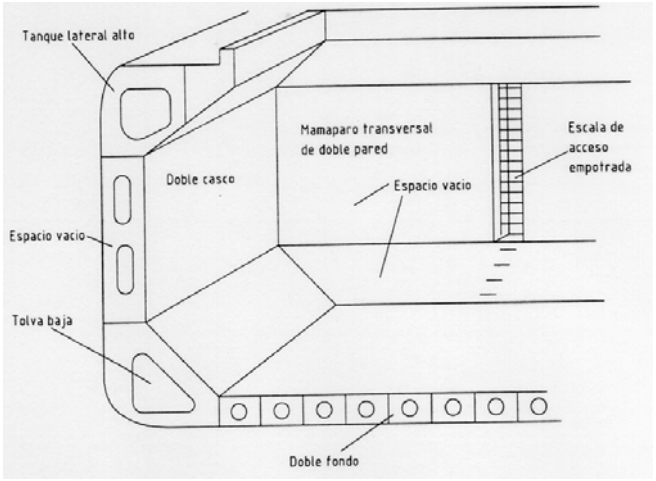
| Length (m) | Number of bulkheads for ships with aft machinery (1) | Numbers of bulkheads for other ships |
|---|---|---|
| $90 \le L < 105$ | 4 | 5 |
| $105 \le L < 120$ | 5 | 6 |
| $120 \le L < 145$ | 6 | 7 |
| $145 \le L < 165$ | 7 | 8 |
| $165 \le L < 190$ | 8 | 9 |
| $L \ge 190$ | To be defined on a case by case basis | |
| (1) After peak bulkhead and aft machinery bulkhead are the same. | | |

## Double Hull - IACS Unified Requirements

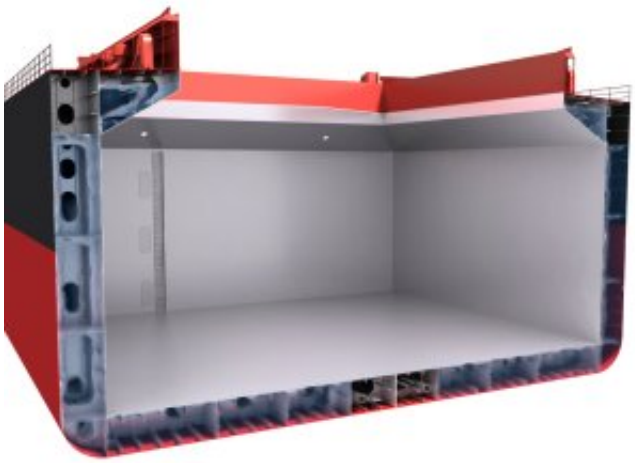
- The definition of bulk carriers with double-hull in which concerns the application of the *Unified Requirements* S17, S18 and S20 has been under discussion in IACS, and the following was decided:
  - Minimum width of the double-hull ≥ 760 mm, for the ship to be considered as double-hull.
  - The width shall also be enough to allow the access and inspection.
  - Hybrid bulkers, with some holds single skin and others with double skin, shall be considered as single skin ships.



## Double Hull Structure (proposal)



# Double Hull Structure

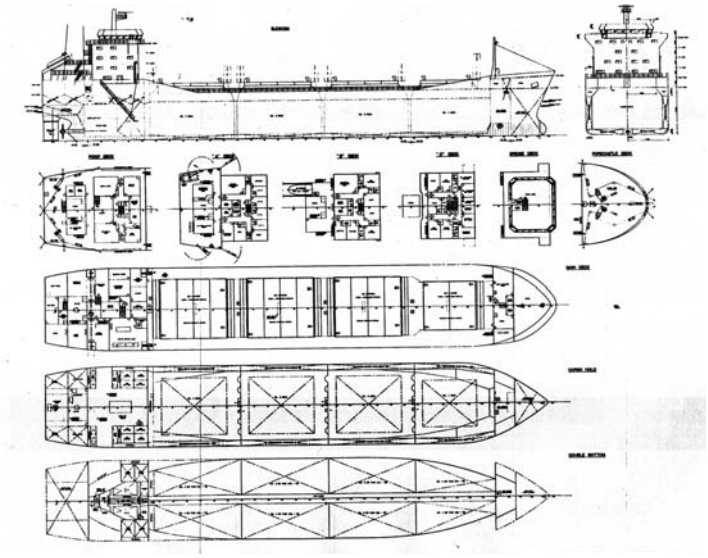




# Some Ships with Double Hull

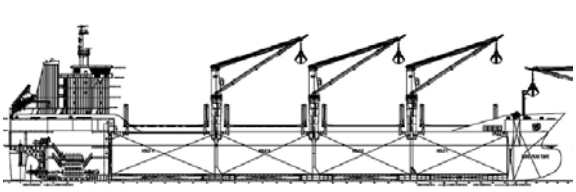
| | | BCT70 (Bulk) | BCT85 (OBO) |
|---|---|---|---|
| Length, overall | [m] | 228.60 | 246.00 |
| Length, between PP. | [m] | 224.60 | 240.00 |
| Breadth, molded | [m] | 32.24 | 32.24 |
| Depth | [m] | 19.00 | 19.00 |
| Draught, design | [m] | 12.50 | 12.50 |
| Draught, max. | [m] | 14.10 | 14.10 |
| Deadweight, at design draught | [t] | 63,000 | 66,000 |
| Deadweight, at max. Draught | [t] | 74,000 | 77,500 |
| Cargo Capacity (grain) | [m3] | 85,000 | 89,800 |
| No. Cargo holds | | 9 | 9 |
| Speed, service | [knots] | 13.8 | 13.6 |
| Potência propulsora (MCR) | [BHP] | 10,900 | 10,900 |

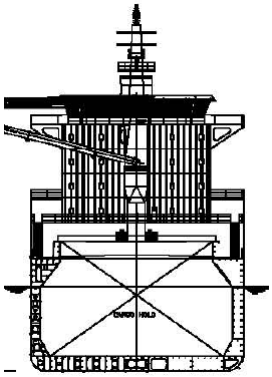
## General Arrangement of Double-Hull Ship with 18.500 tdw



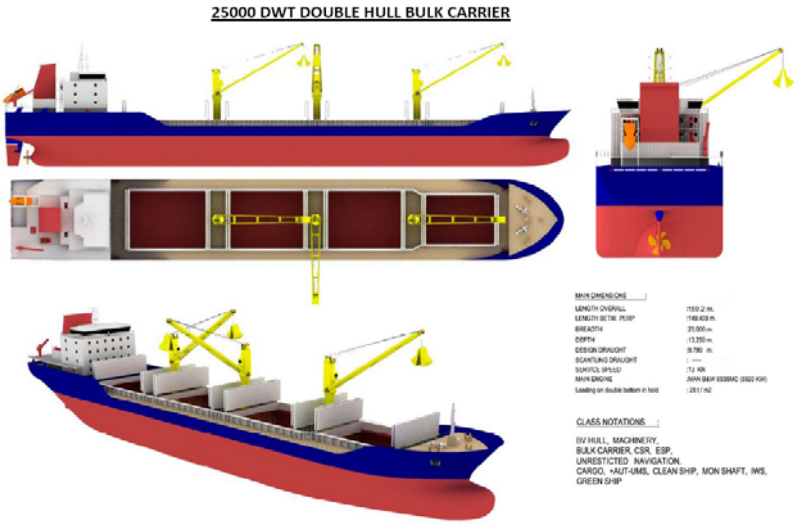
M.Ventura

## 25,000 DW Bulk Carrier





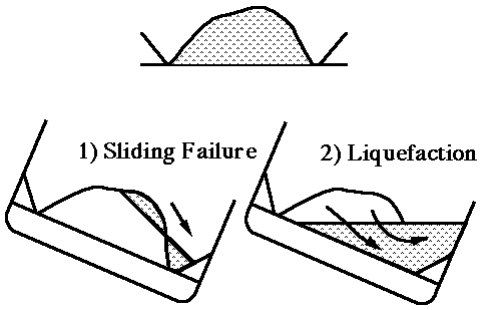
# 25,000 DWT Bulk Carrier




# Annex B. Additional Safety Measures for Bulk Carriers

SOLAS Chap. XII

## Heeling Moment due to Sliding of the Grain




- The stability must be checked taking into consideration the effects of the heeling moment die to the sliding of the grain in accordance with IMO (SOLAS Cap. XII)

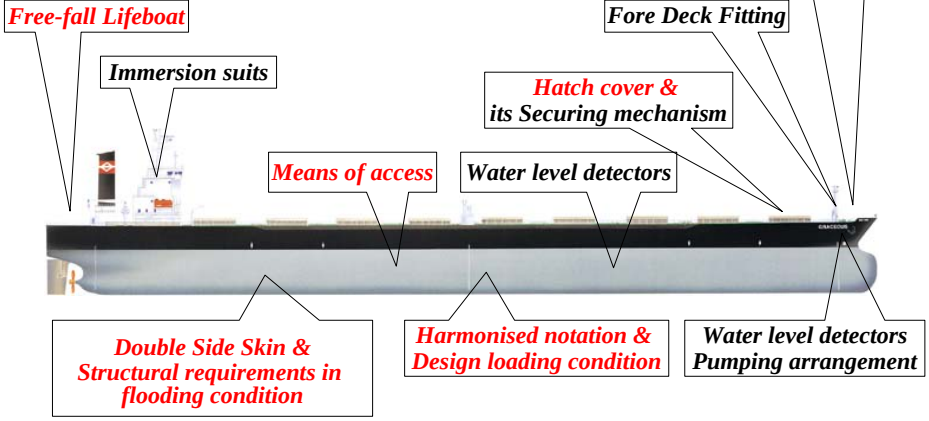


## Bilge of the Compartments

SOLAS Chap.XII requires for bulk carriers:

- Installation of water level indicators in cargo holds, ballast tanks and void spaces, equipped with alarms for max. levels (Regulation 12)
- The means to drain and pump bilge water from void spaces and from ballast tanks which have a part forward of the collision bulkhead, shall be able to be activated from a closed space and always accessible (Regulation 13)

## New Bulk Carriers




*In red:* *for New Bulk Carriers only*
*In black:* *for New & Existing Bulk Carriers*



## Bibliography


- IACS (2006), "Common Structural Rules for Bulk Carriers"

# Annex C. Loading Conditions on Bulk-Carriers

IMO MSC.1159 - Guidelines on the Provision of Stability-Related Information For Bulk Carriers

## Required Loading Conditions

1. Lightship
2. Docking
3. Fully loaded departure, with cargo homogeneously distributed throughout all cargo
4. Spaces and with full stores and fuel
5. Fully loaded arrival, with cargo homogeneously distributed throughout all cargo
6. Spaces and with 10% stores and fuel remaining
7. Ballast departure, without cargo but with full stores and fuel;
8. Ballast arrival, without cargo but with 10% stores and fuel remaining
9. Other departure and arrival conditions typical of the ship's intended service, such as:
   - Alternate hold loading, ore loading, deep ballast, etc. as applicable; and
   - Where appropriate, other conditions used for ballast water exchange.

## Links

- http://www.jbprules.com
- http://www.intercargo.org
- http://www.shipstructure.org/derby.shtml