



UNIVERSIDADE DA CORUÑA



Escola Politécnica Superior

**TRABAJO FIN DE GRADO  
CURSO 2019/20**

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*MEGAYATE DE LUJO*

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**Grado en Ingeniería Naval y Oceánica**

**Cuaderno 8  
CUADERNA MAESTRA**

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**GRADO EN INGENIERÍA NAVAL Y OCEÁNICA**  
**TRABAJO FIN DE GRADO**

*CURSO 2018-2019*

**PROYECTO NÚMERO 19-19**

**TIPO DE BUQUE:** MEGAYATE DE LUJO DE DESPLAZAMIENTO, DE 114 M DE ESLORA. TIPO WORLD GRAND EXPLORER

**CLASIFICACIÓN, COTA Y REGLAMENTOS DE APLICACIÓN:** BUQUE DE PASAJE, OCEÁNICO, SOLAS MARPOL MCA, ZONA ECA POLAR CODE B ICE. RUTAS DE LA ANTÁRTIDA PERIODOS RESTRINGIDOS Y ÁRTICO (VERANO). PANAMÁ.

**CARACTERÍSTICAS DE LA CARGA:** PERSONAS EN CRUCEROS TURÍSTICOS DE GRAN LUJO

**VELOCIDAD Y AUTONOMÍA:** 17 KNOTS AL 90% MCR Y 10% MM. AUTONOMÍA A 3500 MILLAS.

**SISTEMAS Y EQUIPOS DE CARGA / DESCARGA:** GRÚA A BORDO, JACUZZI, GARAJE PARA MOTOS DE AGUA, PISCINA

**PROPULSIÓN:** UNO O DOS MOTORES DIESEL

**TRIPULACIÓN Y PASAJE:** 50 PASAJEROS Y 42 TRIPULANTES.

**OTROS EQUIPOS E INSTALACIONES:** GARAJE, WATERMAKER x 2, STABILIZER TRAC, AIR CONDITIONING CRUISAIR, HELIPUERTO (NO CERTIFICADO). MARINA EN POPA Y LATERALES, BOTES TENDER.

Ferrol, diciembre 2019

ALUMNO/A: **Rosa Pérez Ramón**

TUTOR: **Raúl Villa Caro**

## 1 INTRODUCCIÓN

En este cuaderno se van a realizar todos los cálculos convenientes para definir la Cuaderna maestra del buque, tanto el dimensionamiento como el cálculo del módulo. Además, se elegirá el tipo de estructura y el tipo de quilla que tendrá el buque.

El objetivo es analizar el comportamiento estructural del buque y definir las cargas a las que será sometida la estructura durante el periodo de vida del buque.

Como primer paso, se va a definir el tipo de estructura y las particularidades de este tipo de buques. Se va a continuar con la obtención de los escantillones de los elementos estructurales siguiendo el reglamento de la Sociedad de Clasificación, Lloyd's Register. La definición de la estructura se hará siguiendo también la Sociedad de Clasificación.

Normalmente los yates se construyen con una configuración de materiales de acero para el casco y aluminio para la superestructura; aunque en la actualidad la tendencia es hacer estos tipos de buques completamente de aluminio.

El material que se empleará en la estructura es acero de alta resistencia, todo el casco será de este material, así como la superestructura, ya que el buque está diseñado para la Zona Eca Polar según las RPA. Por ello la parte expuesta al hielo se hará de acero de alta resistencia.

Como base para comenzar los cálculos, se utilizarán las dimensiones principales obtenidas en el Cuaderno 1: "Dimensionamiento Preliminar y Elección de la Cifra de Mérito":

L (M)	B (M)	D (M)	T (M)
111,15	21,63	8,77	5,17

Definición de buque de pasaje según la sociedad de clasificación. (Parte 3, Capítulo 1, Sección 6).

### 6.7 Passenger ship

6.7.1 A passenger ship is a ship which carries more than 12 passengers.

Definición de Yate de pasaje según la sociedad de clasificación. (Parte 4, Capítulo 2, Sección 1).

(f) A **passenger yacht** is defined as a yacht that is specially designed and constructed in accordance with National Administration requirements for passenger yachts.

## 2 DEFINICIÓN DE LA ESTRUCTURA

En este apartado vamos a definir los tipos de estructuras que existen, para seleccionar uno de los para el buque proyecto:

- . Estructura Transversal
- . Estructura Longitudinal
- . Estructura Mixta

La diferencia entre la estructura longitudinal y la transversal es la dirección en la cual estarán situados los refuerzos, para que absorban las tensiones en sentido longitudinal o transversal.

Generalmente, la estructura transversal se utiliza en buques de poca eslora, esto se debe a que conforme se aumenta la eslora, aumentan las cargas en sentido longitudinal. Este tipo de estructura se utiliza también en buques con forma, por ello, a pesar de que la eslora es de 111,15 m, se va a elegir una estructura transversal.

### 3 DISEÑO CONCEPTUAL DE LA CUADERNA MAESTRA

Se va a proceder a realizar todas las descripciones de la estructura antes de comenzar con el cálculo del escantillonado.

#### 3.1 QUILLA

El túnel de quilla (duct kell) se utiliza en algunos buques, para poder pasar por ella los tubos y cables del doble fondo. El túnel de quilla suele tener la siguiente disposición:

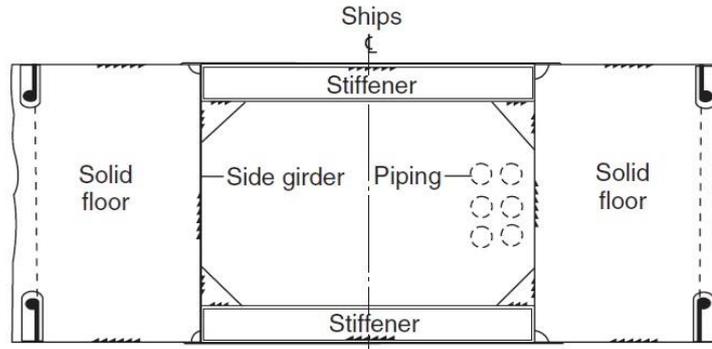
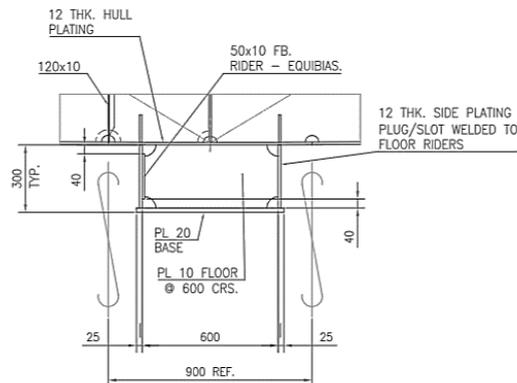


Imagen 1: Tunel de quilla

El túnel de quilla se utiliza generalmente en los buques de este tipo, en este buque proyecto no se instalará este tipo de estructura, en su lugar irá un cajón de quilla (box kell) que es un tipo de estructura que se utiliza para la varada.

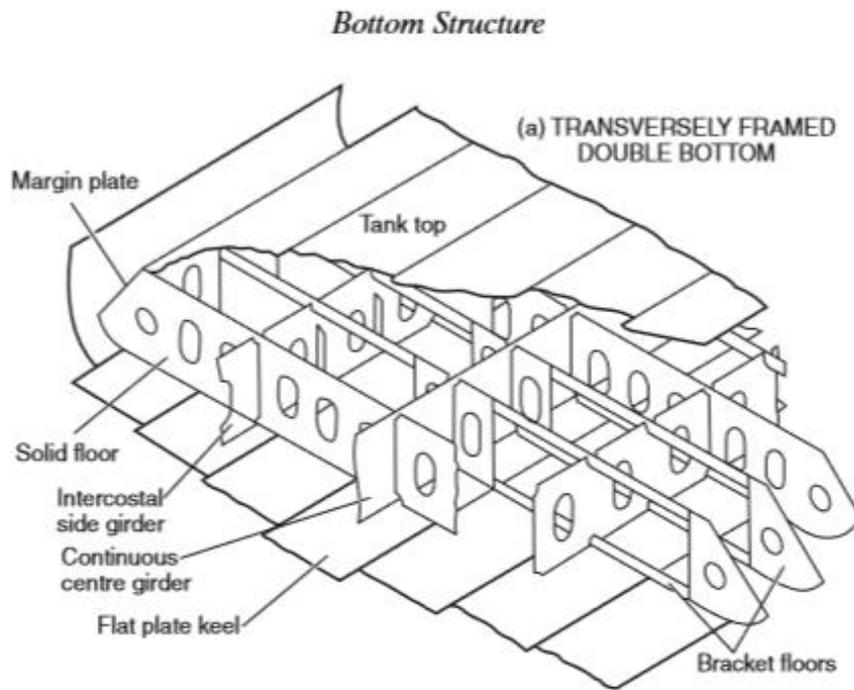


DETAIL IWO. KEEL BOX.  
DETALLE QUILLA DE CAJON

Imagen 2: Box Kell

### 3.2 DOBLE FONDO

El buque tendrá una estructura transversal, como ya se mencionó anteriormente, por ello, el doble fondo tendrá una estructura transversal como muestra la imagen:



*Imagen 3: Doble Fondo*

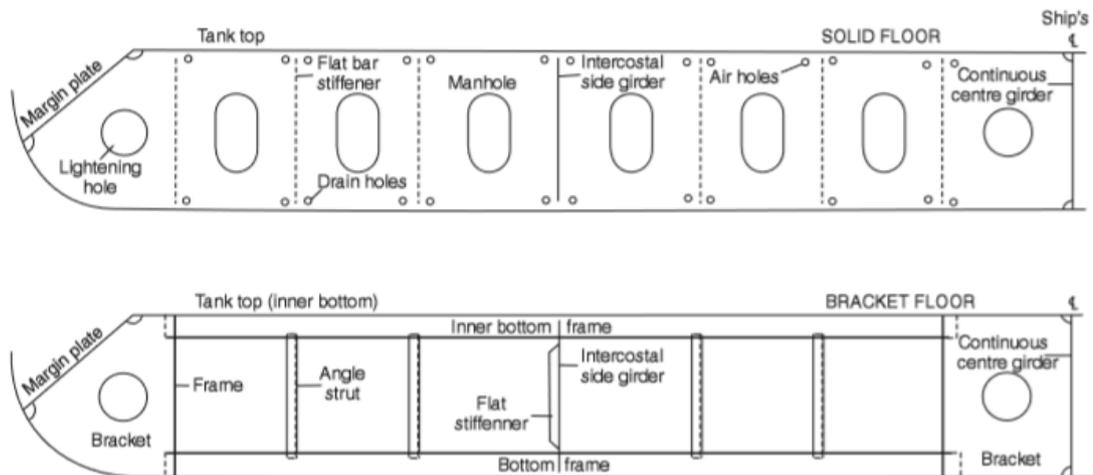


FIGURE 16.4 Transversely framed double bottom construction

*Imagen 4: Doble Fondo*

### 3.3 COSTADO

La estructura del costado será transversal, como muestra la imagen.

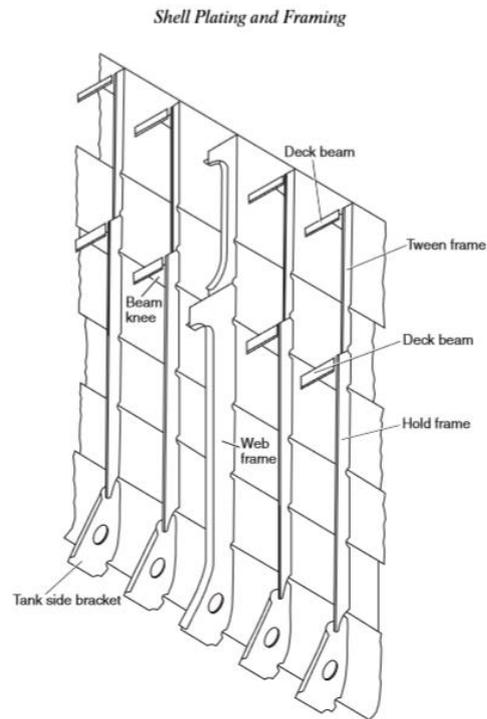
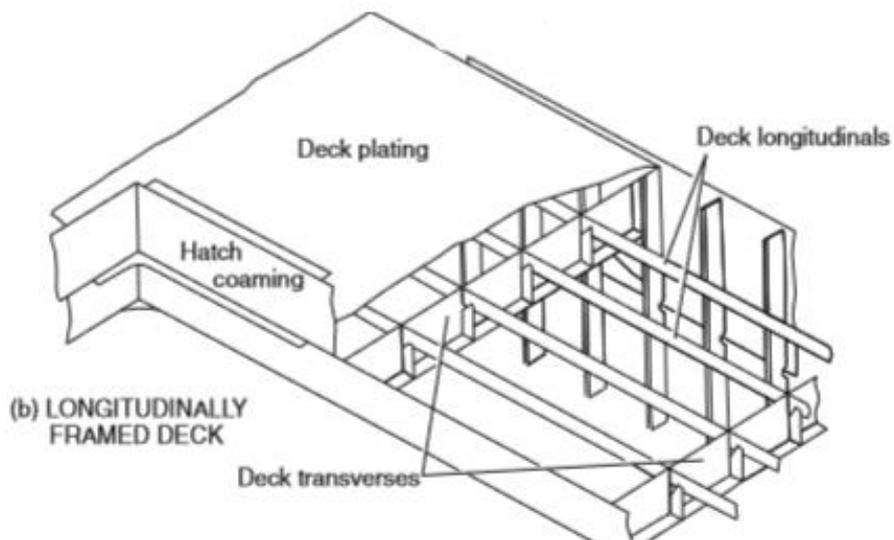


FIGURE 17.2 Side shell with transverse framing

*Imagen 5: Costado*

### 3.4 CUBIERTA

La estructura de la cubierta será longitudinal, como muestra la imagen:



*Imagen 6: Cubierta*

### 3.5 PLANO REFERENCIA CUADERNA MAESTRA

Se ha tomado como referencia el plano de un buque cuya estructura se asemeja a la requerida para este buque proyecto:

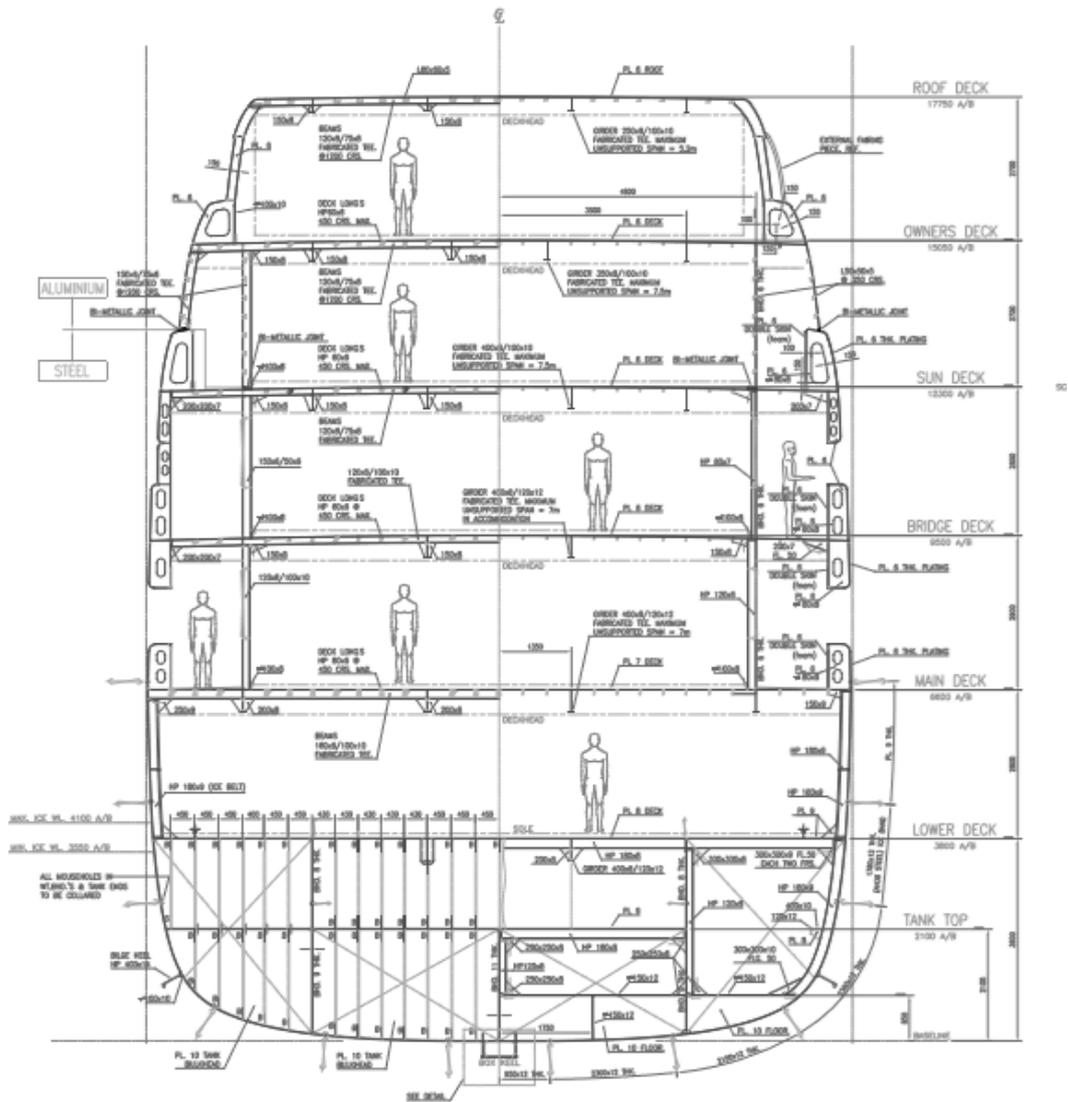


Imagen 7: Cuaderna Maestra Referencia

Se muestra a continuación una tabla con las alturas a las que se encuentran las cubiertas en el buque proyecto. Para visualizar la disposición de la cuaderna maestra final, ver el apartado 7 de este cuaderno.

Deck 1	2,80 m
Deck 2	5,17 m
Deck 3	8,17 m
Deck 4	11,17 m
Deck 5	14,17 m
Deck 6	17,17 m
Roof	20,87 m

## 4 ESCANTILLONADO LOCAL DE LA CUADERNA MAESTRA

### 4.1 DIMENSIONES

Se han obtenido las dimensiones principales según el reglamento de la Sociedad de Clasificación Lloyd's Register, Julio 2019.

· **ESLORA DE ESCANTILLONADO:**

La eslora de escantillonado es la distancia en metros, medida sobre la flotación para el calado de escantillonado. Esta distancia no deberá ser menor del máximo entre el 96% de la eslora total para el calado de escantillonado y la eslora entre perpendiculares del buque, y tampoco debe exceder el 97% de la eslora total para el calado de escantillonado, tal como se refleja en la fórmula:

$$L = \max \left\{ \begin{array}{l} 0.96 \cdot L_{WL} \\ \min \left\{ \begin{array}{l} 0.97 \cdot L_{WL} \\ L_{PP} \end{array} \right. \end{array} \right.$$

La eslora de escantillonado será igual a:

$$0,96L_{wl} = 105,74 \text{ m}$$

$$0,97L_{wl} = 106,84 \text{ m} = L \text{ escantillonado}$$

$$L_{pp} = 111,15 \text{ m}$$

· **CALADO DE ESCANTILLONADO:**

Máximo Calado al que puede navegar el buque. Determinado por el francobordo mínimo de verano.

$$T \text{ escantillonado} = 5 \text{ m}$$

· **MANGA DE ESCANTILLONADO:**

Manga máxima al calado de escantillonado.

$$B \text{ escantillonado} = 21,654 \text{ m}$$

· **PUNTAL DE ESCANTILLONADO:**

Distancia vertical desde la línea base a la cubierta continua más alta media en el centro del buque.

$$D \text{ escantillonado} = 11,17 \text{ m}$$

· **PUNTAL DE ESCANTILLONADO:**

Distancia vertical desde la línea base a la cubierta continua más alta media en el centro del buque.

$$D \text{ escantillonado} = 11,17 \text{ m}$$

· **PUNTAL DE ESCANTILLONADO:**

**COEFICIENTE DE BLOQUE AL CALADO:**

$$Cb = \frac{6106}{21,654 \cdot 106,84 \cdot 1,025 \cdot 5} = 0,51$$

Se muestra a continuación los datos de las hidrostáticas:

	Measurement	Value	Units
1	Displacement	6106	t
2	Volume (displaced)	5956,850	m <sup>3</sup>
3	Draft Amidships	5,170	m
4	Immersed depth	5,000	m
5	WL Length	110,145	m
6	Beam max extents on WL	21,654	m
7	Wetted Area	2347,287	m <sup>2</sup>
8	Max sect. area	91,359	m <sup>2</sup>
9	Waterpl. Area	1884,881	m <sup>2</sup>
10	Prismatic coeff. (Cp)	0,592	
11	Block coeff. (Cb)	0,500	
12	Max Sect. area coeff. (Cm)	0,855	
13	Waterpl. area coeff. (Cwp)	0,790	
14	LCB length	53,970	from zero pt. (+ve fwd) m
15	LCF length	46,914	from zero pt. (+ve fwd) m
16	LCB %	48,999	from zero pt. (+ve fwd) % Lwl
17	LCF %	42,593	from zero pt. (+ve fwd) % Lwl
18	KB	3,313	m
19	KG fluid	0,000	m
20	BMt	10,167	m
21	BML	231,466	m
22	GMt corrected	13,480	m
23	GML	234,779	m
24	KMt	13,480	m
25	KML	234,779	m
26	Immersion (TPc)	19,320	tonne/cm
27	MTc	130,319	tonne.m
28	RM at 1deg = GMt.Disp.sin(1)	1436,407	tonne.m
29	Length:Beam ratio	5,087	
30	Beam:Draft ratio	4,331	
31	Length:Vol <sup>0.333</sup> ratio	6,076	
32	Precision	Highest	213 stations

Imagen 8: Captura Pantalla de las Hidrostáticas

## 4.2 CLARAS ENTRE CUADERNAS

El buque tiene la siguiente disposición de cuadernas:  
 . De popa hasta proa:  $s = 700 \text{ mm}$ .

A su vez se considera:  
 . Varengas dispuestas cada 3 claras de cuaderna.

## 4.3 NÚMERO DE EQUIPO

A continuación, se calcula el número de equipo siguiendo la regla de la SSCC (para ver el reglamento, consultar Anexo II de este cuaderno).

$$EN = \Delta^{\frac{2}{3}} + 2BH + \frac{A}{10}$$

$$B = 21,63 \text{ m}$$

$$\Delta = 6106 \text{ t}$$

$$A = 820 \text{ m}^2$$

$$H = 17,32 \text{ m}$$

$$EN = 1165,20$$

## 4.4 MATERIAL

Se ha elegido acero para la construcción del buque. El acero con un límite de elasticidad de  $235 \text{ N/mm}^2$  se considera "mild Steel".

### 1.2 Steel

1.2.1 Steel having a specified minimum yield stress of  $235 \text{ N/mm}^2$  is regarded as mild steel. Steel having a higher specified minimum yield stress is regarded as higher tensile steel.

1.2.2 For the determination of the hull girder section modulus, where higher tensile steel is used, a higher tensile steel factor,  $k_L$ , is given in *Table 2.1.1 Values of  $k_L$* .

Specified minimum yield stress in $\text{N/mm}^2$	$k_L$
235	1,0
265	0,92
315	0,78
355	0,72
390	0,68 (0,66 see Note 3)
460 see Note 4	0,62 see Note 4

Note 1. Intermediate values by linear interpolation.

Note 2. For the purpose of calculating hull moment of inertia as specified in *Pt 3, Ch 4, 5.8 Hull moment of inertia 5.8.1*,  $k_L = 1,0$ .

Note 3. A  $k_L$  factor of 0,66 may be applied to all ship types provided that a fatigue assessment is carried out as required by *Pt 3, Ch 2, 1.2 Steel 1.2.4*.

Note 4. Grade only applies to thickness above 50 mm for upper deck, hatch coamings, shear strake, uppermost strake of longitudinal bulkhead and other longitudinal strength members in way of the above structures of container ships. The requirements specified in *Ch 3, 3 Higher strength steels for ship and other structural applications* of the Rules for Materials apply, see *Pt 3, Ch 2, 1.2 Steel 1.2.4* and *Pt 3, Ch 2, 1.2 Steel 1.2.5*.

*Imagen 9: Reglamento de la Sociedad de Clasificación Parte 3, Capítulo 2, Sección 1.*

Se va a utilizar Acero de 235 N/mm<sup>2</sup> K<sub>L</sub> = 1 Grado A. Este buque puede operar en áreas con bajas temperaturas del aire (por debajo de los -10°) durante la temporada de invierno. Por ello se utilizará la Clase I AH36 de 355 N/mm<sup>2</sup> para las zonas expuestas a bajas temperaturas (K<sub>L</sub> = 0,72).

En la Parte 3, Capítulo 2, Sección 2 del Reglamento Lloyd's Register, se encuentra una tabla que describe los materiales de Clase I que serán expuestos aire a baja temperatura. Ésta se muestra a continuación:

Table 2.2.6 Materials for Class I for low air temperatures

Thickness, mm	Design air temperature									
	-11°C to -15°C		-16°C to -25°C		-26°C to -35°C		-36°C to -45°C		-46°C to -55°C	
	MS	HT	MS	HT	MS	HT	MS	HT	MS	HT
$t \leq 10$	A	AH	A	AH	B	AH	D	DH	D	DH
$10 < t \leq 15$	A	AH	B	AH	D	DH	D	DH	D	DH
$15 < t \leq 20$	A	AH	B	AH	D	DH	D	DH	E	EH
$20 < t \leq 25$	B	AH	D	DH	D	DH	D	DH	E	EH
$25 < t \leq 30$	B	AH	D	DH	D	DH	E	EH	E	EH
$30 < t \leq 35$	D	DH	D	DH	D	DH	E	EH	E	EH
$35 < t \leq 45$	D	DH	D	DH	E	EH	E	EH	n/a	FH
$45 < t \leq 50$	D	DH	E	EH	E	EH	n/a	FH	n/a	FH

Note MS and HT are defined as Mild Steel and High Tensile Steel respectively.

## 4.5 DISEÑO DE LA ESTRUCTURA

En este apartado se va a mostrar el diseño esquemático del desglose de la estructura en regiones del buque proyecto.

“Fore end Region”: se considera la región a proa de la zona media del buque (0,4L).

“Aft end Region”: se considera la región a popa de la zona media del buque (0,4L).

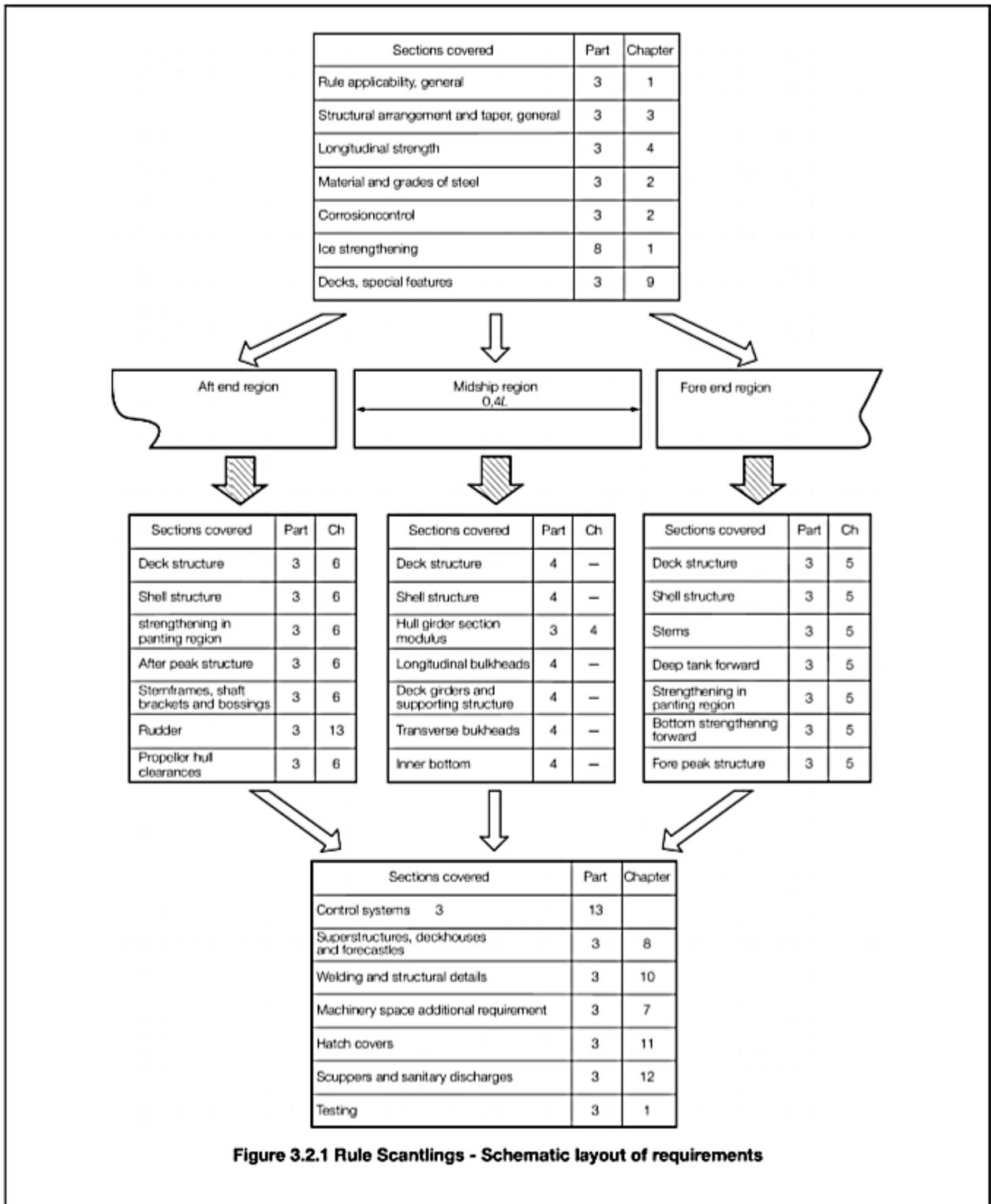


Imagen 10: Reglamento Loyd's Register Parte 3, Capítulo 3, Sección 2

## 4.6 MAMPAROS ESTANCOS

Todos los barcos deben tener un mamparo de colisión y un mamparo hermético en cada extremo del espacio de la cámara de máquinas. Para el buque proyecto, se instalarán además mamparos adicionales para que el número total de mamparos se ajuste al de la tabla siguiente:

Table 3.4.1 Total number of bulkheads

Length, $L$ , in metres	Total number of bulkheads	
	Machinery amidships	Machinery aft, see Note
$\leq 65$	4	3
$> 65 \leq 85$	4	4
$> 85 \leq 90$	5	5
$> 90 \leq 105$	5	5
$> 105 \leq 115$	6	5
$> 115 \leq 125$	6	6
$> 125 \leq 145$	7	6
$> 145 \leq 165$	8	7
$> 165 \leq 190$	9	8
$> 190$	To be considered individually	

Note With after peak bulkhead forming after boundary of machinery space.

Imagen 11: Parte 3, Capítulo 3, Sección 4 del Reglamento de la Sociedad de Clasificación

Para el caso de la eslora de este buque proyecto, la configuración óptima será de 6 mamparos estancos. Los planos se encuentran en el "Cuaderno 7: Disposición General".

Se van a tener en cuenta las siguientes consideraciones:

- La situación de los mamparos estancos coincidirá con sus respectivas cuadernas.
- Por lo dicho anteriormente, será necesario definir la separación entre cuadernas. El valor estándar dentro de estos barcos de estas dimensiones oscila entre 500mm y 700mm. Pero como se estableció anteriormente, el espaciado entre cuadernas será de 700 mm.

## 4.7 MAMPARO DE COLISIÓN

Se instalará un mamparo de colisión que será hermético hasta la cubierta más alta continua. Este mamparo se dimensionará según indica la Sociedad de Clasificación en la Parte 3, Capítulo 3, Sección 4 en el Reglamento.

Distancia mínima desde la perpendicular de proa:

$$0,05L = 5,56$$

Distancia máxima desde la perpendicular de proa:

$$0,08L = 8,89$$

$$0,05L + 3 = 8,56$$

Consideración Práctica, se ha decidido utilizar una distancia de 6,4m.

**4.2 Collision bulkhead**

4.2.1 A collision bulkhead shall be fitted which shall be watertight up to the bulkhead deck. This bulkhead shall be located at a distance from the forward side of the stem, on the waterline on which  $L_L$  is measured, of not less than  $0,05L_L$  or 10 m, whichever is the less, and, except as may be permitted by the Administration, not more than  $0,08L_L$  or  $0,05L_L + 3$  m, whichever is the greater.

4.2.2 Where any part of the ship below the waterline extends forward of the forward side of the stem, on the waterline on which  $L_L$  is measured, e.g. a bulbous bow, the distances stipulated in *Pt 3, Ch 3, 4.2 Collision bulkhead 4.2.1* are to be measured from a point either:

- (a) at the mid-length of such extension;
- (b) at a distance  $0,015L_L$  forward of the forward side of the stem, on the waterline on which  $L_L$  is measured; or
- (c) at a distance 3 m forward of the forward side of the stem, on the waterline on which  $L_L$  is measured, whichever is the least.

4.2.3 No doors, manholes, access openings, ventilation ducts or any other openings shall be fitted in the collision bulkhead below the bulkhead deck.

**4.4 Height of bulkheads**

4.4.1 The collision bulkhead is normally to extend to the uppermost continuous deck or, in the case of ships with combined bridge and forecastle or a long superstructure which includes a forecastle, to the superstructure deck. However, if a ship is fitted with more than one complete superstructure deck, the collision bulkhead may be terminated at the deck next above the freeboard deck. Where the collision bulkhead extends above the freeboard deck, the extension need only be to weathertight standards.

## 5 CÁLCULO ESPESORES MÍNIMOS

Este buque proyecto se va a clasificar como 100A1 yate de pasajeros. Se muestra nuevamente, el esquema estructural en el que se divide el buque proyecto:

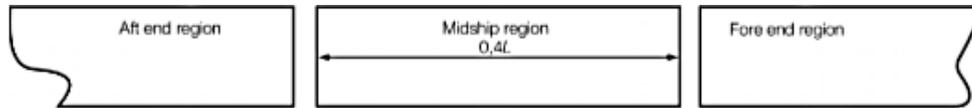


Imagen 12: Reglamento Lloyd's Register Parte 3, Capítulo 3, Sección 2

### 5.1 DECK STRUCTURE

En este apartado, se realizará el cálculo de la estructura de la cubierta, la cual será un tipo de estructura longitudinal. Para ello se seguirá el reglamento de la Sociedad de Clasificación Lloyd's Register (Julio 2019) Parte 4, Capítulo 1, Sección 4.

#### 5.1.1 DECK PLATING

El espesor de la cubierta a la intemperie "**weather Deck**" debe tomar el valor mayor de las siguientes expresiones:

$$t = 0,001 \cdot s_1 \cdot (0,059 \cdot L_1 + 7) \cdot \sqrt{\frac{FD}{kL}}$$

$$t = 9,31 \text{ mm} \approx 9,5 \text{ mm}$$

$$t = 0,00083 \cdot s_1 \cdot \sqrt{Lk} + 2,5$$

$$t = 8,51 \text{ mm} \approx 8,5 \text{ mm}$$

Siendo,

$S_1$	Separación entre refuerzos	700 mm
$L_1$	Eslora del reglamento	106,84 m
$FD$		1
$kL$	Factor de acero	1
$L$	Eslora del reglamento	106,84 m
$k$	Factor acero	1

El espesor de la cubierta a la intemperie será de 9,5 mm. Éste se deberá incrementar un 20% en los extremos de la cubierta y superestructura.

A continuación se va a calcular el espesor del resto de cubiertas, mediante la siguiente expresión:

$$t = 0,012 \cdot s_1 \cdot \sqrt{k}$$

$$t = 8,5 \text{ mm}$$

El espesor de la cubierta "**Lower Deck**" en la zona central del buque deberá cumplir con la expresión de la tabla 1.4.2 Lower Deck Plating del reglamento de la sociedad de Clasificación (Ver anexo V) que hace referencia a la cubierta que corresponde con el techo de la zona de tanques:

$$t = 0,004 \cdot s \cdot f \cdot \sqrt{\rho \cdot k \cdot \frac{h4}{1,025}} + K1$$

$$t = 0,004 \cdot 700 \cdot 0,97 \cdot \sqrt{\frac{1,025 \cdot 1 \cdot 6,4}{1,025}} + 3,5$$

$$t = 9,85 \text{ mm} \approx 10 \text{ mm}$$

Se va a calcular el espesor también como techo de un tanque:

$$t = 0,004 \cdot f \cdot s \cdot \sqrt{\frac{\rho \cdot k \cdot h4}{1,025}} + k2$$

$$t = 0,004 \cdot 0,97 \cdot 700 \cdot \sqrt{1,025 \cdot 1 \cdot \frac{5,47}{1,025}} + 3,5$$

$$t = 8,85 \text{ mm} \approx 9 \text{ mm}$$

Siendo,

<i>F</i>		0,97
<i>s</i>	Separación de refuerzos	700 mm
<i>k</i>	Factor del acero	1
<i>H4</i>	Altura reglamento	5,17 m
<i>K2</i>	Constante para techo de tanque	3,5 mm
<i>rho</i>	densidad	No menor de 1,025

Según lo que dice el reglamento, se obtiene la altura H4 de la siguiente manera:

$$h4 = \left(\frac{2}{3}\right) \cdot H_{tanque} + 450 \text{ mm} + h_{cubiertaestanca} / 2$$

$$h4 = \frac{\left(\frac{2}{3}\right) \cdot 2,6 \text{ m} + 450 + 8,77 \text{ m}}{2} = 5,47 \text{ m}$$

La cubierta Lower Deck, por tanto, tendrá un espesor de 10,5 mm.

En conclusión, se tienen los siguientes espesores para las cubiertas:

	<i>t(mm)</i>
<i>Weather Deck</i>	9,5
<i>Normal Deck</i>	8,5
<i>Lower Deck</i>	10

### 5.1.2 DECK STIFFENING

A continuación vamos a proceder con el cálculo de **longitudinales**, para ello se va a utilizar la Tabla 1.4.4 que se encuentra en el Anexo V de este cuaderno.

$$Z = s \cdot k \cdot \frac{5,1 \cdot L1 + 25 \cdot h3 \cdot Le^2}{10000}$$

$$Z = 700 \cdot 1 \cdot \frac{5,1 \cdot 106,84 + 25 \cdot 1,2 \cdot 2,1^2}{10000}$$

$$Z = 47,40 \text{ cm}^3$$

Siendo,

<i>s</i>	Separación refuerzos	700 mm
<i>l</i>	Factor del acero	1
<i>L1</i>	Eslora reglamento	106,84 m
<i>H3</i>	Altura reglamento	1,2 m
<i>Le</i>	Luz de los refuerzos	2,1 m

Con este valor, se va a una tabla de Llantas de bulbo y se obtienen las dimensiones más adecuadas:

Dimensión Nominal	Width (mm)	Thickness (mm)	Height (mm)	Rodius (mm)
<b>120x6</b>	120	6	17	5

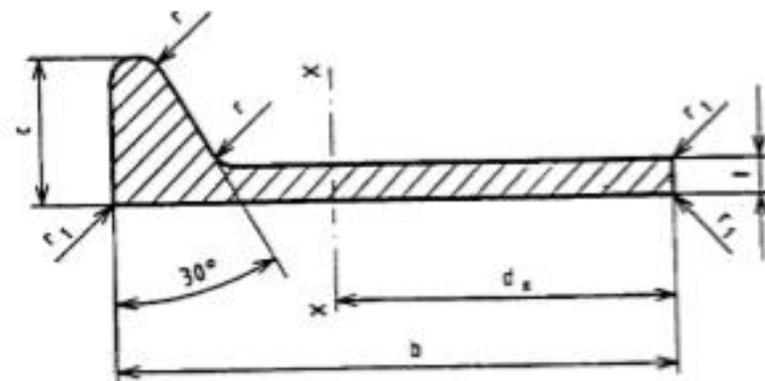


Imagen 13: Llanta de bulbo - (UAHE2001, 2001)

**Dimension range, weight/m and static values**

Width a mm	Thickness s mm	Height e mm	Radius r mm	Area A cm <sup>2</sup>	Weight kg/m	e mm	fx mm	Wx* cm <sup>3</sup>
60	4	13	3.5	3.58	2.81	382	12.2	13
	5	13	3.5	4.18	3.28	3.70	14.4	14
	6	13	3.5	4.78	3.75	3.62	16.4	16
80	5	14	4	5.40	4.24	4.89	33.8	23
	6	14	4	6.20	4.87	4.78	39.0	25
	7	14	4	7.00	5.50	4.69	43.3	27
100	6	15.5	4.5	7.74	6.08	5.98	76.1	38
	7	15.5	4.5	8.74	6.86	5.87	85.3	41
	8	15.5	4.5	9.74	7.65	5.78	94.3	45
120	6	17	5	9.31	7.31	7.20	133	54
	7	17	5	10.5	8.25	7.07	148	59
	8	17	5	11.7	9.19	6.96	164	63

## 5.2 SHELL ENVELOPE PLATING

El tipo de estructura de este buque en la zona del fondo es transversal, por ello, el casco debe ser reforzado con refuerzos longitudinales continuos o intercostales.

### 5.2.1 QUILLA

El área de la sección transversal y el grosor de las quillas de barra debe cumplir con los requisitos de la siguiente tabla:

**Table 1.5.1 Bar and plate keels**

Item and parameter	Requirement
(1) Bar keels:	
Cross-sectional area	$A = (1,8L - 16) \text{ cm}^2$
Thickness	$t = (0,6L + 8) \text{ mm}$
(2) Plate keels:	
Breadth	$b = 70B \text{ mm}$ but need not exceed 1800 mm and is not to be less than 750 mm

*Imagen 14: Reglamento Sociedad Clasificación Parte 4, Capítulo 1, Sección 5*

Por lo que las dimensiones de la quilla deben de ser:

$$A = (1,8L - 16)$$

$$A = 176,31 \text{ cm}^2$$

$$t = (0,6L + 8)$$

$$t = 72,10 \text{ mm}$$

Como se ha descrito anteriormente, se tendrá un cajón de quilla, que es un tipo de estructura que se utiliza para la varada. El reglamento no contempla que forme parte de la estructura, por ello se ha dimensionado como quilla de barra. Se muestra a continuación un ejemplo:

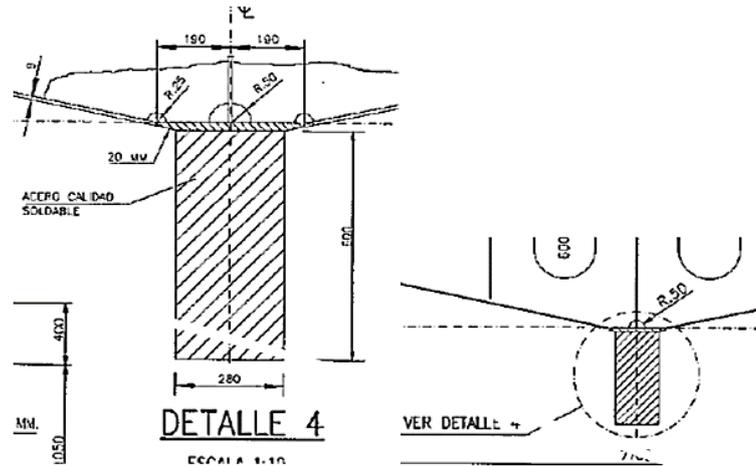


Imagen 14: Box Kell

### 5.2.2 BOTTOM SHELL BILGE

En la región intermedia, el espesor del casco, hasta la parte superior del pantoque será el requerido para poder proporcionar el módulo requerido según la parte 3, capítulo 4, Sección 5 Resistencia a la flexión del Caco del Reglamento. Tampoco podrá ser inferior a los valores mínimos dados en la “Tabla 1.5.2 Bottom Shell and Bilge Plating” que se mostrará a continuación.

Table 1.5.2 Bottom shell and bilge plating

Location	Minimum thickness, in mm	
	Longitudinal framing	Transverse framing
(1) Bottom plating, see Notes 1 and 2	<p>The greater of the following:</p> <p>(a) <math>t = 0,001s_1(0,043L_1 + 10)\sqrt{\frac{F_B}{k_L}}</math></p> <p>(see Note 4)</p> <p>(b) <math>t = 0,0052s_1\sqrt{\frac{h_{T2}k}{1,8 - F_B}}</math></p>	<p>The greater of the following:</p> <p>(a) <math>t = 0,001s_1f_1(0,056L_1 + 16,7)\sqrt{\frac{F_B}{k_L}}</math></p> <p>(see Note 4)</p> <p>(b) <math>t = 0,0063s_1\sqrt{\frac{h_{T2}k}{1,8 - F_B}}</math></p>
(2) Bilge plating - where framed, see Notes 1 and 2	<i>t</i> as for (1)	<i>t</i> as for (1)

(3) Bilge plating - where unframed, see Note 3	<p>Provided that transverses or adequate bilge brackets are spaced not more than</p> $\frac{8t^2}{DR_B} \sqrt{\frac{t}{R_B}} \times 10^6 \text{ mm apart}$ <p><math>f = \frac{R_B F_B}{165k_L}</math> but is to be not less than the adjacent bottom plating</p>
Symbols	
<p><math>L, D, T, s, S, k_L, k</math> as defined in Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1</p> <p><math>C_w</math> is as defined in Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1.</p> <p>Where</p> <p><math>L &gt; 227 \text{ m}</math>, <math>C_w</math> is not to be taken less than 6,446 m</p> $f_1 = \frac{1}{1 + \left(\frac{s}{10003}\right)^2}$ <p><math>h_{T2} = (T + 0,5 C_w)</math>, in metres but need not be taken greater than 1,2T m</p> <p><math>s_1 = s</math>, but is not to be taken less than the smaller of</p> $470 + \frac{L}{0,6} \text{ mm or } 700 \text{ mm}$ <p><math>F_B =</math> as defined in Pt 3, Ch 4, 5.7 Local reduction factors</p> <p><math>L_1 = L</math> but need not be taken greater than 190 m</p> <p><math>R_B =</math> bilge radius, in mm, see Note 3</p>	
<p>Note 1. The thickness derived in accordance with (1) is also to satisfy the buckling requirements of Pt 3, Ch 4, 7 Hull buckling strength.</p> <p>Note 2. The thickness of bottom shell or bilge plating is to be not less than the basic shell end thickness for taper as given in Pt 3, Ch 3 Structural Design, Table 3.2.1 Taper requirements for hull envelope. The basic shell end thickness for taper applied to the midship region bottom shell or bilge plating need not be taken greater than 16 mm.</p> <p>Note 3. Where longitudinally framed and the lowest side longitudinal lies a distance <math>a</math> mm above the uppermost turn of bilge and/or the outermost bottom longitudinal lies a distance <math>b</math> inboard of the lower turn of bilge, the bilge radius is to be taken as <math>R_B + \frac{(a+b)}{2}</math> mm. In no case is <math>a</math> or <math>b</math> to be greater than <math>s</math>.</p> <p>Note 4. Where separate maximum sagging and hogging still water bending moments are assigned, <math>F_B</math> may be based on the hogging moment.</p>	

Imagen 15: "Tabla 1.5.2 Bottom Shell and Bilge Plating"

Por lo que, el espesor del fondo tiene que ser el mayor de:

$$ta = 0,001 \cdot s_1 \cdot f_1 \cdot (0,056 \cdot L_1 + 16,7) \cdot \sqrt{\frac{FB}{KL}} = 0,001 \cdot 700 \cdot 1 \cdot (0,056 \cdot 106,84 + 16,7) \cdot \sqrt{\frac{1}{1}}$$

$$ta = 15,88 \text{ mm} \approx 16 \text{ mm}$$

$$tb = 0,0063 \cdot s_1 \cdot \sqrt{\left(HT2 \cdot \frac{K}{1,8 - FB}\right)} = 0,0063 \cdot 700 \cdot \sqrt{6 \cdot \frac{1}{1,8 - 1}}$$

$$tb = 8,05 \text{ mm} \approx 8 \text{ mm}$$

HT2 no debe ser mayor que:

$$HT2 = 1,2 \cdot T = 6 \text{ m}$$

Y como:

$$HT2 = T + 0,5 \cdot C_w = 8,22$$

Se toma para HT2 un valor de 6 m.

Siendo,		
$s1$	separación refuerzos	entre 700 mm
$F1$		1
$L1$	Eslora reglamento	106,84 m
$FB$		1
$kL$	Factor del acero	1
$HT2$	Altura reglamento	6 m
$K$	Factor del acero	1
$S$	Separación refuerzos	2,1 m
$Cw$	Coeficiente de ola	6,45
$T$	Calado escantillonado	5 m

Se va a calcular el espesor del fondo como “Deep tank”, siguiendo la Parte 4, Capítulo 1, Sección 9 del reglamento de la Sociedad de clasificación Lloyd’s Register:

$$t = 0,004 \cdot s \cdot f \cdot \sqrt{\rho \cdot h4 \cdot \frac{k}{1,025}} + 2,5$$

$$t = 0,004 \cdot 700 \cdot 1 \cdot \sqrt{1,025 \cdot 5,47 \cdot \frac{1}{1,025}} + 2,5$$

$$t = 8,85 \text{ mm} \approx 9 \text{ mm}$$

Según el reglamento, no puede ser menor a 7,5 mm para esloras mayores de 90.

Por lo que finalmente, el espesor del fondo es  $t = 16 \text{ mm}$ . Que es igual que el espesor del pantoque.

El espesor del pantoque es el mismo que el del fondo, es decir, 16 mm.

### 5.2.3 SIDE SHELL

En la región intermedia del buque, el espesor de la chapa lateral (Side Shell) no puede ser menor que los valores que surjan de las expresiones siguientes:

**Within D/4 from gunwale:**

$$t1 = 0,001 \cdot s1 \cdot f1 \cdot (0,083 \cdot L1 + 10) \cdot \sqrt{\frac{FD}{kL}} = 0,01 \cdot 500 \cdot 1 \cdot (0,083 \cdot 106,84 + 10) \cdot \sqrt{\frac{1}{1}}$$

$$t1 = 9,43 \text{ mm} \approx 9 \text{ mm}$$

$$t2 = 0,001 \cdot s1 \cdot \sqrt{L \cdot k} + 2,5 = 0,001 \cdot 500 \cdot 1 \cdot \sqrt{106,84 \cdot 1} + 2,5$$

$$t2 = 7,67 \text{ mm} \approx 8 \text{ mm}$$

Se toma el valor de 9 mm.

**Within D/4 from mid-depth:**

$$t1 = 0,001 \cdot s1 \cdot (0,059 \cdot L1 + 7) \cdot \sqrt{\frac{FB}{kL}}$$

$$t1 = 0,001 \cdot 500 \cdot (0,059 \cdot 106,84 + 7) \cdot \sqrt{\frac{1}{1}}$$

$$t1 = 6,65 \text{ mm} \approx 6,5 \text{ mm}$$

$$t2 = 0,0051 \cdot s1 \cdot \sqrt{HT1 \cdot k}$$

$$t2 = 0,0051 \cdot 500 \cdot \sqrt{6,8 \cdot 1}$$

$$t2 = 6,65 \text{ mm} \approx 6,5 \text{ mm}$$

Se toma el valor de 6,5 mm.

**Within D/4 from base:**

$$t1 = 0,00085 \cdot s1 \cdot f1 \cdot (0,083 \cdot L1 + 10) \cdot \sqrt{\frac{FB}{k}}$$

$$t1 = 0,00085 \cdot 500 \cdot 1 \cdot (0,083 \cdot 106,84 + 10) \cdot \sqrt{\frac{1}{1}}$$

$$t1 = 8,02 \text{ mm} \approx 8 \text{ mm}$$

$$t2 = 0,0056 \cdot s1 \cdot \left(\frac{HT2 \cdot k}{1,8 - FB}\right)^{0,5}$$

$$t2 = 0,0056 \cdot 500 \cdot \left(\frac{6 \cdot 1}{1,8 - 1}\right)^{0,5}$$

$$t2 = 7,67 \text{ mm} \approx 7,5 \text{ mm}$$

Se toma el valor de 8 mm para este caso.

**Sheerstrake:** se tomará como espesor de trancañil el valor mayor de las siguientes expresiones:

$$t1 = 0,001 \cdot s1 \cdot f1 \cdot (0,083 \cdot L1 + 10) \cdot \left(\frac{FD}{kL}\right)^{\frac{1}{2}}$$

$$t1 = 0,001 \cdot 500 \cdot 1 \cdot (0,083 \cdot 106,84 + 10) \cdot \left(\frac{1}{1}\right)^{\frac{1}{2}}$$

$$t1 = 9,43 \text{ mm} \approx 9,5 \text{ mm}$$

$$t2 = 0,001 \cdot s1 \cdot \sqrt{L \cdot k} + 2,5$$

$$t2 = 0,001 \cdot 500 \cdot \sqrt{106,84 \cdot 1} + 2,5$$

$$t2 = 7,67 \text{ mm} \approx 7,5 \text{ mm}$$

En conclusión se tiene los siguientes espesores:

		<i>t (mm)</i>
<i>Side Shell</i>	Within D/4 from gunwale	9
	Within D/4 from mid-depth	6,5
	Within D/4 from base	8
	Sheerstrake	9,5

Nota: Las **tomas de mar**, u otras aberturas tendrán las esquinas bien redondeadas y, se evitará situarlas cerca del radio de pantoque. Las aberturas que se sitúen en o cerca del radio de pantoque serán elípticas.

Siendo,

<i>s1</i>	separación refuerzos	entre	500 mm
<i>F1</i>			1
<i>L1</i>	Eslora reglamento		106,84 m
<i>L</i>	Eslora reglamento		106,84 m
<i>k</i>	Factor del acero		1
<i>HT2</i>	Altura reglamento		6 m
<i>HT1</i>	Altura reglamento		6,8 m
<i>FB</i>	Separación refuerzos		2,1 m

El valor de HT1 se calcula mediante la siguiente expresión:

$$HT1 = T + Cw = 5 + 6,45$$

$$HT1 = 11,45 \text{ m}$$

Pero HT1 no puede exceder el valor de:

$$HT1 = 1,36 \cdot 5$$

$$HT1 = 6,8 \text{ m}$$

Por tanto, HT1 toma el valor de 6,8 m.

### 5.3 SHELL ENVELOPE FRAMING

Seguendo el Reglamento, se va a calcular el “Shell Framing” según la Tabla 1.6.3 de la Parte 4, Capítulo 1, Sección 6.

6.3.1 The scantlings of main and 'tween deck frames, and bottom frames in way of bracket floors, in the midship region are to comply with the requirements given in *Table 1.6.3 Shell framing (transverse)*.

Para consultar la tabla 1.6.3 visualizar Anexo IV de este cuaderno.

· **Módulo:** se ha de coger el de mayor valor de las siguientes expresiones:

“Main “tween deck and superstructure frames in dry spaces”

$$Za = C \cdot s \cdot k \cdot hT1 \cdot \frac{H^2}{1000}$$

$$Zb = 9,1 \cdot s \cdot k \cdot \frac{D1}{1000}$$

Inercia:

$$I = 3,2 \cdot H \cdot \frac{Z}{k}$$

HT1 se va a calcular mediante la siguiente expresión cuando “frames where the mid-length of frame is above the waterline, at draught T”

$$HT1 = Cw \cdot \left(1 - \frac{h6}{D1 - T}\right) \cdot F\gamma$$

Siendo,

$$\left(1 - \frac{h6}{D1 - T}\right) \cdot F\gamma > 0,7$$

HT1 se va a calcular mediante la siguiente expresión cuando “for frames where the mid-length of frame is below the waterline at draught T”

$$HT1 = (h6 + Cw \cdot \left(1 - \frac{h6}{2T}\right)) \cdot F\gamma$$

Siendo:

$F\gamma$		1
$H$	Vertical Framing depth	3 m
$Cw$	Factor de ola	6,45
$C$	End correctio factor	3,4
$D1$		8 m
$s$	Separación de refuerzos	500 mm

		WL			Za (cm3)	Zb (cm3)	Inercia	Perfil Bulbo
H6 1	1,09	Below	HT1	6,83	142,31	36,40	1593	180x8
H6 2	1,67	Above	HT1	4,51	93,97	36,40	1052	160x7
H6 3	4,67	Above	HT1	4,51	93,97	36,40	1052	160x7

## Bulb Flats



Dimension range, weight/m and static values

Width a mm	Thickness s mm	Height e mm	Radius r mm	Area A mm <sup>2</sup>	Weight kg/m	e mm	$f_x$ mm	$W_x^*$ cm <sup>3</sup>
60	4	13	3.5	3.58	2.81	382	12.2	13
	5	13	3.5	4.18	3.28	3.70	14.4	14
	6	13	3.5	4.78	3.75	3.62	16.4	16
80	5	14	4	5.40	4.24	4.89	33.8	23
	6	14	4	6.20	4.87	4.78	39.0	25
	7	14	4	7.00	5.50	4.69	43.3	27
100	6	15.5	4.5	7.74	6.08	5.98	76.1	38
	7	15.5	4.5	8.74	6.86	5.87	85.3	41
	8	15.5	4.5	9.74	7.65	5.78	94.3	45
120	6	17	5	9.31	7.31	7.20	133	54
	8	17	5	11.7	9.19	6.96	164	63
140	7	19	5.5	12.4	9.74	8.31	241	80
	8	19	5.5	13.8	10.8	8.18	266	87
	9	19	5.5	15.2	11.9	8.07	291	93
160	7	22	6	14.6	11.4	9.66	373	110
	8	22	6	16.2	12.7	9.49	411	118
	9	22	6	17.8	14.0	9.36	448	126
180	8	25	7	18.9	14.8	10.9	609	157
	9	25	7	20.7	16.2	10.7	663	166
	10	25	7	22.5	17.6	10.6	717	177

Imagen 16: Perfil Llanta de Bulbo – Smooth Corners

Se muestra a continuación un modelo de consolas, que puede ser aplicado para este buque proyecto:

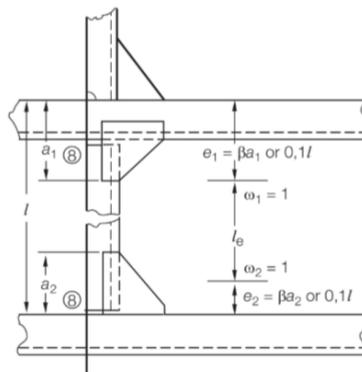


Imagen 17: Reglamento Figura 1.9.1 Parte 4, Capítulo 1, Sección 9.

## 5.4 DOUBLE BOTTOM STRUCTURE

Reglamento de la Sociedad de Clasificación Lloyd's Register (Julio 2019) Parte 4, Capítulo 1, Sección 8.

### 5.4.1 GIRDERS

El puntal mínimo en el centro del girder va a ser el de valor superior de los valores obtenidos con las siguientes expresiones:

$$d_{DB} = 28 \cdot B + 205 \cdot \sqrt{T} = 1064,71 \text{ mm}$$

$$d_{DB} = 50 \cdot B = 1082,7 \text{ mm}$$

$$d_{DB} = 760 \text{ mm}$$

Se va a tomar como  $d_{DB}$  el valor de 1083 mm.

El girder central tiene que tener un espesor no menor a:

$$t = (0,008 \cdot d_{DB} + 4) \cdot \sqrt{k}$$

$$t = (0,008 \cdot 1083 + 4) \cdot \sqrt{1}$$

$$t = 12,7 \text{ mm} \approx 13 \text{ mm}$$

### 5.4.2 WATERTIGHT SIDE GIRDERS

Como la manga del buque, es superior a 10 m, se van a colocar dos vagras a cada lado, aproximadamente entre la línea de crujía y el forro.

Las vagras laterales estancas deben tener un espesor de recubrimiento correspondiente al de la siguiente expresión:

$$t = (0,0075 \cdot d_{DB} + 1) \cdot \sqrt{k}$$

$$t = (0,0075 \cdot 1083 + 1) \cdot \sqrt{1}$$

$$t = 9,12 \text{ mm} \approx 9 \text{ mm}$$

Si se calculase como un mamparo de tanque, se obtendría un valor de:

$$t = 0,004 \cdot s \cdot f \cdot \sqrt{\rho \cdot h^4 \cdot \frac{k}{1,025}} + 2,5 = 5,78 \text{ mm} \approx 6 \text{ mm}$$

*Pero según el reglamento, no puede ser menor a 7,5 mm.*

En la cuaderna maestra, se van a instalar dos vagras a cada lado, separadas una distancia de 3,5 m. Tendrán un espesor de 13 mm.

### 5.4.3 INNER BOTTOM PLATING

El espesor del revestimiento del "inner Bottom Plating" en los tanques no puede ser menor que:

$$t = 0,00136 \cdot (s + 660) \cdot \sqrt[4]{k^2 \cdot L \cdot T}$$

$$t = 8,89 \text{ mm} \approx 9 \text{ mm}$$

Se va a calcular el espesor también como techo de un tanque:

$$t = 0,004 \cdot f \cdot s \cdot \sqrt{\frac{\rho \cdot k \cdot h^4}{1,025}} + k^2$$

$$t = 0,004 \cdot 0,97 \cdot 700 \cdot \sqrt{1,025 \cdot 1 \cdot \frac{5,17}{1,025}} + 3,5$$

$$t = 9,85 \text{ mm} \approx 10 \text{ mm}$$

Siendo,

<i>f</i>		0,97
<i>s</i>	Separación de refuerzos	700 mm
<i>k</i>	Factor del acero	1
<i>H4</i>	Altura reglamento	5,17 m
<i>K2</i>	Constante para techo de tanque	3,5 mm
<i>rho</i>	densidad	No menor de 1,025

En conclusión, para este apartado se han obtenido los siguientes valores:

		<i>t (mm)</i>
<i>Double</i>	Girders	13
<i>Bottom</i>		
<i>Structure</i>	Inner Bottom plating	10

## 6 PILLARS

Para el cálculo de los puntales se va a seguir el reglamento de la Sociedad de Clasificación, concretamente la Parte 4, Capítulo 1, Sección 4 de la Lloyd's Register, July 2019.

Para calcular el área de la sección se va a aplicar la siguiente fórmula:

$$A_p = (k \cdot P) / (12,36 - 51,5 \cdot \frac{I_e}{r \cdot \sqrt{k}})$$

$$A_p = 25,64 \text{ cm}^2$$

Siendo,

$A_p$ aproximación	$\frac{\sqrt{k \cdot P}}{9,32}$	49,4424 cm <sup>2</sup>	
$r$	$r = 10 \cdot \sqrt{\frac{I}{A_p}}$	16,4 mm	Radio de giro mínimo de la sección transversal del puntal.
$l_e$		3 m	Longitud efectiva del puntal
$k$		1	Factor de Acero
$b$		250 mm	Ancho del pilar
$S$		4,2 m	Separación entre pilares
$H_g$	H3	1,2 m	Calculada en anteriores apartados.
$C$		1,39	Standard Stowage rate.
$P$	$P = \frac{9,81 \cdot S \cdot H_g \cdot l_p}{C}$		Load (kN)
$L_p$		7 m	Distancia en metros entre dos centros de dos tramos de vigas sostenidos por el puntal.

Continuando con los cálculos, se procede ahora a obtener el espesor del pilar rectangular que se va a instalar a bordo:

$$ta = \frac{P}{b \cdot \left(0,5 - 1,95 \cdot \frac{le}{r}\right)}$$

$$tb = b \cdot \frac{r}{600 \cdot le}$$

$$tc = \frac{b}{55}$$

Se obtienen los siguientes valores:

<i>ta</i>	6,95 mm ≈ 7 mm	
<i>tb</i>	2,28 mm ≈ 6,5 mm	No puede ser menor a 7,5 mm
<i>tc</i>	4,55 mm ≈ 4,5 mm	No puede ser menor a 7,5 mm

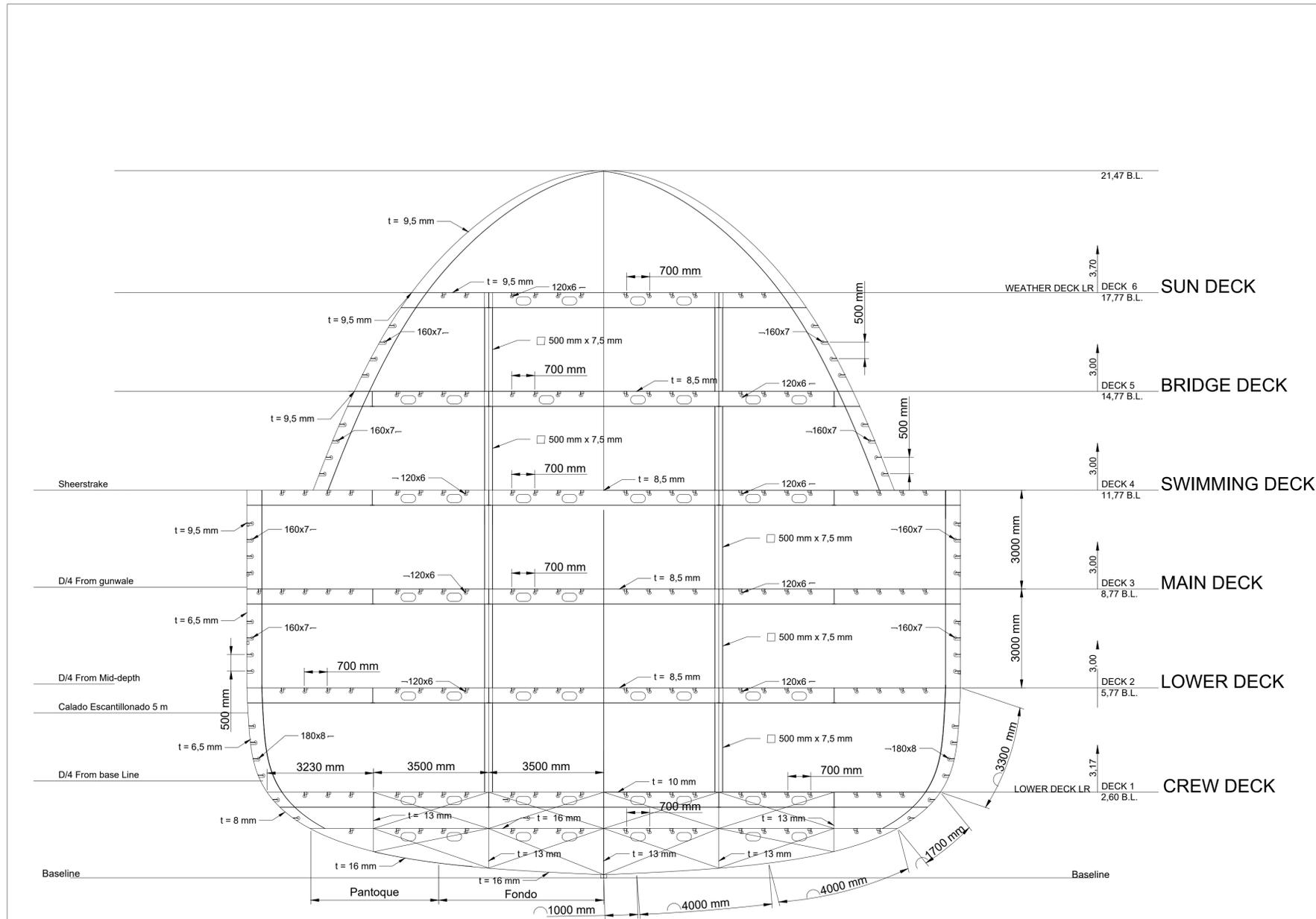
Por lo que se va a tener que t puntal equivale a 7,5 mm.

Table 1.4.7 Pillars

Symbols	Parameter	Requirement
<i>b</i> = breadth of side of a hollow rectangular pillar or breadth of flange or web of a built or rolled section, in mm	(1) Cross-sectional area of all types of pillar	$A_p = \frac{kP}{12,36 - 51,5 \frac{e}{r\sqrt{k}}} \text{ cm}^2$
<i>d<sub>p</sub></i> = mean diameter of tubular pillars, in mm		See Note
<i>k</i> = local scantling higher tensile steel factor, see Pt 3, Ch 2, 1.2 Steel 1.2.3, but not less than 0,72	(2) Minimum wall thickness of tubular pillars	The greater of the following:
<i>l</i> = overall length of pillar, in metres		(a) $t = \frac{P}{d_p \left(0,392 - 1,53 \frac{e}{r}\right)} \text{ mm}$
<i>l<sub>e</sub></i> = effective length of pillar, in metres, and is taken as: for hold pillars 0,65 <i>l</i> for 'tween deck pillars 0,80 <i>l</i>		(b) $t = \frac{d_p}{40} \text{ mm}$
<i>l<sub>p</sub></i> = distance, in metres, between centres of two adjacent spans of girders or transverses supported by the pillar.		but not to be less than (c) <i>t</i> = 5,5 mm where <i>L</i> < 90 m, or = 7,5 mm where <i>L</i> ≥ 90 m

<p><math>r</math> = least radius of gyration of pillar cross-section, in mm, and may be taken as:</p> $r = 10 \sqrt{\frac{I}{A_p}} \text{ mm}$ <p><math>A_p</math> = cross-sectional area of pillar, in <math>\text{cm}^2</math></p> <p><math>C, S</math> as defined in Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1</p> <p><math>H_g</math> as defined in Table 1.4.6 Deck girders, transverses and hatch beams</p> <p><math>I</math> = least moment of inertia of cross-section, in <math>\text{cm}^4</math></p>	<p>(3) Minimum wall thickness of hollow rectangular pillars or web plate thickness of I or channel sections</p>	<p>The lesser of (b) and (c) and not to be less than (a):</p> $(a) t = \frac{P}{b \left( 0.5 - 1,95 \frac{e}{r} \right)} \text{ mm}$ $(b) t = \frac{br}{800l_e} \text{ mm}$ $(c) t = \frac{b}{35} \text{ mm}$ <p>but to be not less than</p> <p><math>t = 5,5 \text{ mm}</math> where <math>L &lt; 90 \text{ m}</math>, or</p> <p><math>= 7,5 \text{ mm}</math> where <math>L \geq 90 \text{ m}</math></p>
<p><math>P</math> = load, in kN, supported by the pillar and is to be taken as</p> $\frac{9,81SH}{C} \frac{l_e}{P} + p_a$ <p>but not less than 19,62 kN</p>	<p>(4) Minimum thickness of flanges of angle or channel sections</p>	<p>The lesser of the following:</p> $(a) t_f = \frac{br}{200l_e} \text{ mm}$ $(b) t_f = \frac{b}{18} \text{ mm}$
<p><math>P_a</math> = load, in kN, from pillar or pillars above (zero if no pillars over)</p>	<p>(5) Minimum thickness of flanges of built or rolled I sections</p>	<p>The lesser of the following:</p> $(a) t_f = \frac{br}{400l_e} \text{ mm}$ $(b) t_f = \frac{b}{36} \text{ mm}$
<p>Note As a first approximation <math>A_p</math> may be taken as <math>\frac{\sqrt{kP}}{9,32}</math> and the radius of gyration estimated for a suitable section having this area.</p> <p>Note If the area calculated using this radius of gyration differs by more than 10 per cent from the first approximation, a further calculation using the radius of gyration corresponding to the mean area of the first and second approximation is to be made.</p>		

## PLANO CÁMARA DE MÁQUINAS



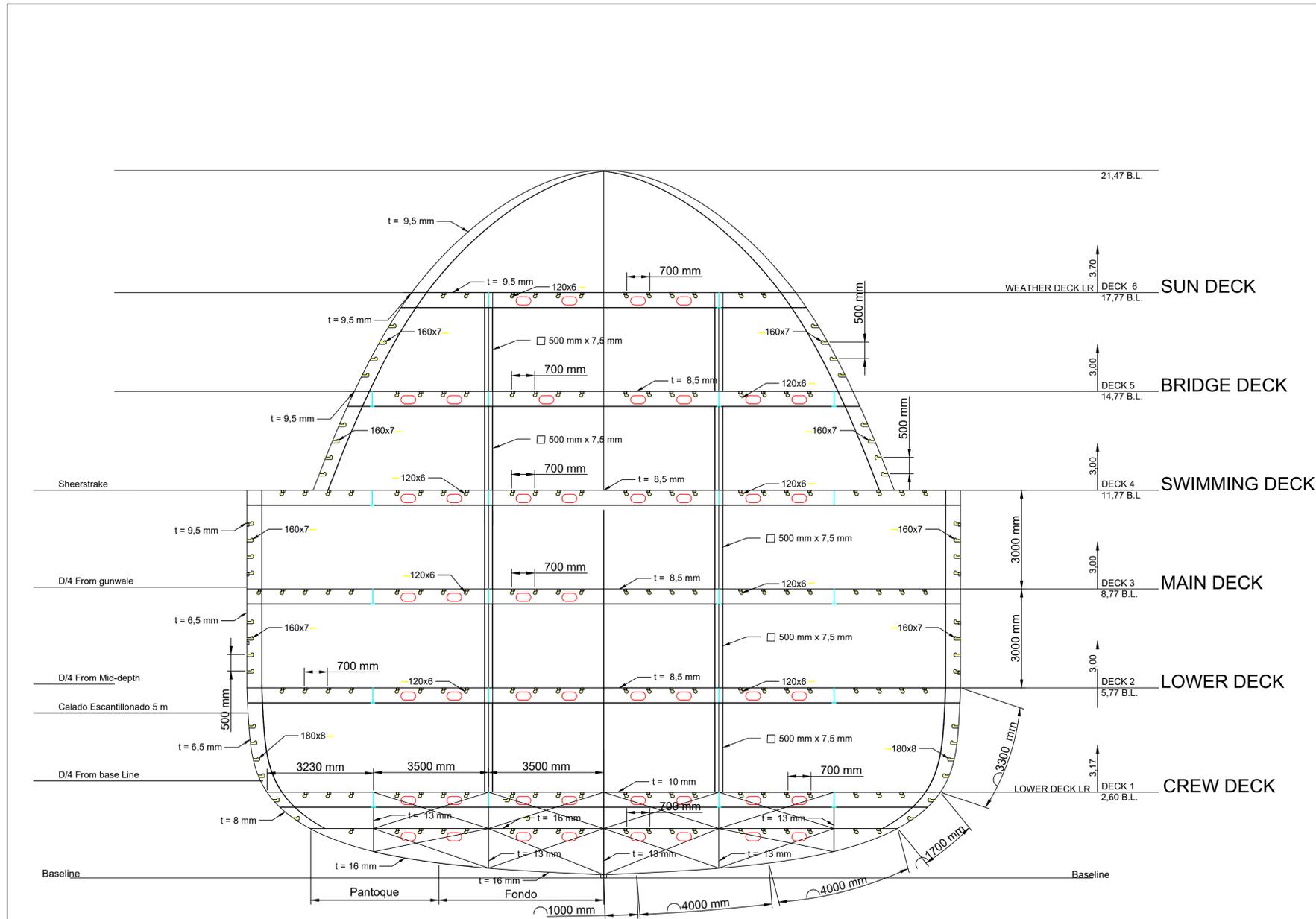
CUADERNA MAESTRA	
DIMENSIÓN	DESCRIPCIÓN
L 106,84 m	ESLORA ESCANTILLONADO
T 5 m	CALADO ESCANTILLONADO
B 21,65 m	MANGA ESCANTILLONADO
D 11,17 m	PUNTAL ESCANTILLONADO
Cb 0,51	COEFICIENTE DE BLOQUE
ACERO A	ACERO CLASE A 235 N/mm2
ACERO AH36	ACERO CLASE AH36 I 355 N/mm2
HE 8,77 m	CUBIERTA ESTANQUEIDAD

SECCIÓN 75  
CUADERNA MAESTRA

TFG – MEGAYATE DE LUJO
ROSA PÉREZ RAMÓN
CUADERNA MAESTRA
ESCALA 1:80      DIN A1

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CUADERNA MAESTRA	
DIMENSIÓN	DESCRIPCIÓN
L 106,84 m	ESLORA ESCANTILLONADO
T 5 m	CALADO ESCANTILLONADO
B 21,65 m	MANGA ESCANTILLONADO
D 11,17 m	PUNTAL ESCANTILLONADO
Cb 0,51	COEFICIENTE DE BLOQUE
ACERO A	ACERO CLASE A 235 N/mm2
ACERO AH36	ACERO CLASE AH36 I 355 N/mm2
HE 8,77 m	CUBIERTA ESTANQUEIDAD

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## ANEXO I: DEFINICIONES REGLAMENTO

Sociedad de Clasificación Lloyd's Register: Part 3, Chapter 1, Section 6.

### ■ Section 6 Definitions

#### 6.1 Principal particulars

6.1.1 Rule length,  $L$ , is the distance, in metres, on the waterline at draught  $T$ , from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post.  $L$  is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the waterline. For ships without rudders, the Rule length is to be taken as 97 per cent of the extreme length on the waterline. In ships with unusual stem or stern arrangements the Rule length,  $L$ , will be specially considered.

6.1.2 Amidships is to be taken as the middle of the Rule length,  $L$ , measuring from the forward side of the stem.

6.1.3 Breadth,  $B$ , is the greatest moulded breadth, in metres.

6.1.4 Depth,  $D$ , is measured, in metres, at the middle of the length,  $L$ , from top of keel to top of the deck beam at side on the uppermost continuous deck, or as defined in appropriate Chapters. When a rounded gunwale is arranged, the depth  $D$  is to be measured to the continuation of the moulded deck line.

6.1.5 Draught,  $T$ , is the summer draught, in metres, measured from top of keel, or a greater value if such a value has been specified as 'scantling draught'. Both of the draughts are to be indicated on the midship plan, irrespective of whether or not they are of the same value.

6.1.6 The block coefficient,  $C_b$ , is the moulded block coefficient at draught,  $T$ , based on Rule length,  $L$ , and moulded breadth,  $B$ , as follows:

$$C_b = \frac{\text{moulded displacement (m}^3\text{) at draught } T}{LBT}$$

6.1.7 Length between perpendiculars,  $L_{pp}$ , is the distance, in metres, on the waterline at draught  $T$ , from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post. In ships with unusual stern arrangements the length,  $L_{pp}$ , will be specially considered. The forward perpendicular, F.P., is the perpendicular at the intersection of the waterline with the fore side of the stem. The after perpendicular, A.P., is the perpendicular at the intersection of the waterline with the after side of the rudder post. For ships without a rudder post, the A.P. is the perpendicular at the intersection of the waterline with the centreline of the rudder stock.

6.1.8 Load line length,  $L_L$ , is to be taken as 96 per cent of the total length on a waterline at 85 per cent of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that is greater. In ships designed with a rake of keel, the waterline on which this length is measured is to be parallel to the designed waterline. The length  $L_L$  is to be measured in metres.

6.1.9 Load line block coefficient,  $C_{bL}$ , is defined as:

$$C_{bL} = \frac{\nabla}{L_L B T_L}$$

where

$\nabla$  = volume of the moulded displacement, in  $m^3$ , excluding appendages, taken at draught  $T_L$

$T_L$  = moulded draught, in metres, measured to the waterline at 85 per cent of the least moulded depth.

6.1.10 Maximum service speed,  $V$ , means the maximum ahead service speed, in knots, which the ship is designed to maintain, at the summer load waterline at maximum propeller RPM and corresponding MCR.

6.1.11 Bow reference height,  $H_b$ , is defined as:

For ships less than 250 m in length:

$$H_b = 0,056L_L \left( 1 - \frac{L_L}{500} \right) \left( \frac{1,36}{C_{bL} + 0,68} \right) \text{m}$$

For ships 250 m or greater in length:

$$H_b = 7 \left( \frac{1,36}{C_{bL} + 0,68} \right) \text{m}$$

where

$L_L$  = is defined in *Pt 3, Ch 1, 6.1 Principal particulars 6.1.8*

$C_{bL}$  = is defined in *Pt 3, Ch 1, 6.1 Principal particulars 6.1.9 ADD*, but is not to be taken less than 0.68

## 6.2 Freeboard deck

6.2.1 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, and below which all openings in the sides of the ship are fitted with permanent means of watertight closing.

6.2.2 For the purposes of the Load Lines Conventions, as applicable, where the assigned summer freeboard is increased such that the resulting draught is not more than that corresponding to a minimum summer freeboard for the same ship, but with

## ANEXO II: NÚMERO DE EQUIPO

### Sociedad de Clasificación Part 3, Chapter 1, Section 7

#### ■ Section 7 Equipment Number

##### 7.1 Calculation of Equipment Number

7.1.1 The equipment of anchors and chain cables specified in *Pt 3, Ch 13, 7 Equipment* is based on an 'Equipment Number' which is to be calculated as follows:

$$\text{Equipment Number} = \Delta^{2/3} + 2BH + \frac{A}{10}$$

where

$A$  = area, in  $\text{m}^2$ , in profile view of the hull, within the Rule length of the vessel, and of superstructures and houses above the summer load waterline, which are within the Rule length of the vessel, and also having a breadth greater than  $\frac{B}{4}$

= See also *Pt 3, Ch 1, 7.1 Calculation of Equipment Number 7.1.3* and *Pt 3, Ch 1, 7.1 Calculation of Equipment Number 7.1.4*

$B$  = greatest moulded breadth, in metres

$H$  = freeboard amidships, in metres, from the summer load waterline to the upper deck, plus the sum of the heights at the centreline, in metres, of each tier of houses having a breadth greater than  $\frac{B}{4}$

= See also *Pt 3, Ch 1, 7.1 Calculation of Equipment Number 7.1.2*, *Pt 3, Ch 1, 7.1 Calculation of Equipment Number 7.1.3* and *Pt 3, Ch 1, 7.1 Calculation of Equipment Number 7.1.4*

$\Delta$  = moulded displacement, in tonnes, to the summer load waterline.

7.1.2 In the calculation of  $H$ , sheer and trim are to be ignored. Where there is a local discontinuity in the upper deck,  $H$  is to be measured from a notional deckline.

7.1.3 If a house having a breadth greater than  $\frac{B}{4}$  is above a house with a breadth of  $\frac{B}{4}$  or less, then the wide house is to be included, but the narrow house ignored.

7.1.4 Screens and bulwarks more than 1,5 m in height are to be regarded as parts of houses when determining  $H$  and  $A$ . Where a screen or bulwark is of varying height, the portion to be included is to be that length the height of which exceeds 1,5 m. The height of the hatch coamings and that of any deck cargo, such as containers, may be disregarded when determining  $H$  and  $A$ .

7.1.5 The Equipment Number for tugs is to be calculated as follows:

$$\text{Equipment Number} = \Delta^{\frac{2}{3}} + 2(Bf + \sum bh) + \frac{A}{10}$$

where

$\Delta$ ,  $B$  and  $A$  = are defined in *Pt 3, Ch 1, 7.1 Calculation of Equipment Number 7.1.1*

$b$  = breadth, in metres, of the widest superstructure or deckhouse on each tier having a breadth greater than  $\frac{B}{4}$

$f$  = freeboard amidships, in metres, from the summer load waterline

$h$  = the height, in metres, of each tier of superstructure or deckhouse at side having a breadth of  $\frac{B}{4}$  or greater. In the calculation of  $h$ , sheer and trim are to be ignored.

7.1.6 In the case of dredgers having normal ship shape underwater hull, bucket ladders and gallows are not to be included in the Equipment Number calculations. If the dredger has an unusual underwater hull design or has a limited service area, the anchoring equipment needs to be specially considered.

7.1.7 The Equipment Number formulae for anchoring equipment as given in this Section are based on an assumed maximum current speed of 2,5 m/s, maximum wind speed of 25 m/s and a minimum scope of chain cable of 6, the scope being the ratio between length of chain paid out and water depth. For ships with a Rule length, L, greater than 135 m, the required anchoring equipment is also considered adequate for a maximum current speed of 1,54 m/s, a maximum wind speed of 11 m/s and waves with maximum significant height of 2 m.

## ANEXO III: MINIMUM HULL SECTION MODULUS

“Minimum hull section modulus”: el módulo de la sección del casco sobre el eje neutral transversal, en la cubierta o en la quilla, no debe ser inferior a:

$$Z_{min} = f_1 \cdot K_L \cdot C_1 \cdot L^2 \cdot B \cdot \frac{C_b + 0,7}{10^6}$$

$$Z_{min} = 0,5 \cdot 1 \cdot 28,86 \cdot (106,84)^2 \cdot 21,65 \cdot \frac{0,5 + 0,7}{10^6}$$

$$Z_{min} = 4,228 \text{ cm}^3$$

Siendo,

$f_1$ , factor de servicio del barco.

$K_L$ , toma el valor de 1.

$C_1$ , factor de momento flector de onda. Que se obtiene de la siguiente forma:

$$C_1 = 10,75 \cdot \left( \frac{300 - L}{100} \right)^{1,5}$$

$$C_1 = 28,86$$

C1	F1	KL
28,86	0,5	1

### 5.4 Minimum hull section modulus

5.4.1 The hull midship section modulus about the transverse neutral axis, at the deck or the keel, is to be not less than:

$$Z_{min} = f_1 k_L C_1 L^2 B (C_b + 0,7) \times 10^{-6} \text{ m}^3$$

= and  $f_1$  is to be taken not less than 0,5.

5.4.2 For materials to be included in the calculation of actual hull section properties, see Pt 3, Ch 3, 3 *Structural idealisation*.

5.4.3 The midship section modulus for ships with a service restriction notation is to be not less than half the minimum value required for unrestricted service.

5.4.4 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section modulus requirements given in Pt 3, Ch 4, 5.4 *Minimum hull section modulus 5.4.1* are to be maintained within 0,4L amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0,4L part, bearing in mind the desire not to inhibit the vessel's loading flexibility.

5.4.5 Outside 0,4L amidships, as a minimum, hull girder bending strength checks are to be carried out at the following locations:

- In way of the forward end of the engine room.
- In way of the forward end of the foremost cargo hold.
- At any locations where there are significant changes in hull cross-section.
- At any locations where there are changes in the framing system.

*Reglamento de la Parte 3, Capítulo 4, Sección 5.*

## ANEXO IV: SHELL FRAMING

Se muestra a continuación un recorte de la Sociedad de Clasificación Lloyd's Register, Parte 4, Capítulo 1, Sección 6 – con la tabla 1.6.3 Shell Framing (Transverse).

**Table 1.6.3 Shell framing (transverse)**

Location	Modulus, in cm <sup>3</sup>	Inertia, in cm <sup>4</sup>
(1) Main, 'tween deck and superstructure frames in dry spaces, see Note 3	The greater of the following: (a) $Z = C s k h_{T1} H^2 \times 10^{-3}$ (b) $Z = 9,1 s k D_1 \times 10^{-3}$	$I = \frac{3,2}{k} H Z$
(2) Main and 'tween deck frames in way of fuel or water ballast tanks or cargo holds used for water ballast	The greater of the following: (a) $1,15 \times Z$ from (1) (b) $Z = 6,7 s k h H_2^2 \times 10^{-3}$	$I = \frac{3,2}{k} H Z$
(3) Frames supporting hatch end beams or deck transverses, see Note 2	The greater of the following: (a) $Z$ from (1) (b) $Z = 2,5 (0,2 I_s^2 + H_1^2) k S_1 H_g$	$I = \frac{3,2}{k} H Z$
(4) Bottom frames of double bottom bracket floors	$Z = 2,15 s k T I_e \times 10^{-2}$	—
Symbols		
<p><i>D, T, s, k as defined in Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1</i></p> <p>C = end connection factor</p> <ul style="list-style-type: none"> <li>= 3,4 where two Rule standard brackets are fitted</li> <li>= 3,4 (1,8 - 0,8 (I<sub>a</sub>/I)) where one Rule standard bracket and one reduced bracket fitted</li> <li>= 3,4 (2,15 - 1,15 (I<sub>mean</sub>/I)) where two reduced brackets are fitted</li> <li>= 6,1 where one Rule standard bracket is fitted</li> <li>= 6,1 (1,2 - 0,2 (I<sub>a</sub>/I)) where one reduced bracket is fitted</li> <li>= 7,3 where no bracket is fitted</li> </ul> <p>The requirements for frames where brackets larger than Rule standard are fitted will be specially considered</p> <p>I<sub>a</sub> = equivalent arm length, in mm, as derived from Pt 3, Ch 10, 3.4 Scantlings of end brackets 3.4.1</p> <p>I<sub>mean</sub> = mean equivalent arm length, in mm, for both brackets</p> <p>h<sub>T1</sub> = head, in metres, at middle of H</p> <p>= <math>C_w \left( 1 - \frac{h_6}{D_1 - T} \right) F_{\lambda}</math>, in metres for frames where the mid-length of frame is above the waterline, at draught T</p> <p>where <math>\left( 1 - \frac{h_6}{D_1 - T} \right)</math> is not to be taken less than 0,7</p> <p>= <math> h_6 + C_w \left( 1 - \frac{h_6}{2T} \right) F_{\lambda} </math>, in metres for frames where the mid-length of frame is below the waterline at draught T</p> <p>h = h<sub>4</sub> or h<sub>5</sub>, whichever is the greater</p> <p>h<sub>4</sub> = tank head, in metres, as defined in Pt 3, Ch 3, 5 Design loading</p> <p>h<sub>5</sub> = head, in metres, measured from the mid-length of H, to the deck at side</p>		

$h_6$  = vertical distance in metres, from waterline at draught  $T$  to the mid-length of  $H$

$l_s$  = distance, in metres, from side shell to inboard support of beam or transverse

$l_6$  = effective length, in metres, of bottom frames for double bottom bracket floors

$l_h$  = length, in metres, of hatch side girder

$C_w$  = a wave head, in metres,  
 $= 7,71 \times 10^{-2} L e^{-0,0044L}$   
 = where  $e$  = base of natural logarithm 2,7183

$F_L$  = 1,0 for  $L \leq 200$  m  
 $= (1,0 + 0,0023 (L - 200))$  for  $L > 200$  m

$D_1$  =  $D$ , but need not be taken greater than  $1,6T$

$H$  =  $H_{MF}$  or  $H_{TF}$  as applicable, see Note 1

$H_{MF}$  = vertical framing depth, in metres, of main frames, as shown in *Figure 1.6.1 Framing depths for various structural configurations*, but is to be taken not less than 3,5 m

$H_{TF}$  = vertical framing depth, in metres, of 'tween deck frames, as shown in *Figure 1.6.1 Framing depths for various structural configurations*, but is to be taken not less than 2,5 m

$H_1$  =  $H$ , but need not be taken greater than 3,5 m

$H_2$  =  $H$ , where  $H_{MF}$  is to be taken not less than 2,5 m

$H_9$  = weather head,  $h_1$ , or cargo head,  $h_2$ , in metres, as defined in *Pt 3, Ch 3, 5 Design loading*, whichever is applicable

$S$  = spacing, in metres, of deck transverses

$S_1$  =  $\frac{l_h}{4}$  for hatch end beams  
 =  $S$  for transverses

Note 1. Where frames are inclined at more than  $15^\circ$  to the vertical,  $H_{MF}$  or  $H_{TF}$  is to be measured along a chord between span points of the frame.

Note 2. If the modulus obtained from (3) for frames under deck transverses exceeds that obtained from (1) and (2), the intermediate frames may be reduced provided that the combined modulus is maintained and the reduction in any intermediate frame is not greater than 35 per cent. The reduced modulus is to be not less than that given by (1)(b).

Note 3. The scantlings of main frames are not to be less than those of the 'tween deck frames above.

## ANEXO V: DECK STRUCTURE

Se muestra a continuación la Tabla del reglamento de la sociedad de clasificación para el cálculo “Deck Plating”.

**Table 1.4.1 Strength/weather deck plating**

Location	Minimum thickness, in mm	
	Longitudinal framing	Transverse framing
(1) Outside line of openings (see Notes 1 and 2)	<p>The greater of the following:</p> <p>(a) <math>t = 0,001s_1(0,059L_1 + 7) \sqrt{\frac{F_D}{k_L}}</math></p> <p>(b) <math>t = 0,00083s_1 \sqrt{L_1} + 2,5</math></p>	<p>The greater of the following:</p> <p>(a) <math>t = 0,001s_1 f_1 (0,083L_1 + 10) \sqrt{\frac{F_D}{k_L}}</math></p> <p>(b) <math>t = 0,001s_1 \sqrt{L_1} + 2,5</math></p>
(2) Inside line of openings (see Note 2)	<p>(b) <math>t = 0,00083s_1 \sqrt{L_1} + 2,5</math> but not less than 6,5</p>	<p><math>t = 0,00083s_1 \sqrt{L_1} + 1,5</math> but not less than 6,5</p>
(3) In way of the crown of a tank	<p><math>t = 0,004s_1 \sqrt{\frac{pkh_4}{1,025}} + 3,5</math></p> <p>or as (1) or (2), whichever is the greater,</p> <p>but not less than 7,5 mm where <math>L \geq 90m</math>,</p> <p>or 6,5 mm where <math>L &lt; 90 m</math></p>	
Symbols		
<p><math>L, k_L, k, \rho, s, S</math> as defined in Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1</p> <p><math>f = 1, 1 - \frac{s}{2500S}</math> but not to be taken greater than 1,0</p> <p><math>f_1 = \frac{1}{1 + \left(\frac{s}{1000S}\right)^2}</math></p> <p><math>h_4</math> = tank head, in metres, as defined in Pt 3, Ch 3, 5 Design loading</p> <p><math>s_1 = s</math> but is not to be taken less than the smaller of <math>470 + \frac{L}{0,6}</math> mm or 700 mm</p> <p><math>F_D</math> = as defined in Pt 3, Ch 4, 5.7 Local reduction factors</p> <p><math>L_1 = L</math> but need not be taken greater than 190 m.</p>		
<p>Note 1. The thickness derived in accordance with (1) is also to satisfy the buckling requirements of Pt 3, Ch 4, 7 Hull buckling strength.</p> <p>Note 2. The deck thickness is to be not less than the basic deck end thickness for taper as given in Pt 3, Ch 3 Structural Design, Table 3.2.1 Taper requirements for hull envelope</p>		

Se muestra a continuación la tabla para el cálculo del espesor de la cubierta “Lower Deck”.

**Table 1.4.2 Lower deck plating**

Location	Minimum thickness, in mm	
	Second deck	Third or platform decks
(1) Outside line of openings	$t = 0,012s_1 \sqrt{k}$ but not less than 6,5	$t = 0,01s_1 \sqrt{k}$ but not less than 6,5
(2) Inside line of openings	$t = 0,01s_1 \sqrt{k}$ but not less than 6,5	
(3) In way of the crown or bottom of a tank	$t = 0,004s_1 f \sqrt{\frac{\rho k h_4}{1,025} + K_1}$ but not less than 7,5 where $L \geq 90$ m, or 6,5 where $L < 90$ m	
(4) Plating forming the upper flange of underdeck girders	Clear of deck openings, $t = \sqrt{\frac{A_f}{1,8k}}$ In way of deck openings, $t = 1,1 \sqrt{\frac{A_f}{1,8k}}$ Minimum breadth, $b = 760$ mm	
Symbols		
<p><math>s, S, k, \rho</math>, as defined in Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1</p> <p><math>b</math> = breadth of increased plating, in mm</p> <p><math>f = 1,1 - \frac{s}{2500S}</math> but not to be taken greater than 1,0</p> <p><math>h_4</math> = tank head, in metres, as defined in Pt 3, Ch 3, 5 Design loading</p> <p><math>s_1 = s</math> but is not to be taken less than the smaller of <math>470 + \frac{L}{0,6}</math> mm or 700 mm</p> <p><math>A_f</math> = girder face area, in <math>\text{cm}^2</math></p> <p><math>K_1 = 2,5</math> mm at bottom of tank = 3,5 mm at crown of tank</p> <p>Note Where a deck loading exceeds <math>43,2 \text{ kN/m}^2</math> (<math>4,4 \text{ tonne-t/m}^2</math>), the thickness of plating will be specially considered.</p>		

**Table 5.2.2 Lower deck plating forward**

Symbols	Location	Thickness, in mm
<p><math>L, s, S, k, \rho</math> as defined in Pt 3, Ch 5, 1.4 Symbols and definitions 1.4.1</p> <p><math>b</math> = breadth of increased plating, in mm</p> <p><math>f = 1,1 - \frac{s}{2500s}</math> but is to be taken not greater than 1,0</p> <p><math>h_4</math> = tank head, in metres, as defined in Pt 3, Ch 3, 5 Design loading</p> <p><math>K_2 = 2,5</math> mm at bottom tank, or = 3,5 mm at crown of tank</p> <p><math>s_1 = s</math>, but is to be taken not less than <math>\left(470 + \frac{L_1}{0,8}\right)</math> mm</p> <p><math>A_f</math> = girder face area, in cm<sup>2</sup></p> <p><math>L_1 = L</math>, but need not be taken greater than 190 m</p> <p>Note 1. Where the deck loading exceeds 43,2 kN/m<sup>2</sup>, the thickness of plating will be specially considered. This is equivalent to a 'tween deck height of 6,1 m in association with the standard stowage rate 1,39 m<sup>3</sup>/tonne.</p> <p>Note 2. For minimum thickness of deck plating in oil tankers, see Pt 4, Ch 9, 10.2 Compartment minimum thickness.</p>	(1) Forward of 0,075L from the F.P.	$t = 0,01s_1\sqrt{k}$ but not less than 6,5 mm
	(2) Aft of 0,075L from the F.P., inside line of openings	$t = 0,01s_1\sqrt{k}$ but not less than 6,5 mm
	(3) Aft of 0,075L from the F.P., outside line of openings	As determined by a taper line from the midship thickness to the end thickness given by (1)
	(4) In way of crown or bottom of tank	$t = 0,004fs_1\sqrt{\frac{\rho kh_4}{1,025}} + K_2$ or as in (1), (2) or (3) as applicable, whichever is the greater but not less than: = 7,5 mm where $L \geq 90$ m, or = 6,5 mm where $L < 90$ m
	(5) Plating forming the upper flange of underdeck girders	Clear of cargo hatches $t = \sqrt{\frac{A_f}{1,8k}}$  In way of hatch side girders $t = 1,1\sqrt{\frac{A_f}{1,8k}}$
	Minimum breadth	$b = 760$ mm

Se muestra la tabla para el cálculo de longitudinales:

**Table 1.4.4 Cargo and accommodation deck longitudinals**

Location	Modulus, in cm <sup>3</sup>	Inertia, in cm <sup>4</sup>
(1) Cargo decks		
(a) $L \geq 90$ m	$Z = sk(5,9L_1 + 25h_2 l_e^2) \times 10^{-4}$	—
(b) $L < 90$ m	$Z = 0,005s k h_2 l_e^2$	—
(2) Accommodation decks		
(a) $L \geq 90$ m	$Z = sk(5,1L_1 + 25h_3 l_e^2) \times 10^{-4}$	—
(b) $L < 90$ m	$Z = 0,00425s k h_3 l_e^2$ See Note 1	—
(3) In way of the crown or bottom of a tank	As in (1) or (2) as applicable, or $Z = \frac{0,0113 \rho s k h_4 l_e^2}{\gamma}$ whichever is the greater	$I = \frac{2,3}{k} l_e Z$
Symbols		
<p><math>L, s, k, \rho</math> as defined in Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1</p> <p><math>d_w</math> = web depth of longitudinal, in mm, see Note 2</p> <p><math>h_2</math> = cargo head, in metres, as defined in Pt 3, Ch 3, 5 Design loading</p> <p><math>h_3</math> = accommodation head, in metres, as defined in Pt 3, Ch 3, 5 Design loading</p> <p><math>h_4</math> = tank head, in metres, as defined in Pt 3, Ch 3, 5 Design loading</p> <p><math>l_e</math> = as defined in Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1, but not to be taken less than 1,5 m</p> <p><math>L_1 = L</math> but need not be taken greater than 190 m</p> <p><math>\gamma = 1,4</math> for rolled or built sections <math>= 1,6</math> for flat bars</p>		
Note 1. The section modulus of accommodation deck longitudinals need not be taken greater than the value required by location (1)(a), in Table 1.4.3 Strength/weather deck longitudinals.		
Note 2. The web depth of longitudinals, $d_w$ , to be not less than 60 mm.		

Para el cálculo de los Baos:

**Table 1.4.5 Strength/weather, cargo and accommodation deck beams**

Location	Modulus, in cm <sup>3</sup>	Inertia, in cm <sup>4</sup>
(1) Strength/weather decks	The lesser of the following: (a) $Z = (K_1 K_2 TD + K_3 B_1 s h_1 l_e^2) k \times 10^{-4}$ (b) $Z = 2K_3 B_1 s k h_1 l_e^2 \times 10^{-4}$	—
(2) Cargo decks	$Z = (400K_1 TD + 38,8s h_2 l_e^2) k \times 10^{-4}$	—
(3) Accommodation decks	$Z = (530K_1 TD + 38,8s h_3 l_e^2) k \times 10^{-4}$	—

(4) In way of the crown or bottom of a tank	As (1), (2) or (3) as applicable, or $Z = \frac{0,0113 p s k h_4 l^2 e}{\gamma}$ whichever is the greater	$I = \frac{2,3}{k} l_e Z$
Symbols		
<p><i>B, D, T, s, k, ρ</i> as defined in Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1</p> <p><i>d<sub>w</sub></i> = depth of beam, in mm</p> <p><i>h<sub>1</sub></i> = weather deck head in metres, see Pt 3, Ch 3, 5 Design loading</p> <p><i>h<sub>2</sub></i> = cargo head in metres, see Pt 3, Ch 3, 5 Design loading</p> <p><i>h<sub>3</sub></i> = accommodation head in metres, see Pt 3, Ch 3, 5 Design loading</p> <p><i>h<sub>4</sub></i> = tank head in metres, see Pt 3, Ch 3, 5 Design loading</p> <p><i>l<sub>e</sub></i> as defined in Pt 4, Ch 1, 1.5 Symbols and definitions 1.5.1, but to be taken as not less than 1,83 m</p> <p><i>B<sub>1</sub></i> = <i>B</i>, but need not be taken greater than 21,5 m</p> <p><i>K<sub>1</sub></i> = a factor dependent on the number of decks (including poop and bridge superstructures) at the position of the beam under consideration:</p> <ul style="list-style-type: none"> <li>= 1 deck 20,0</li> <li>= 2 decks 13,3</li> <li>= 3 decks 10,5</li> <li>= 4 or more 9,3</li> </ul> <p><i>K<sub>2</sub></i> = a factor dependent on the location of the beam:</p> <ul style="list-style-type: none"> <li>= at short bridge and poops 133</li> <li>= elsewhere 530</li> </ul> <p><i>K<sub>3</sub></i> = a factor dependent on the location of the beam:</p> <ul style="list-style-type: none"> <li>= elsewhere 3,3</li> <li>= span adjacent to the ship side 3,6</li> </ul> <p><math>\gamma</math> = 1,4 for rolled or built sections</p> <ul style="list-style-type: none"> <li>= 1,6 for flat bars</li> </ul>		
<p>Note 1. Where weather decks are intended to carry deck cargo and the load is in excess of 8,5 kN/m<sup>2</sup>, the scantlings of beams may be required to be increased to comply with the requirements for location (2) using the equivalent design head, for specified cargo loading, for weather decks given in Table 3.5.1 Design heads and permissible cargo loadings.</p> <p>Note 2. The web depth of beams, <i>d<sub>w</sub></i>, is to be not less than 60 mm.</p>		

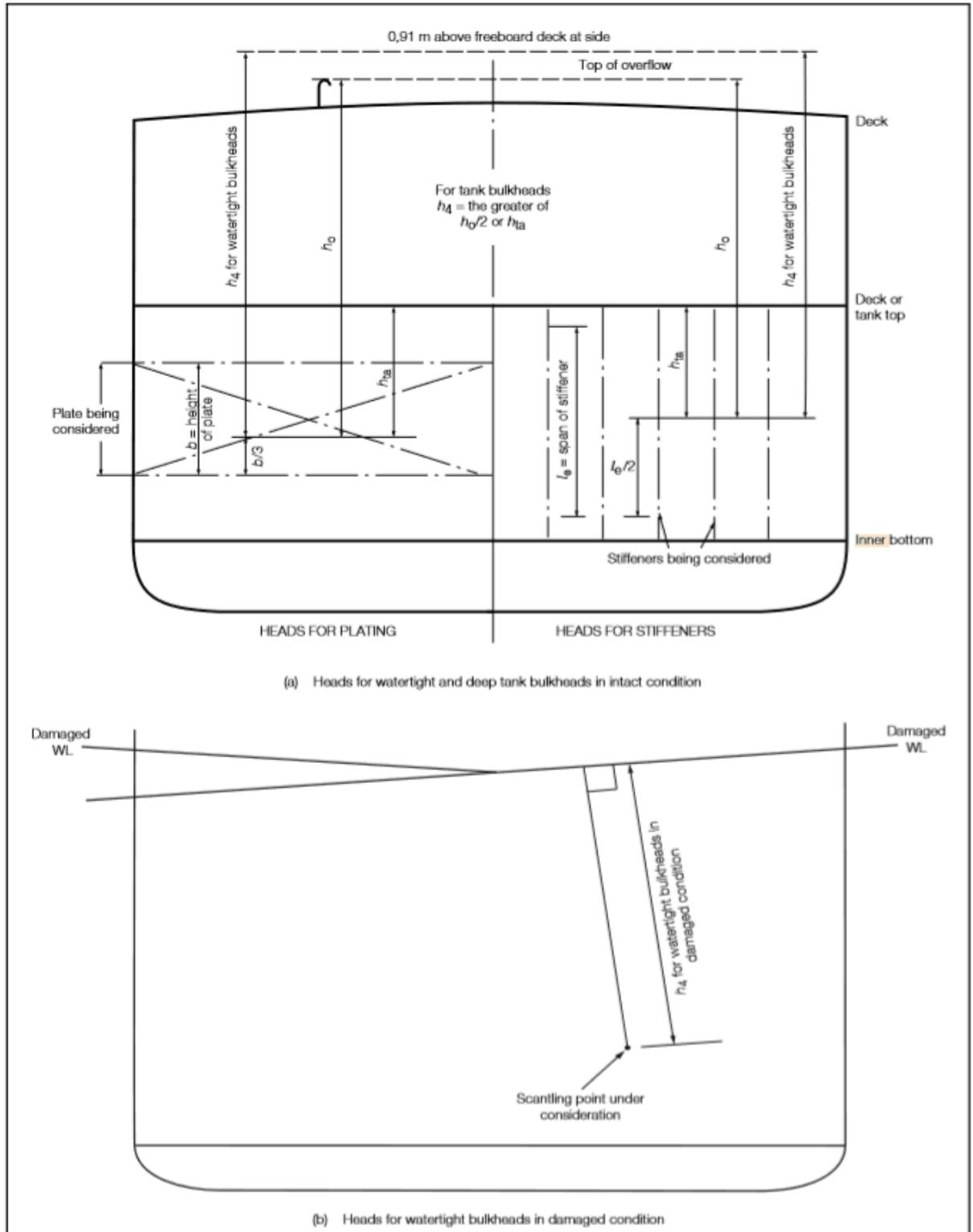
## ANEXO VI: DESIGN HEADS AND PERMISSIBLE LOADINGS

Table 3.5.1 Design heads and permissible cargo loadings

Structural item and position	Component	Standard stowage rate $C$ , in $m^3/tonne$	Design loading $\rho$ , in $kN/m^2$	Equivalent design head $h_1$ in metres	Permissible cargo loading in $kN/m^2$	Equivalent permissible head, in metres
<b>Design heads and permissible cargo loadings (SI units)</b>						
Weather deck (general cargo)				$h_1$		
(a) Loading for minimum scantlings						
Forward of 0,075L from F.P.	Beams and longitudinals	1,39	12,73	1,8	8,5	1,2
	Primary structure		$29,64 + 14,41E$	$4,2 + 2,04E$		
Between 0,12L and 0,075L from F.P.	Beams and longitudinals	1,39	10,61	1,5	8,5	1,2
	Primary structure		$22,59 + 14,41E$	$3,2 + 2,04E$		
Aft of 0,12L from F.P.	Beams and longitudinals	1,39	$8,5 + 14,41E$	$1,2 + 2,04E$	8,5	1,2
	Primary structure					
(b) Specified cargo loading						
Forward of 0,075L from F.P.	Beams and longitudinals	1,39	$2,47\rho_a + 14,41E$ or as (a), whichever is larger (Note 1)	$0,35\rho_a + 2,04E$ (Note 1)	$\rho_a$	$0,14\rho_a$
	Primary structure		$3,5\rho_a + 14,41E$ or as (a), whichever is larger (Note 1)	$0,5\rho_a + 2,04E$ (Note 1)		
Between 0,12L and 0,075L from F.P.	Beams and longitudinals	1,39	$1,98\rho_a + 14,41E$ or as (a), whichever is larger (Note 1)	$0,28\rho_a + 2,04E$ (Note 1)		
	Primary structure		$2,67\rho_a + 14,41E$ or as (a), whichever is larger (Note 1)	$0,38\rho_a + 2,04E$ (Note 1)	$\rho_a$	$0,14\rho_a$
Aft of 0,12L from F.P.	Beams and longitudinals	1,39	$\rho_a + 14,41E$ (Note 1)	$0,14\rho_a + 2,04E$ (Note 1)	$\rho_a$	$0,14\rho_a$
	Primary structure					

Cargo decks				$h_2$		
General cargo (standard loads)	All structure	1,39	$7,07H_{ld}$	$H_{ld}$	$7,07H_{ld}$	$H_{ld}$
Special cargo (specified loads)		C	$p_a$	$\frac{Cp_a}{9,82}$	$p_a$	$\frac{Cp_a}{9,82}$
Machinery space, workshop and stores		1,39	18,37	2,6	-	-
Ship stores		1,39	14,14	2,0	-	-
Accommodation decks (clear of tanks)	All structure	1,39	8,5	$h_3$	-	-
				1,2		
Superstructure decks (Note 2)				$h_3$		
1st tier	Beams and longitudinals	-	-	0,9	Where the deck is exposed to the weather, add 2,04E	-
2nd tier				0,6		
3rd tier and above				0,4 5		
Decks forming crown of tunnels and deep tanks	Plating and stiffeners	C	$\frac{9,82h}{C}$	$h_4$ $h$	-	-
(c) Bulk carrier (see Pt 3, Ch 3, 1.1 Application 1.1.3) with topside tanks						
Weather deck outside line of hatchways in way of cargo hold region, when topside tanks empty	Beams and longitudinals	1,39	-	-	7,06h	$h = \text{the lesser of}$ (i) $0,22B$ (ii) $1,2 + 0,14 \frac{W_b}{A}$ where $W_b = \text{weight of water ballast in the topside tank per frame space, in kN}$ $A = \text{Corresponding area, (m}^2\text{), of deck in way over one hold frame space}$
	Primary Structure	1,39	-	-		
Cargo hatch covers (standard loading)				$h_H$		
Steel cover	Webs, stiffeners and plating	1,39	$7,07H_{ld}$	$H_{ld}$	$7,07H_{ld}$	$H_{ld}$
Wood cover	-	1,39	-	-	$7,07H_{ld}$	$H_{ld}$
Inner bottom				$H$		

Ship without heavy cargo notation	Plating and stiffeners	1,39	—	—	$9,82T$	$1,39T$
Ship with heavy cargo notation		$C \text{ but } \leq 0,865$	$\frac{H}{C}$	$H$	$\frac{H}{C}$	$H$
Watertight bulkheads	Plating and stiffeners	0,975	$10,07h_4$	$h_4$ from Fig 3.5.2	—	—
Deep tank bulkhead	Plating and stiffeners	$C \text{ but } \leq 0,975$	$\frac{9,82h_4}{C}$	$h_4$ from Fig 3.5.2	—	—
<p>Note 1. In the case of beams and longitudinals, the equivalent design head is to be used in conjunction with the appropriate formulae.</p> <p>Note 2. For forecastle decks forward of 0,12L from F.P., see Weather decks.</p> <p>Note 3. For hatch covers of non-CSR bulk carriers, ore carriers and combination carriers, see Pt 4, Ch 7, 12 Steel hatch covers.</p> <p>Note 4. For hatch covers of ship types excluding non-CSR bulk carriers, ore carriers and combination carriers, see Pt 3, Ch 11, 2 Steel hatch covers.</p> <p>Note 5. For pontoon hatch covers, see Pt 3, Ch 11, 2.17 Pontoon covers.</p>						



## ANEXO VII: DEEP TANKS

Siguiendo el reglamento de la Sociedad de Clasificación, en la Parte 4, Capítulo 1, Sección 9 se encuentran los cálculos de “Deep Tank Bulkheads”:

Table 1.9.1 Watertight and deep tank bulkhead scantlings

Item and requirement	Watertight bulkheads	Deep tank bulkheads
(1) Plating thickness for plane, symmetrically corrugated and double plate bulkheads	$t = 0,004s_f \sqrt{h_4 k}$ mm but not less than 5,5 mm	$t = 0,004s_f \sqrt{\frac{\rho h_4 k}{1,025}} + 2,5$ mm but not less than 6,5 mm, where $L < 90$ m not less than 7,5 mm, where $L \geq 90$ m
	In the case of symmetrical corrugations, $s$ is to be taken as $b$ or $c$ in Figure 3.3.1 Corrugation dimensions in Pt 3, Ch 3, whichever is the greater	
(2) Modulus of rolled and built stiffeners, swedges, double plate bulkheads and symmetrical corrugations	$Z = \frac{skh_4 I_e^2}{71 \gamma (\omega_1 + \omega_2 + 2)} \text{ cm}^3$	$Z = \frac{\rho skh_4 I_e^2}{22 \gamma (\omega_1 + \omega_2 + 2)} \text{ cm}^3$
	In the case of symmetrical corrugations, $s$ is to be taken as $p$ , see also Note 2	
(3) Inertia of rolled and built stiffeners and swedges	—	$I = \frac{2,3}{k} I_e Z \text{ cm}^4$
(4) Symmetrical corrugations and double plate bulkheads	Additional requirements to be complied with as detailed in Table 1.9.2 Symmetrical corrugations and double plate bulkheads (additional requirements)	
(5) Stringers or webs supporting vertical or horizontal stiffening		
(a) Modulus	$Z = 5,5kh_4 S I_e^2 \text{ cm}^3$	$Z = 11,7\rho kh_4 S I_e^2 \text{ cm}^3$
(b) Inertia	—	$I = \frac{2,5}{k} I_e Z \text{ cm}^4$
Symbols		

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