Escola Politécnica Superior

Trabajo Fin de Grado
CURSO 2019/20

Buque Portacontenedores Postpanamax 11000 TEUS

Grado en Ingeniería Naval y Oceánica

ALUMNA/O

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FECHA

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Resumen

En este trabajo se va a desarrollar el proyecto de un buque portacontenedores postpanamax con capacidad para 11000 TEUS.

Nuestro buque estará propulsado por un motor diésel directamente acoplado y dispondrá de generación eléctrica de gas en zonas portuarias con el fin de reducir la contaminación.

La tripulación estará formada por un total de 30 tripulantes y todos ellos dispondrán de camarotes individuales.

El buque no contará con sistemas de carga y descarga propios, a excepción de una pequeña grúa para el abastecimiento de víveres.

En sus cubiertas se dispondrán dos TEUS en sentido longitudinal, o un FEU si fuera el caso, porque las guías de nuestro buque estarán adaptadas a dicho propósito.

Resumo

Neste traballo irase desenvolvendo o proxecto dun buque portacontenedores postpanamax con capacidade para 11000 TEU´s.

O noso buque estará propulsado por un motor diésel directamente acoplado e disporá de xeración eléctrica de gas en zonas portuarias coa fin de reducir a contaminación.

A tripulación estará formada por un total de 30 tripulantes e todos eles disporán de camarotes individuais.

O buque non contará con sistemas de carga e descarga propios, a excepción dunha pequena grúa para o abastecemento de viveres.

Nas súas cubertas disporanse os TEU´s en sentido lonxitudinal, ou un FEU se fora o caso, porque as guias do noso buque estarán adaptadas a dito propósito.

Summary

In this work, the project of a post-Panamax container ship with capacity for 11000 TEUS will be developed.

Our ship will be powered by a directly coupled diesel engine and will have electric gas generation in port areas in order to reduce pollution.

The crew will be available for a total of 30 crew members and all of them will have individual cabins.

The ship does not have its own loading and unloading systems, with the exception of a small crane for supplying food.

On its decks two TEUS will be arranged longitudinally, or in FEU if applicable, because the guides of our ship are adapted to this purpose.

Escola Politécnica Superior

TRABAJO FIN DE GRADO

CURSO 2019/20

Buque Portacontenedores Postpanamax 11000 TEUS

Grado en Ingeniería Naval y Oceánica

Documento

CUADERNO 8: CUADERNA MAESTRA

ESCOLA POLITÉCNICA SUPERIOR

UNIVERSIDADE DA CORUÑA

GRADO EN INGENIERÍA NAVAL Y OCEÁNICA

TRABAJO FIN DE GRADO

CURSO 2.019-2020

PROYECTO NÚMERO 192024

TIPO DE BUQUE: BUQUE PORTACONTENEDORES POSTPANAMAX

CLASIFICACIÓN, COTA Y REGLAMENTOS DE APLICACIÓN: DNV-GL, SOLAS Y MARPOL.

CARACTERÍSTICAS DE LA CARGA: 11000 TEUS

VELOCIDAD Y AUTONOMÍA: Velocidad servicio 20 kn, 85% MCR, 10%MM, 14.000 millas de autonomía.

SISTEMAS Y EQUIPOS DE CARGA / DESCARGA: SIN GRUAS

PROPULSIÓN: Motor diésel directamente acoplado, Generación eléctrica a Gas en zonas portuarias

TRIPULACIÓN Y PASAJE: 30 tripulantes

OTROS EQUIPOS E INSTALACIONES: LOS HABITUALES EN ESTE TIPO DE BUQUE

Ferrol, 12 Setiembre 2020

ALUMNO/A: **Dª MANUEL GARCÍA PENSADO**

Tabla de contenido

1 INTRODUCCIÓN

En este cuaderno realizaremos el estudio de la cuaderna maestra para que cumpla con los criterios mínimos de resistencia longitudinal y escantillones fijados por la sociedad de clasificación DNV-GL.

A continuación, calcularemos los módulos y escantillones de los refuerzos y planchas que formarán la estructura del buque (tipo longitudinal) y comprobaremos que el módulo cumple con lo estipulado en el reglamento.

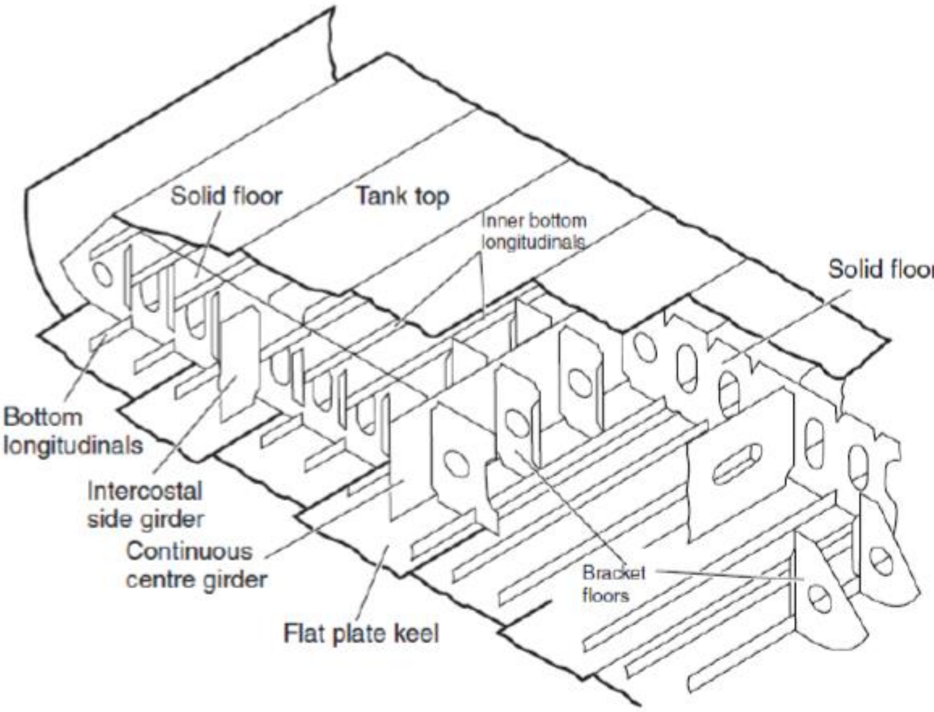
Las características de nuestro buque son:

Dimensiones	
L_{oa}	342,62 m
L_{PP}	326 m
B	47 m
D	28 m
T	16 m
C_B	0,671
Δ	172205 t
F_N	0,1817
C_M	0,992
C_P	0,677
C_F	0,827
Velocidad	20 nudos
TEU´s totales	11000
TEU´s cubierta	6168
TEU´s bodega	4840
Tripulación	30

2 DISEÑO CONCEPTUAL DE LA CUADERNA MAESTRA

Nuestro buque proyecto presentará una estructura longitudinal que nos permitirá disponer de un volumen de bodega limpio para albergar los contenedores y un menor peso estructural. El buque deberá de soportar grandes esfuerzos en las zonas mas alejadas del eje neutro (fondo y cubierta).

Los elementos principales en dicha estructura serán: esloras, palmejares y vagras.



- Espaciado entre refuerzos longitudinales: s = 900 mm
- Espaciado entre bulárcamas: colocaremos una bulárcama cada 3 cuadernas.
  l = 3 x 900 = 2700 mm

3 CUADERNA MAESTRA

En las RPA´s se especifica que para el escantillonado del buque emplearemos el reglamento de la sociedad de clasificación DNV-GL.

El casco y la estructura del buque se construirá con acero naval (“Acero Grado A”), cuyas características se detallan a continuación

Designación de Aceros según límite elástico (Pt.3 Ch.1 Sec.2 B201-203)

Descripción	Factor del Material	Límite Elástico
NV-NS	f1 = 1.00	235 N/mm^2
NV-27	f1 = 1.08	265 N/mm^2
NV-32	f1 = 1.28	315 N/mm^2
NV-36	f1 = 1.39	355 N/mm^2
NV-40	f1 = 1.43	390 N/mm^2

3.1 Definición de los parámetros reglamentarios

Los principales parámetros que necesitaremos en el cálculo de la cuaderna maestras se especifican en Pt 3 Ch1 Sec 1, donde:

Para los cálculos hemos empleado las características del buque obtenidas en el cuaderno 4 para un calado de 16 m (trimado de 0 m).

Draft Amidships (m)	**16,000**
Displacement t	172110
Heel deg	0,0
Draft at FP m	16,000
Draft at AP m	16,000
Draft at LCF m	16,000
Trim (+ve by stern) m	0,000
WL Length m	332,937
Beam max extents on WL m	47,000
Wetted Area m^2	20552,699
Waterpl. Area m^2	12933,772
Prismatic coeff. (Cp)	0,676
Block coeff. (Cb)	0,671
Max Sect. area coeff. (Cm)	0,992
Waterpl. area coeff. (Cwp)	0,827
LCB from zero pt. (+ve fwd) m	155,347
LCF from zero pt. (+ve fwd) m	142,356
KB m	8,561
KG m	16,000
BMt m	11,892
BML m	541,913
GMt m	4,452
GML m	534,474
KMt m	20,452
KML m	550,474
Immersion (TPc) tonne/cm	132,571
MTc tonne.m	2821,675
RM at 1deg = GMt.Disp.sin(1) tonne.m	13373,912
Max deck inclination deg	0,0000
Trim angle (+ve by stern) deg	0,0000

3.1.1.1 Eslora reglamentaria

Eslora de escantillonado es la eslora en la flotación de verano entre la cara posterior de la mecha del timón hasta la cara anterior de la roda. Según el reglamento L no será menor del 96% de Lw, no es necesario que sea superior al 97% de Lw.

O,97 * Lw = 0,97 * 333 = 323 m

0,96 * Lw = 0,96 * 333 = 3319,68 m

Donde:

- Lw es la eslora en la flotación. Lw = 333 m

Por lo tanto, la eslora de escantillonado será:

$$\mathbf{L_{escantillonado} = 323\ m}$$

3.1.1.2 Manga de escantillonado

La eslora de escantillonado será igual a la eslora de trazado

$$\mathbf{B_{escantillonado} = 47\ m}$$

3.1.1.3

3.1.1.4 Puntal de escantillonado

El puntal es la distancia medida en el costado, desde la línea de base a la cubierta continua mas alta. El puntal será hasta la cubierta principal:

$$\mathbf{D_{escantillonado} = 28\ m}$$

3.1.1.5 Calado de escantillonado

El calado del buque se define como el calado de francobordo de verano.

$$\mathbf{T_{escantillonado} = 16\ m}$$

3.1.1.6 Coeficiente de boque

El coeficiente de bloque se obtiene mediante la siguiente fórmula:

$$C_B = \frac{\Delta}{1{,}025 * L * B * T}$$

Donde:

- Δ: desplazamiento en la línea de carga de verano. Δ = 172110 t
- B: manga en la línea de carga de verano. B = 47 m
- T: calado de escantillonado. T = 16 m
- L: eslora de escantillonado. L = 323 m

$$\mathbf{C_B = 0{,}671}$$

4 ESCANTILLONADO DE LOS ELEMENTOS

A continuación, calcularemos el escantillonado de los elementos de la cuaderna maestra, que estará situada en la sección media del buque.

4.1 Altura del doble fondo

La altura del doble fondo viene definido en el reglamento, donde se especifica:

2.3 Height of double bottom

Where a double bottom is required to be fitted the inner bottom shall be continued out to the ship side in such a manner as to protect the bottom to the turn of bilge. Such protection will be deemed satisfactory if the inner bottom is not lower at any part than a plane parallel with the keel line and which is located not less than a vertical distance h_{DB} measured from the keel line, in mm, as calculated by the formula:

$$h_{DB} = 1000 \cdot B/20, \text{ minimum } 760 \text{ mm}$$

The height, h_{DB}, need not be taken more than 2000 mm.

The height, h_{DB}, shall be sufficient to give good access to all parts of the double bottom. For ships with large rise of floor, the minimum height may have to be increased after special consideration.

$$h_{DB} = 2350 \text{ mm}$$

Sin embargo, por motivos de mantenimiento, reparaciones e inspecciones esta distancia es insuficiente, por lo que tomaremos una altura del doble fondo igual a 2,5 m

$$h_{DB} = 2500 \text{ mm} = 2,5 \text{ m}$$

4.2 Chapas

Realizaremos el cálculo de los espesores mínimos de las planchas del fondo, doble fondo, costado y de un mamparo. Para ello debemos emplear la formulación de la Pt3 Ch6 Sec 3 (pag 13):

SECTION 3 MINIMUM THICKNESSES

Symbols

For symbols not defined in this section, see Ch.1 Sec.4.

1 Plating

1.1 Minimum thickness requirements

1.1.1 The net thickness of plating, in mm, shall not be taken less than:

$$t = a + bL_2\sqrt{k}$$

where:

a = coefficient as defined in Table 1

b = coefficient as defined in Table 1.

For aluminum alloys, material factor $k$may be taken as equal to 1.

Table 1 Minimum net thickness for plating

Element	Location		a	b
Shell	Keel		5.0	0.05
	Bottom and bilge		4.5	0.035
	Side shell and superstructure side	From upper end of bilge plating to T_{SC} + 4.6 m	4.0	0.035
		From T_{SC} + 4.6 m to T_{SC} + 6.9 m		0.025
		From T_{SC} + 6.9 m to T_{SC} + 9.2 m		0.015
		Elsewhere[6)]		0.01
	Sea chest boundaries		4.5	0.05
Deck	Weather deck[1),2),3),4)] and strength deck[2),3)]		4.5	0.02
	Boundary for cargo tanks, water ballast tanks and hold intended for cargo in bulk			0.015
	Other decks[3),4),5)]			0.01
Inner bottom	Cargo spaces loaded through cargo hatches except container holds		5.5	0.025
	Other spaces		4.5	0.02
Bulkheads	Bulkheads for cargo tanks, water ballast tanks and hold intended for cargo in bulk		4.5	0.015
	Peak bulkheads			
	Watertight bulkheads and other tanks bulkheads			0.01
	Non-tight bulkheads in tanks		5.0	0.005
	Other non-tight bulkheads			0
	Walls in accommodation		4.5	0

Para obtener el valor de L_2 debemos consultar la Pt3 Ch1 Sec4 (pag 28):

L_2 = L ya que L<300 m

L_2 = 323 m

Chapa de fondo:

$$t = 4{,}5 + 0{,}035 \times 323 \times \sqrt{1} = 16\ mm$$

Traca de pantoque:

$$t = 4{,}5 + 0{,}035 \times 323 \times \sqrt{1} = 16\ mm$$

Quilla:

$$t = 5 + 0{,}005 \times 323 \times \sqrt{1} = 21{,}34\ mm$$

Chapa de doble fondo:

$$t = 4{,}5 + 0{,}02 \times 323 \times \sqrt{1} = 11\ mm$$

Chapa del costado:

Planchas del forro exterior por encima de D/2 (costado 1):

$$t = 4 + 0{,}015 \times 323 \times \sqrt{1} = 8{,}9\ mm$$

Planchas del forro exterior por debajo de D/2 (costado 2):

$$t = 4 + 0{,}025 \times 323 \times \sqrt{1} = 12{,}17\ mm$$

Planchas de unión del costado con el pantoque:

$$t = 4 + 0{,}035 \times 323 \times \sqrt{1} = 15{,}44\ mm$$

Planchas de la traca de cinta:

$$t = 4 + 0{,}01 \times 323 \times \sqrt{1} = 7{,}2689\ mm$$

Chapa del mamparo:

$$t = 4{,}5 + 0{,}015 \times 323 \times \sqrt{1} = 9{,}4\ mm$$

4.2.1.1 Tabla resumen de espesores mínimos

Espesores minimos	**t**	
Chapa de fondo	16	mm
Traca del pantoque	16	mm
Quilla	21,34	mm
Chapa del doble fondo	11	mm
Chapa del costado		
Costado 1	8,9	mm
Costado 2	12,17	mm
Costado 3	15,44	mm
Traca de cinta	7,268 9	mm
Chapa del mamparo	9,4	mm

4.2.1.2 Espesor en función de las presiones

Para calcular el espesor de las chapas en función del espesor debemos usar la formulación de la Pt3 Ch6 Sec4 (pag 16):

1 Plating subjected to lateral pressure

1.1 General

1.1.1 Plating

The net thickness, in mm, shall not be taken less than the greatest value for all applicable design load sets, as defined in Sec.2 [2.1.3], given by:

$$t = 0{,}0158\alpha_p b\sqrt{\frac{|P|}{C_a R_{eH}}}$$

where:

C_a = permissible bending stress coefficient for plate taken equal to:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{R_{eH}}$$ not to be taken greater than $C_{a\text{-}max}$

β_a = coefficient as defined in Table 1

α_a = coefficient as defined in Table 1

$C_{a\text{-}max}$ = maximum permissible bending stress coefficient as defined in Table 1.

Donde C_a es el coeficiente de tensión de flexión para la placa, R_{eH} es el límite elástico (R_{eH} = 235 MPa), σ_{hg} es la tensión longitudinal de la viga del casco (σ_{hg} = 205 N/mm^2) y los valores de α_a, β_a y $C_{a\text{-}max}$ se toman de la siguiente tabla:

Table 1 Plating, definition of β_a, α_a and $C_{a\text{-}max}$

Acceptance criteria	Structural member		β_a	α_a	$C_{a\text{-}max}$
AC-I	Longitudinal members	Longitudinal stiffened plating	0.90	0.50	0.80
		Transverse stiffened plating	0.90	1.00	0.80
	Other members		0.80	0.00	0.80
AC-II	Longitudinal members	Longitudinal stiffened plating	1.05	0.50	0.95
		Transverse stiffened plating	1.05	1.00	0.95
	Other members		0.95	0.00	0.95
AC-III	Longitudinal bulkhead members including possible bench structures between tanks and dry spaces or dry cargo holds not intended to carry liquid or bulk cargo	Longitudinal stiffened plating	1.25	0.5	1.15
		Transverse stiffened plating	1.15	1.0	1.15
	Other longitudinal members	Longitudinal stiffened plating	1.10	0.50	1.00
		Transverse stiffened plating	1.10	1.00	1.00
	Transverse boundaries of ballast water tanks Transverse boundaries between tanks and dry spaces or dry cargo holds not intended to carry liquid or bulk cargo		1.15	0.00	1.15
	Other members		1.00	0.00	1.00
	Longitudinal watertight boundaries [1)]	Longitudinal stiffened plating	1.25	0.50	1.15
		Transverse stiffened plating	1.15	1.00	1.15
	Other watertight boundaries [1)]		1.15	0.00	1.15

1) Only applicable for flooding pressure

4.2.1.3 <u>Presiones</u>

Las presiones que emplearemos se definen en la tabla del reglamento de la Pt3 Ch6 Sec2 (pag 9):

Table 1 Design load sets

Structural member	*Design load set*	*Design load scenario*	*Load component* 4)	*Draught*	*Acceptance criteria*	*Loading condition for definition of GM and k_r*
External shell and exposed deck	SEA-1 5)	2 5)	$P_S + P_W$, P_D	T_{SC}	AC-II	Full load condition
Superstructure side			max(P_W;P_{SI})			
External shell	SEA-2 5)	1 5)	P_S	T_{SC}	AC-I	-
Boundaries of water ballast tanks and ballast holds	WB-1 5)	2 5)	$P_{ls\text{-}1} + P_{ld} - (P_S + P_W)$ 1)	T_{BAL}	AC-II	Normal ballast condition
	WB-2	3	$P_{ls\text{-}2} + P_{ld} - (P_S + P_W)$ 1)	T_{BAL}	AC-II	Normal ballast condition
	WB-3	4	max($P_{ls\text{-}4}$;$P_{ls\text{-}ST}$) − P_S 1)	min(T_{BAL}; 0.25T_{SC})	AC-III	-
	WB-4 5)	1 5)	$P_{ls\text{-}3} - P_S$ 1)	T_{BAL}	AC-I	-
Boundaries of tanks other than ballast water tanks	TK-1 5)	2 5)	$P_{ls\text{-}1} + P_{ld} - (P_S + P_W)$ (1)	T_{BAL}	AC-II	Normal ballast condition
	TK-2	4	max($P_{ls\text{-}4}$; $P_{ls\text{-}ST}$) 6)	-	AC-III	-
	TK-3 5)	1 5)	$P_{ls\text{-}3} - P_S$ 1)	T_{BAL}	AC-I	-
Internal structures in tanks	INT-1	1	P_{int}	T_{SC}	AC-I	-
Collision bulkhead	FD-1	5	P_{fs}	T_{DAM}	AC-I	-
Watertight boundaries other than collision bulkhead					AC-III	
Exposed decks and non-exposed decks and platforms with distributed load	UDL-1 2)5)	2 5)	$P_{dl\text{-}s} + P_{dl\text{-}d}$ $F_{U\text{-}s} + F_{U\text{-}d}$	T_{BAL} 3)	AC-II	Normal ballast condition 3)
	UDL-2 2)5)	1 5)	$P_{dl\text{-}s}$ $F_{U\text{-}s}$	-	AC-I	-
Decks and hatch covers/ RO/RO equipments with wheel loading	WL-1 2)	2	$P_{wl\text{-}2}$	T_{BAL} 3)	AC-II	Normal ballast condition 3)
	WL-2 2)	1	$P_{wl\text{-}1}$	-	AC-I	-

4.2.1.4 Coeficiente de olas

SECTION 4 HULL GIRDER LOADS

Symbols

For symbols not defined in this section, see Ch.1 Sec.4.

x = X coordinate, in m, of the calculation point with respect to the reference coordinate system defined in Sec.1 [1.2.1]

C_W = wave coefficient, shall be taken as:

$C_w = 0.0856L$ for $L < 90$

$C_w = 10.75 - \left(\frac{300 - L}{100}\right)^{1.5}$ for $90 \leq L \leq 300$

$C_w = 10.75$ for $300 < L \leq 350$

$C_w = 10.75 - \left(\frac{L - 350}{150}\right)^{1.5}$ for $350 < L \leq 500$

f_β = heading correction factor, shall be taken as:
for strength assessment:
f_β = 1.0 in general
f_β = 0.8 for BSR and BSP load cases for the extreme sea loads design load scenario
for fatigue assessment:
f_β = 1.0

f_{ps} = coefficient, as defined in Sec.3

f_{fa} = 0.85; fatigue coefficient

BSR, BSP, HSM, HSA, FSM, OST, OSA = dynamic load cases, as defined in Sec.2.

Como la $L_{escantillonado}$ = 323 m, el valor de Cw será 10,75.

Cw = 10,75

4.3 Chapa de fondo

La chapa del fondo deberá soportar las cargas del mar (Ps + Pw) y de los tanques de lastre (interior). Para el cálculo en función de las presiones emplearemos la formulación de la Pt3 Ch6 Sec4 (pag 16):

1 Plating subjected to lateral pressure

1.1 General

1.1.1 Plating

The net thickness, in mm, shall not be taken less than the greatest value for all applicable design load sets, as defined in Sec.2 [2.1.3], given by:

$$t = 0.0158\alpha_p b \sqrt{\frac{|P|}{C_a R_{eH}}}$$

where:

C_a = permissible bending stress coefficient for plate taken equal to:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{R_{eH}}$$ not to be taken greater than $C_{a\text{-}max}$

β_a = coefficient as defined in Table 1

α_a = coefficient as defined in Table 1

$C_{a\text{-}max}$ = maximum permissible bending stress coefficient as defined in Table 1.

El cálculo de las presiones se especifica en la tabla 1 (Pt3 Ch6 Sec 2 Pag 9):

Table 1 Design load sets

Structural member	*Design load set*	*Design load scenario*	*Load component*[4)]	*Draught*	*Acceptance criteria*	*Loading condition for definition of GM and k_r*
External shell and exposed deck	SEA-1[5)]	2[5)]	$P_S + P_W$, P_D	T_{SC}	AC-II	Full load condition
Superstructure side			max(P_W;P_{SI})			

4) Local loads:

P_S = hydrostatic sea pressure as given in Ch.4 Sec.5 [1.2]

P_W = wave pressure as given in Ch.4 Sec.5 [1.3]

P_D = external dynamic design pressure for exposed decks and wheelhouse top due to green sea loading as given in Ch.4 Sec.5 [2.2] and Ch.4 Sec.5 [3.2], respectively

(Pt3 Ch4 Sec5 pag 48)

1.2 Hydrostatic pressure

1.2.1 The hydrostatic pressure, P_S at any load point, in kN/m^2, is obtained from Table 1. See also Figure 1.

Table 1 Hydrostatic pressure, PS

Location	*Hydrostatic pressure, P_S, in kN/m^2*
$z \le T_{LC}$	$\rho g\ (T_{LC}-z)$
$z > T_{LC}$	0

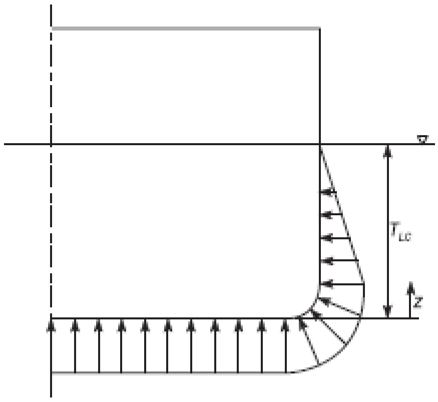


Figure 1 Transverse distribution of hydrostatic pressure Ps

(Pt3 Ch4 Sec3 pag 27)

T_{LC} = draught, in m, amidships for the considered loading condition. In case loading condition is not defined, T_{LC} = T_{SC} shall be applied

(Pt3 Ch1 Sec 4 pag 28)

T_{SC}	scantling draught	m

Dado que la z = 0 en el punto que estamos considerando (fondo), z < T_{LC} y por tanto existe una presión hidrostática por parte del mar que será:

$$Ps = \rho \times g \times (Tlc - z) = 1{,}025 \times 9{,}81 \times (16 - 0)$$

Ps = 160,884 KN/m^2

Cálculo de P_w:

Para calcular el valor de la P_w empleamos la formulación siguiente:

(Pt3 Ch4 Sec5 pag 49)

Table 2 Hydrodynamic pressures for HSM load cases

	Wave pressure, in kN/m^2		
Load case	$z \le T_{LC}$	$T_{LC} < z \le h_W + T_{LC}$	$z > h_W + T_{LC}$
HSM-1	$P_W = \max\{-P_{HS}; \rho g(z - T_{LC})\}$	$P_W = P_{W,WL} - \rho g(z - T_{LC})$	$P_W = 0.0$
HSM-2	$P_W = \max\{P_{HS}; \rho g(z - T_{LC})\}$		

where:

$$P_{HS} = C_{f_T} f_{ps} f_{n\ell} f_h k_a k_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

C_{fT} = $f_T + 0.5 - (0.7 f_T - 0.2) C_B$

$f_{n\ell}$ = coefficient considering non-linear effects, to be taken as:

for extreme sea loads design load scenario:

$f_{nl} = 0.7$ at $f_{xL} = 0$

$f_{nl} = 0.9$ at $f_{xL} = 0.3$

$f_{nl} = 0.9$ at $f_{xL} = 0.7$

$f_{nl} = 0.6$ at $f_{xL} = 1$

for ballast water exchange design load scenario:

$f_{nl} = 0.85$ at $f_{xL} = 0$

$f_{nl} = 0.95$ at $f_{xL} = 0.3$

$f_{nl} = 0.95$ at $f_{xL} = 0.7$

$f_{nl} = 0.80$ at $f_{xL} = 1$

Intermediate values are obtained by linear interpolation

f_{yz} = girth distribution coefficient, to be taken as:

$$f_{yz} = C_x \cdot \frac{z}{T_{LC}} + \left(2 - C_x\right) f_{yB} + 1$$

C_x = coefficient to be taken as:

$$C_x = 1{,}5 - \frac{|x - 0{,}5L|}{L}$$

f_h = coefficient to be taken as:

$$f_h = 3.0\left(1.21 - 0.66 f_T\right)$$

k_a = amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$$k_a = \left(0.5 + f_T\right)\left[\left(3 - 2\sqrt{f_{yB}}\right) - \frac{20}{9} f_{xL}\left(7 - 6\sqrt{f_{yB}}\right)\right] + \frac{2}{3}\left(1 - f_T\right) \quad \text{for } f_{xL} < 0.15$$

$$k_a = 1.0 \quad \text{for } 0.15 \le f_{xL} < 0.7$$

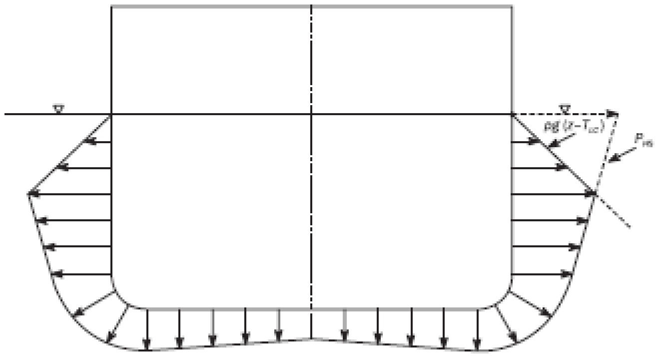
$$k_a = 1 + \left(f_{xL} - 0.7\right)\left\{\left(\frac{40}{3} f_T - 5\right) + 2\left(1 - f_{yB}\right)\left[\frac{18}{C_B} f_T\left(f_{xL} - 0.7\right) - 0.25\left(2 - f_T\right)\right]\right\} \quad \text{for } f_{xL} \ge 0.7$$

λ = wave length of the dynamic load case, in m, to be taken as: $\lambda = 0.6(1 + f_T)L$

k_p = phase coefficient to be obtained from Table 3. Intermediate values shall be interpolated.

Table 3 Definition of phase coefficient K_p

f_{xL}	0	$0.3 - 0.1\, f_T$	$0.35 - 0.1\, f_T$	$0.8 - 0.2\, f_T$	$0.9 - 0.2\, f_T$	1.0
k_p	$-0.25\, f_T(1 + f_{yB})$	-1	1	1	-1	-1



Se considera la condición dinámica HSM-2 maximizando el momento flector por las olas en la parte del buque y z será menor que T_{LC} por estar en el fondo:

(Pt3 Ch4 Sec2 pag 13)

Table 1 Ship responses for HSM, HSA and FSM load cases - strength assessment

Load case	*HSM-1*	*HSM-2*	*HSA-1*	*HSA-2*	*FSM-1*	*FSM-2*
EDW	HSM		HSA		FSM	
Heading	Head		Head		Following	
Effect	Max. bending moment		Max. vertical acceleration		Max. bending moment	
VWBM	Sagging	Hogging	Sagging	Hogging	Sagging	Hogging
VWSF	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore	Negative-aft Positive-fore	Positive-aft Negative-fore
HWBM	-	-	-	-	-	-
TM	-	-	-	-	-	-
Surge	To stern	To bow	To stern	To bow	To bow	To stern
a_{surge}						
Sway	-	-	-	-	-	-
a_{sway}	-	-	-	-	-	-
Heave	Down	Up	Down	Up	-	-
a_{heave}					-	-
Roll	-	-	-	-	-	-
a_{roll}	-	-	-	-	-	-
Pitch	Bow down	Bow up	Bow down	Bow up	Bow up	Bow down
a_{pitch}						

(Pt3 Ch 4 Sec 3 pag 27)

f_T = ratio between draught at a loading condition and scantling draught, shall be taken as:

$f_T = \frac{T_{LC}}{T_{SC}}$, but shall not be taken less than 0.5

T_{LC} = draught, in m, amidships for the considered loading condition. In case loading condition is not defined, T_{LC} = T_{SC} shall be applied

f_{ps} = coefficient for strength assessments which is dependant on the applicable design load scenario specified in Sec.7, and shall be taken as:

f_{ps} = 1.0 for extreme sea loads design load scenario

f_{ps} = f_r for extreme sea loads design load scenario for vessels with service restriction

f_{ps} = 0.8 for the ballast water exchange design load scenario

f_{ps} = $0.8 \cdot f_r$ for the ballast water exchange design load scenario for vessels with service restriction

(Pt3 Ch4 Sec2 pag 10)

f_{xL} = ratio between X-coordinate of the load point and L, to be taken as:

$f_{xL} = \frac{x}{L}$, but shall not be taken less than 0.0 or greater than 1.0

(Pt3 Ch1 Sec4 pag 28)

L_0	rule length, L, but not to be taken less than 110 m	m

Como L > 110 m, el valor de Lo será de Lo = L = 323 m.

Cálculo de P_{HS}:

C_{fT} = $f_T + 0.5 - (0.7f_T - 0.2)C_B$

$$C_{fT} = 1{,}17$$

f_T = ratio between draught at a loading condition and scantling draught, shall be taken as:

$f_T = \frac{T_{LC}}{T_{SC}}$, but shall not be taken less than 0.5

$$f_T = 1$$

f_{ps} = coefficient for strength assessments which is dependant on the applicable design load scenario specified in Sec.7, and shall be taken as:

f_{ps} = 1.0 for extreme sea loads design load scenario

f_{ps} = f_r for extreme sea loads design load scenario for vessels with service restriction

f_{ps} = 0.8 for the ballast water exchange design load scenario

f_{ps} = 0.8·f_r for the ballast water exchange design load scenario for vessels with service restriction

$$f_{PS} = 1$$

f_h = coefficient to be taken as:

$f_h = 3.0(1.21 - 0.66f_T)$

$$f_h = 1{,}65$$

f_{xL} = ratio between X-coordinate of the load point and L, to be taken as:

$f_{xL} = \frac{x}{L}$, but shall not be taken less than 0.0 or greater than 1.0

$$f_{XL} = 0{,}52 \ (x = 170 \text{ m})$$

$f_{n\ell}$ = coefficient considering non-linear effects, to be taken as:

for extreme sea loads design load scenario:

f_{nl} = 0.7 at f_{xL} = 0

f_{nl} = 0.9 at f_{xL} = 0.3

f_{nl} = 0.9 at f_{xL} = 0.7

f_{nl} = 0.6 at f_{xL} = 1

for ballast water exchange design load scenario:

f_{nl} = 0.85 at f_{xL} = 0

f_{nl} = 0.95 at f_{xL} = 0.3

f_{nl} = 0.95 at f_{xL} = 0.7

f_{nl} = 0.80 at f_{xL} = 1

Intermediate values are obtained by linear interpolation

$$f_{nl} = 0{,}9$$

k_a = amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$$k_a = (0.5 + f_T)\left[\left(3 - 2\sqrt{f_{yB}}\right) - \frac{20}{9} f_{xL}\left(7 - 6\sqrt{f_{yB}}\right)\right] + \frac{2}{3}(1 - f_T) \quad \text{for } f_{xL} < 0.15$$

$$k_a = 1.0 \quad \text{for } 0.15 \le f_{xL} < 0.7$$

$$k_a = 1 + (f_{xL} - 0.7)\left\{\left(\frac{40}{3} f_T - 5\right) + 2\left(1 - f_{yB}\right)\left[\frac{18}{C_B} f_T (f_{xL} - 0.7) - 0.25(2 - f_T)\right]\right\} \quad \text{for } f_{xL} \ge 0.7$$

$K_a = 1 \; (0,15 < f_{XL} < 0,7)$

(Pt3 Ch4 Sec5 pag 47)

f_{yB} = ratio between Y-coordinate of the load point and B_x, to be taken as:

$$f_{yB} = \frac{|2y|}{B_x} \quad \text{but not greater than 1.0}$$

$f_{yB} = 1$ when $B_x = 0$

$F_{yB} = 0 \; (y = 0 \text{ m})$

Table 3 Definition of phase coefficient K_p

f_{xL}	0	$0.3 - 0.1\, f_T$	$0.35 - 0.1\, f_T$	$0.8 - 0.2\, f_T$	$0.9 - 0.2\, f_T$	1.0
k_p	$-0.25\, f_T(1 + f_{yB})$	−1	1	1	−1	−1

$K_p = 1$

C_x = coefficient to be taken as:

$$C_x = 1.5 - \frac{|x - 0.5L|}{L}$$

$C_x = 1,48$

f_{yz} = girth distribution coefficient, to be taken as:

$$f_{yz} = C_x \cdot \frac{z}{T_{LC}} + \left(2 - C_x\right) f_{yB} + 1$$

$F_{yz} = 1$

λ = wave length of the dynamic load case, in m, to be taken as: $\lambda = 0.6(1 + f_T)L$

$\lambda = 392,268$ m

$$P_{HS} = C_{f_T} f_{ps} f_{n\ell} f_h k_a k_p f_{yz} C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

$P_{HS} = 25,18 \text{ KN/m}^2$

Recordando la tabla obtenemos el valor de P_w en la condición HSM-2:

Table 2 Hydrodynamic pressures for HSM load cases

	Wave pressure, in kN/m^2		
Load case	$z \le T_{LC}$	$T_{LC} < z \le h_W + T_{LC}$	$z > h_W + T_{LC}$
HSM-1	$P_W = \max\{-P_{HS}; \rho g(z - T_{LC})\}$	$P_W = P_{W,WL} - \rho g(z - T_{LC})$	$P_W = 0.0$
HSM-2	$P_W = \max\{P_{HS}; \rho g(z - T_{LC})\}$		

$$\rho \times g \times (z - Tlc) = 1{,}025 \times 9{,}81 \times (0 - 16) = -160{,}88\; KN/m^2$$

$P_w = \text{máx}\{25,18 \; ; -160,88\} = 25,18 \text{ KN/m}^2$

La presión debida al mar será:

$$Ps + Pw = 160{,}88 + 25{,}18 = \mathbf{186,\ 064\ KN/m^2}$$

Ahora debemos calcular la presión debida al tanque de lastre, donde en primer lugar es necesario conocer la presión estática y dinámica que se ejercen. Estudiaremos la condición más desfavorable, que será con el tanque lleno.

Presión estática:

(Pt3 Ch6 Sec 2 pag 9)

Internal structures in tanks	INT-1	1	P_{int}	T_{SC}	AC-I	-

La P_{int} está definida, considerando la presión estática y la presión inercial para líquidos:

(Pt3 Ch4 Sec 6 pag77)

1 Pressures due to liquids

1.1 Total pressure

1.1.1 Pressures for the strength and fatigue assessments of intact conditions

The internal pressure due to liquid acting on any load point of a tank and ballast hold boundary, in kN/m^2, for the static (S) design load scenarios, given in Sec.7, shall be taken as:

$$P_{in} = P_{ls} \quad \text{but not less than 0}$$

The internal pressure due to liquid acting on any load point of a tank and ballast hold boundary, in kN/m^2, for the static plus dynamic (S + D) design load scenarios shall be derived for each dynamic load case and shall be taken as:

$$P_{in} = P_{ls} + P_{ld} \quad \text{but not less than 0}$$

where:

P_{ls} = static pressure due to liquid in tanks and ballast holds, in kN/m^2, as defined in [1.2.1] to [1.2.6]
P_{ld} = dynamic inertial pressure due to liquid in tanks and ballast holds, in kN/m^2, as defined in [1.3].

1.2 Static liquid pressure

1.2.1 Normal operations at sea

The static pressure, in kN/m^2, in tanks and ballast holds for normal operations at sea, shall be taken as:

$$P_{ls\text{-}1} = f_{cd}\,\rho_L\,g\left(z_{top} - z\right) + P_{PV} \qquad \text{for tanks arranged with pressure relief valves}$$

$$P_{ls\text{-}1} = \rho_L\,g\left(z_{top} - z\right) \qquad \text{for other cases.}$$

Las alturas a considerar son Z_{TOP} y Z, que son la altura de la parte superior del tanque y la altura de la chapa que estamos dimensionando respectivamente.

$Z_{TOP} = 2{,}5$ m

$Z = 0$ m

Se supondrán los tanques totalmente llenos.

(Pt3 Ch4 Sec 6 pag76)

f_{cd} = factor for joint probability of occurrence of liquid cargo density and maximum sea state in 25 years design life, to be taken as:

f_{cd} = 0.88 for strength assessment with FE analysis of cargo tanks filled with for oil or oil products cargo with $\rho_L \leq 1.025$ t/m^3

f_{cd} = 1.0 for other cases

P_{PV} = design vapour pressure, in kN/m^2, not to be taken less than 25 kN/m^2 and not greater than 70 kN/m^2. Design vapour pressure greater than 70 kN/m^2 may be accepted on a case-by-case basis

Tanque de lastre:

$$P_{\ell s\text{-}1} = f_{cd}\,\rho_L\, g\left(z_{top} - z\right) + P_{PV}$$ for tanks arranged with pressure relief valves

$$Pls - 1 = 1 \times 1{,}015 \times 9{,}81 \times (2{,}5 - 0) + 70 = 95{,}1\ KN/m^2$$

$P_{ls\text{-}1}$ = 95,1 KN/m^2

Presión dinámica:

(Pt3 Ch4 Sec 6 pag 80)

1.3 Dynamic liquid pressure

1.3.1 The dynamic pressure due to liquid in tanks and ballast holds, in kN/m^2 shall be taken as:

$$P_{\ell d} = f_{cd}\,\rho_L\left[a_Z\left(z_0 - z\right) + f_{ull-\ell}\, a_X\left(x_0 - x\right) + f_{ull-t}\, a_Y\left(y_0 - y\right)\right]$$

where:

$f_{ull-\ell}$ = longitudinal acceleration correction factor for the ullage space above the liquid in tanks and ballast holds, taken as:

for strength assessment:

$f_{ull-\ell}$ = 0.62 for cargo tanks filled with any liquids inclusive water ballast

$f_{ull-\ell}$ = 1.0 for other cases

for fatigue assessment:

$$f_{ull-\ell} = 0{,}5 + \frac{\left|z_0 - z\right|}{\ell_{fs}}\frac{180}{\varphi\pi}$$ for cargo tanks and ballast holds

$f_{ull-\ell}$ = 1.0 for other cases

$f_{ull-\ell}$ shall not be less than 0.0 nor greater than 1.0

ℓ_{fs} = cargo tank length at the top of the tank or length of the ballast hold hatch coaming, in m

f_{ull-t} = transverse acceleration correction factor to account for the ullage space above the liquid in tanks and ballast holds, taken as:

for strength assessment:

f_{ull-t} = 0.67 for cargo tanks filled with any liquids inclusive water ballast

f_{ull-t} = 1.0 for other cases

for fatigue assessment:

$$f_{ull-t} = 0{,}5 + \frac{\left|z_0 - z\right|}{b_{top}}\frac{180}{\theta\pi}$$ for cargo tanks and ballast holds

f_{ull-t} = 1.0 for other cases

b_{top} = cargo tank breadth at the top of the tank or breadth of the ballast hold hatch coaming, in m determined at mid length of the tank or ballast hold hatch coaming

x_0 = *X* coordinate, in m, of the reference point

y_0 = *Y* coordinate, in m, of the reference point

z_0 = *Z* coordinate, in m, of the reference point.

The reference point shall be taken as the point with the highest value of V_j, calculated for all points that define the upper boundary of the tank or ballast hold as follows:

$$V_j = a_X(x_j - x_G) + a_Y(y_j - y_G) + (a_Z + g)(z_j - z_G)$$

where:

x_j = X coordinate, in m, of the point j on the upper boundary of the tank or ballast hold
y_j = Y coordinate, in m, of the point j on the upper boundary of the tank or ballast hold
z_j = Z coordinate, in m, of the point j on the upper boundary of the tank or ballast hold.

The following simplified method of determination of the reference point assuming a rectangular shape with area equal A_{top} of the top of the tank or the ballast hold hatch coaming is acceptable, see Figure 1:

$$x_j = x_{top} \pm 0.5\ \ell_{fs}$$

$$y_j = y_{top} \pm 0.5 b_{top}$$

where

x_{top} = X coordinate, in m, of the centre of the rectangular area A_{top} at the top of the tank or the ballast hold hatch coaming
y_{top} = Y coordinate, in m, of the centre of the rectangular area A_{top} at the top of the tank or the ballast hold hatch coaming
A_{top} = $\ell_{fs} \cdot b_{top}$: the area of an rectangular shape at the top of the tank or the ballast hold hatch coaming, in m^2.

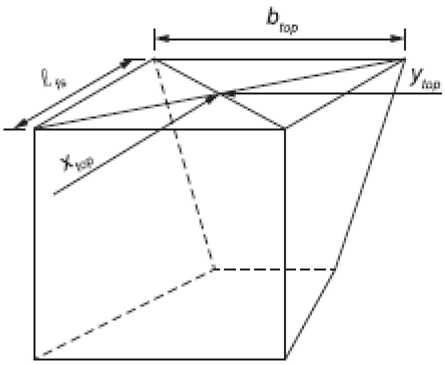


Figure 1 Area of a rectangular shape at the top of a tank

Obtenemos las coordenadas de referencia para los tanques de agua de lastre.

xj1 = 6,3 + 0,5*12,6 = 12,6 m

xj1 = 6,3 - 0,5*12,6 = 0 m

yj1 = 24,8 + 0,5*49,6 = 49,6 m

yj1 = 24,8 - 0,5*49,6 = 0 m

4.4 Cálculo de las aceleraciones

(Pt3 Ch4 Sec3)

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3.2 Accelerations for dynamic load cases

3.2.1 Longitudinal acceleration

The longitudinal acceleration at any position for each dynamic load case, in m/s^2, shall be taken as:

$$a_X = f_\beta\left[\left(-C_{XG}g\sin\varphi\right) + C_{XS}a_{surge} + C_{XP}a_{pitch}(z-R)\right]$$

3.2.2 Transverse acceleration

The transverse acceleration at any position for each dynamic load case, in m/s^2, shall be taken as:

$$a_Y = f_\beta\left[C_{YG}g\sin\theta + C_{YS}a_{sway} - C_{YR}a_{roll}(z-R)\right]$$

3.2.3 Vertical acceleration

The vertical acceleration at any position for each dynamic load case, in m/s^2, shall be taken as:

$$a_Z = f_\beta\left[C_{ZH}a_{heave} + C_{ZR}a_{roll}y - C_{ZP}a_{pitch}(x-0.45L)\right]$$

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a_0 = acceleration parameter, shall be taken as:

$$a_0 = \left(1.58 - 0.47C_B\right)\left(\frac{2.4}{\sqrt{L}} + \frac{34}{L} - \frac{600}{L^2}\right)$$

Donde:

L =323 m

C_B = 0,671

a_o = 0,2953 m/s^2

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2.2.1 Surge acceleration

The longitudinal acceleration due to surge, in m/s^2, shall be taken as:

$$a_{surge} = 0.2\left(1.6 + \frac{1.5}{\sqrt{gL}}\right)f_p a_0 g$$

where:

f_p = coefficient shall be taken as:

$f_p = f_{ps}$ for strength assessment

$f_p = f_R\left[0.27 - \left(15 + 4f_T\right)L \cdot 10^{-5}\right]$ for fatigue assessment.

Donde:

f_p = 1

a_o = 0,2953 m/s^2

a_{surge} = 0,94235 m/s^2

2.2.2 Sway acceleration

The transverse acceleration due to sway, in m/s², shall be taken as:

$$a_{sway} = 0{,}3\left(2{,}25 - \frac{20}{\sqrt{gL}}\right) f_p a_0 g$$

where:

f_p = coefficient shall be taken as:

$f_p = f_{ps}$ for strength assessment

$$a_{away} = 1{,}6484 \text{ m/s}^2$$

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2.2.3 Heave acceleration

The vertical acceleration due to heave, in m/s², shall be taken as:

$$a_{heave} = 0{,}8(1 + 0{,}03v)\left(0{,}72 + \frac{2L}{700}\right)\left(1{,}15 - \frac{6{,}5}{\sqrt{gL}}\right) f_p a_0 g \qquad L < 100 \text{ m}$$

$$a_{heave} = \left(0{,}4 + \frac{L}{250}\right)\left(1 + 0.03v\left(3 - \frac{L}{50}\right)\right)\left(1.15 - \frac{6{,}5}{\sqrt{gL}}\right) f_p a_0 g \qquad 100 \le L < 150 \text{ m}$$

$$a_{heave} = \left(1.15 - \frac{6{,}5}{\sqrt{gL}}\right) f_p a_0 g \qquad L \ge 150 \text{ m}$$

where:

v = unless otherwise specified in Pt.5, to be taken as:

0 kt for $L < 100$ m

5 kt for $L \ge 150$ m

linear interpolation for L between 100 m and 150 m.

f_p = coefficient shall be taken as:

$f_p = f_{ps}$ for strength assessment

$f_p = f_R\left[\left(0{,}27 + 0{,}02 f_T\right) - 17L \cdot 10^{-5}\right]$ for fatigue assessment.

$$a_{heave} = 3 \text{ m/s}^2$$

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2.1.1 Roll motion

The roll period, in s, shall be taken as:

$$T_\theta = \frac{2{,}3\pi k_r}{\sqrt{g\,GM}}$$

The roll angle, in deg, shall be taken as:

$$\theta = \frac{9000\left(1{,}4 - 0{,}035T_\theta\right)f_p f_{BK}}{(1{,}15B + 55)\pi}$$

where:

f_p = coefficient shall be taken as:

$f_p = f_{ps}$ for strength assessment

$f_p = f_R\left(0.23 - 4f_T B \cdot 10^{-4}\right)$ for fatigue assessment

f_{BK} = shall be taken as:

f_{BK} = 1.2 for ships without bilge keel

f_{BK} = 1.0 for ships with bilge keel

k_r = roll radius of gyration, in m, in the considered loading condition. In case k_r has not been calculated, the following values may be used

k_r = 0.39 *B* in general

k_r = 0.35 *B* for tankers in ballast

For fatigue, default values are given in Ch.9.

GM = metacentric height, in m, in the considered loading condition, minimum 0.05 *B*. In case *GM* has not been calculated, the following values may be adopted:

GM = 0.07 *B* in general

GM = 0.12 *B* for tankers

GM = 0.05 *B* for container ship with *B* ≤ 32.2 m

GM = 0.11 *B* for container ship with *B* ≥ 40.0 m

Donde B = 47 m

θ = 22,445 º

T_θ =19,1 s

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2.1.2 Pitch motion

The pitch period, in s, shall be taken as:

$$T_\varphi = \sqrt{\frac{2\pi\lambda_\varphi}{g}}$$

where:

$$\lambda_\varphi = 0{,}6\left(1 + f_T\right)L$$

The pitch angle, in deg, shall be taken as given in formula below and need not to be taken greater than 20 degree.

$$\varphi = 920 f_p L^{-0{,}84}\left\{1{,}0 + \left(\frac{2{,}57}{\sqrt{gL}}\right)^{1{,}2}\right\}$$

where:

f_p = coefficient shall be taken as:

$f_p = f_{ps}$ for strength assessment

$f_p = f_R\left[\left(0{,}27 - 0{,}02f_T\right) - \left(13 - 5f_T\right)\cdot L \cdot 10^{-5}\right]$ for fatigue assessment.

ϕ = 7,28 º

T_ϕ = 15,85 s

2.2.4 Roll acceleration

The roll acceleration, a_{roll}, in rad/s^2, shall be taken as:

$$a_{roll} = f_p \theta \frac{\pi}{180} \left(\frac{2\pi}{T_\theta} \right)^2$$

where:

θ = roll angle in deg, using f_p equal to 1.0

f_p = coefficient shall be taken as:

$f_p = f_{ps}$ for strength assessment

$f_p = f_R \left[0{,}23 - 4 f_T B \cdot 10^{-4} \right]$ for fatigue assessment.

$a_{roll} = 0{,}0424$ m/s^2

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2.2.5 Pitch acceleration

The pitch acceleration, in rad/s^2, shall be taken as:

$$a_{pitch} = 0{,}8(1 + 0{,}05v) f_p \left(0{,}72 + \frac{2L}{700} \right) \left(1{,}75 - \frac{22}{\sqrt{gL}} \right) \varphi \frac{\pi}{180} \left(\frac{2\pi}{T_\varphi} \right)^2 \qquad L < 100 \text{ m}$$

$$a_{pitch} = \left(0{,}4 + \frac{L}{250} \right) \left(1 + 0{,}05v \left(3 - \frac{L}{50} \right) \right) f_p \left(1{,}75 - \frac{22}{\sqrt{gL}} \right) \varphi \frac{\pi}{180} \left(\frac{2\pi}{T_\varphi} \right)^2 \qquad 100 \le L < 150 \text{ m}$$

$$a_{pitch} = f_p \left(1{,}75 - \frac{22}{\sqrt{gL}} \right) \varphi \frac{\pi}{180} \left(\frac{2\pi}{T_\varphi} \right)^2 \qquad L \ge 150 \text{ m}$$

where:

φ = pitch angle in deg, using f_p equal to 1.0

v = as defined in [2.2.3]

f_p = coefficient shall be taken as:

$f_p = f_{ps}$ for strength assessment

$f_p = f_R \left[0{,}28 - (5 + 6 f_T) L \cdot 10^{-5} \right]$ for fatigue assessment.

$a_{pitch} = 0{,}02718$ m/s^2

(Pt3 Ch4 Sec 6 pag 76)

x_G, y_G, z_G = X, Y and Z coordinates, in m, of the volumetric centre of gravity of the tank, considered with respect to the reference coordinate system defined in Sec.1 [1.2]

(Pt3 Ch4 Sec 1 pag 8)

1.2 Definitions

1.2.1 Coordinate system

The coordinate system is defined in Ch.1 Sec.4.

1.2.2 Sign convention for ship motions

The ship motions are defined with respect to the ship's centre of gravity (COG) as shown in Figure 1, where:

- positive surge is translation in the *X*-axis direction (positive forward)
- positive sway is translation in the *Y*-axis direction (positive towards port side of ship)
- positive heave is translation in the *Z*-axis direction (positive upwards)
- positive roll motion is positive rotation about a longitudinal axis through the COG (starboard down and port up)
- positive pitch motion is positive rotation about a transverse axis through the COG (bow down and stern up)
- positive yaw motion is positive rotation about a vertical axis through the COG (bow moving to port and stern to starboard).

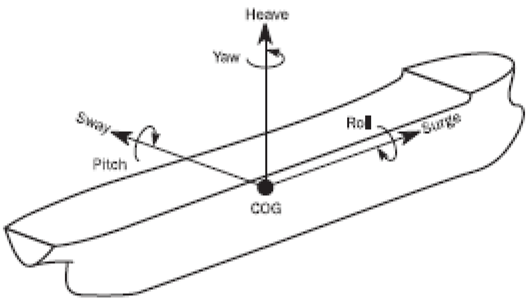


Figure 1 Definition of positive motions

Para los siguientes coeficientes se ha elegido la condición dinámica HSM-2 que maximiza el momento flector vertical por las olas en la parte media del buque:

(Pt3 Ch4 Sec 2 pag 18)

2.2 Load combination factors

2.2.1 The load combinations factors (LCFs) for the global loads and inertia load components for strength assessment are defined in:

— Table 4: LCFs for HSM, HSA and FSM load cases.
— Table 5: LCFs for BSR and BSP load cases.
— Table 6: LCFs for OST and OSA load cases.

Table 4 Load combination factors for HSM, HSA and FSM load cases - strength assessment

Load component		*LCF*	*HSM-1*	*HSM-2*	*HSA-1*	*HSA-2*	*FSM-1*	*FSM-2*
Hull girder loads	M_{WV}	C_{WV}	−1	1	−0.7	0.7	$-0.4f_T - 0.6$	$0.4f_T + 0.6$
	Q_{WV}	C_{QW}	$-1.0f_{tp}$	$1.0f_{tp}$	$-0.6f_{tp}$	$0.6f_{tp}$	$-1.0f_{tp}$	$1.0f_{tp}$
	M_{WH}	C_{WH}	0	0	0	0	0	0
	M_{WT}	C_{WT}	0	0	0	0	0	0
Longitudinal accelerations	a_{surge}	C_{XS}	$0.6 - 0.2f_T$	$0.2f_T - 0.6$	0.2	−0.2	$0.2 - 0.4f_T$	$0.4f_T - 0.2$
	$a_{pitch\text{-}x}$	C_{XP}	$-0.15\text{-}L_1/300$	$0.15+L_1/300$	−1.0	1.0	0.15	−0.15
	$g\ \sin\varphi$	C_{XG}	0.6	−0.6	$0.4f_T + 0.1$	$-0.4f_T - 0.1$	−0.2	0.2
Transverse accelerations	a_{sway}	C_{YS}	0	0	0	0	0	0
	$a_{roll\text{-}y}$	C_{YR}	0	0	0	0	0	0
	$g\ \sin\theta$	C_{YG}	0	0	0	0	0	0
Vertical accelerations	a_{heave}	C_{ZH}	$0.5f_T - 0.15$	$0.15 - 0.5f_T$	0.4	−0.4	0	0
	$a_{roll\text{-}z}$	C_{ZR}	0	0	0	0	0	0
	$a_{pitch\text{-}z}$	C_{ZP}	−0.7	0.7	−1.0	1.0	0.15	−0.15

Los parámetros que obtenemos de la tabla son los siguientes:

Cxg	-0,6
Cxs	-0,1
Cxp	0,7
Cyg	0
Cys	0
Cyr	0
Czh	-0,35
Czr	0
Czp	0,7

(Pt3 Ch4 Sec3 pag 27)

R = vertical coordinate, in m, of the ship rotation centre, shall be taken as:

$$R = \min\left(\frac{D}{4} + \frac{T_{LC}}{2}, \frac{D}{2}\right)$$

Donde:

D = 30,5 m

T_{LC} = 16 m

R = 15,25 m

f_β = heading correction factor, shall be taken as:

for strength assessment:

f_β = 1.0 in general

f_β = 0.8 for BSR and BSP load cases for the extreme sea loads design load scenario

for fatigue assessment:

f_β = 1.0

$f_\beta = 1$

Para obtener el valor de las coordenadas “x” e “y” se tomará como puntos de referencia el centro de gravedad del buque (lo consideramos a la mitad de la eslora y del puntal):

XG_{buque} = 333/2 = 166,5 m

KG_{buque} = 28/2 = 14 m

Teniendo en cuenta que nuestra sección más representativa será la correspondiente a la bodega 9, el centro de gravedad de la maestra es el siguiente

$XG_{maestra}$ = 183 m

$KG_{maestra}$ = 28/3 = 9,33 m

Por lo que las coordenadas serán:

X = $XG_{maestra}$ - XG_{buque} = 16,5 m

Z = $KG_{maestra}$ - KG_{buque} = - 4,67 m

Recordando las fórmulas de las aceleraciones y los parámetros obtenidos anteriormente:

3.2 Accelerations for dynamic load cases

3.2.1 Longitudinal acceleration

The longitudinal acceleration at any position for each dynamic load case, in m/s^2, shall be taken as:

$$a_X = f_\beta\left[\left(-C_{XG}g\sin\varphi\right) + C_{XS}a_{surge} + C_{XP}a_{pitch}(z-R)\right]$$

3.2.2 Transverse acceleration

The transverse acceleration at any position for each dynamic load case, in m/s^2, shall be taken as:

$$a_Y = f_\beta\left[C_{YG}g\sin\theta + C_{YS}a_{sway} - C_{YR}a_{roll}(z-R)\right]$$

3.2.3 Vertical acceleration

The vertical acceleration at any position for each dynamic load case, in m/s^2, shall be taken as:

$$a_Z = f_\beta\left[C_{ZH}a_{heave} + C_{ZR}a_{roll}y - C_{ZP}a_{pitch}(x-0.45L)\right]$$

Cxg	-0,6
Cxs	-0,1
Cxp	0,7
Cyg	0
Cys	0
Cyr	0
Czh	-0,35
Czr	0
Czp	0,7

f_{ps}	1
L	323
C_B	0,671
D	28
T_{LC}	16
R	15,25
θ	22,445
T_θ	19,1
φ	7,28
T_φ	15,85
a_o	0,2953
a_{surge}	0,94235
a_{away}	1,6484

a_{heave}	3
a_{pitch}	0,02718
a_{roll}	0,0424

ax = 0,2635 m/s²

ay = 0 m/s²

az =1,5 m/s²

Recordando el valor de la presión dinámica P_{ld} :

1.3 Dynamic liquid pressure

1.3.1 The dynamic pressure due to liquid in tanks and ballast holds, in kN/m² shall be taken as:

$$P_{\ell d} = f_{cd}\,\rho_L\left[a_Z(z_0 - z) + f_{ull-\ell}\,a_X(x_0 - x) + f_{ull-t}\,a_Y(y_0 - y)\right]$$

where:

$f_{ull-\ell}$ = longitudinal acceleration correction factor for the ullage space above the liquid in tanks and ballast holds, taken as:

for strength assessment:

$f_{ull-\ell}$ = 0.62 for cargo tanks filled with any liquids inclusive water ballast

$f_{ull-\ell}$ = 1.0 for other cases

for fatigue assessment:

$$f_{ull-\ell} = 0.5 + \frac{|z_0 - z|}{\ell_{fs}}\frac{180}{\varphi\pi}$$ for cargo tanks and ballast holds

$f_{ull-\ell}$ = 1.0 for other cases

$f_{ull-\ell}$ shall not be less than 0.0 nor greater than 1.0

ℓ_{fs} = cargo tank length at the top of the tank or length of the ballast hold hatch coaming, in m

f_{ull-t} = transverse acceleration correction factor to account for the ullage space above the liquid in tanks and ballast holds, taken as:

for strength assessment:

f_{ull-t} = 0.67 for cargo tanks filled with any liquids inclusive water ballast

f_{ull-t} = 1.0 for other cases

for fatigue assessment:

$$f_{ull-t} = 0.5 + \frac{|z_0 - z|}{b_{top}}\frac{180}{\theta\pi}$$ for cargo tanks and ballast holds

f_{ull-t} = 1.0 for other cases

b_{top} = cargo tank breadth at the top of the tank or breadth of the ballast hold hatch coaming, in m determined at mid length of the tank or ballast hold hatch coaming

x_0 = *X* coordinate, in m, of the reference point

y_0 = *Y* coordinate, in m, of the reference point

z_0 = *Z* coordinate, in m, of the reference point.

P_{ld} = 13,727 KN/m²

Recordando que la expresión que definía el espesor de la chapa en función de la presión es:

(Pt3 Ch6 Sec4 pag 16)

1.1 General

1.1.1 Plating

The net thickness, in mm, shall not be taken less than the greatest value for all applicable design load sets, as defined in Sec.2 [2.1.3], given by:

$$t = 0.0158\alpha_p b\sqrt{\frac{|P|}{C_a R_{eH}}}$$

where:

C_a = permissible bending stress coefficient for plate taken equal to:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{R_{eH}}$$ not to be taken greater than $C_{a\text{-}max}$

β_a = coefficient as defined in Table 1

α_a = coefficient as defined in Table 1

$C_{a\text{-}max}$ = maximum permissible bending stress coefficient as defined in Table 1.

Donde:

b = lado corto de la chapa = 900 mm

a = lado largo de la chapa = 2700 mm

R_{eh} = 235 MPa

σ_{Hg} = 205 N/mm^2

Acceptance criteria	Structural member		β_a	α_a	$C_{a\text{-}max}$
AC-II	Longitudinal members	Longitudinal stiffened plating	1.05	0.50	0.95
		Transverse stiffened plating	1.05	1.00	0.95
	Other members		0.95	0.00	0.95

β_a = 1,05

α_a = 0,5

$C_{a\text{-}max}$ = 0,95

Obtenemos los siguientes resultados:

C_a = 0,61 < $C_{a\text{-}max}$ = 0,95

α_p = 1

P = presión más alta que deberá soportar la chapa. De las presiones obtenidas anteriormente la mayor correspondía a las ejercida por el mar, con un valor de **186 KN/m²**.

$$t = 0{,}0158 \times 1 \times 900 \times \sqrt{\frac{186}{0{,}61 \times 235}}$$

t = 16,2 mm

Como t min = 16 mm (calculado anteriormente), vemos que cumple el espesor mínimo.

4.5 Chapa del doble fondo

Esta chapa está a una altura de 2,5 m de altura sobre la línea base, y debe soportar el peso de los contenedores por encima y las cargas de los tanques de lastre, pero no las cargas del mar, ya que no está expuesto al mismo.

Para calcularlas presiones que ejercen los líquidos de los tanques seguimos la misma metodología que en la chapa del fondo anteriormente descrita, donde supondremos los tanques llenos como condición más desfavorable.

(Pt3 Ch4 Sec6 pag 77)

1 Pressures due to liquids

1.1 Total pressure

1.1.1 Pressures for the strength and fatigue assessments of intact conditions

The internal pressure due to liquid acting on any load point of a tank and ballast hold boundary, in kN/m^2, for the static (S) design load scenarios, given in Sec.7, shall be taken as:

$$P_{in} = P_{ls} \quad \text{but not less than 0}$$

The internal pressure due to liquid acting on any load point of a tank and ballast hold boundary, in kN/m^2, for the static plus dynamic (S + D) design load scenarios shall be derived for each dynamic load case and shall be taken as:

$$P_{in} = P_{ls} + P_{ld} \quad \text{but not less than 0}$$

where:

$P_{\ell s}$ = static pressure due to liquid in tanks and ballast holds, in kN/m^2, as defined in [1.2.1] to [1.2.6]

$P_{\ell d}$ = dynamic inertial pressure due to liquid in tanks and ballast holds, in kN/m^2, as defined in [1.3].

Presión estática:

(Pt3 Ch4 Sec6 pag 77)

1.2 Static liquid pressure

1.2.1 Normal operations at sea

The static pressure, in kN/m^2, in tanks and ballast holds for normal operations at sea, shall be taken as:

$P_{\ell s\text{-}1} = f_{cd}\,\rho_L\, g\left(z_{top} - z\right) + P_{PV}$ for tanks arranged with pressure relief valves

$P_{\ell s\text{-}1} = \rho_L\, g\left(z_{top} - z\right)$ for other cases.

(Pt3 Ch4 Sec6 pag 76)

f_{cd} = factor for joint probability of occurrence of liquid cargo density and maximum sea state in 25 years design life, to be taken as:

- $f_{cd} = 0.88$ for strength assessment with FE analysis of cargo tanks filled with for oil or oil products cargo with $\rho_L \leq 1.025$ t/m^3
- $f_{cd} = 1.0$ for other cases

P_{PV} = design vapour pressure, in kN/m^2, not to be taken less than 25 kN/m^2 and not greater than 70 kN/m^2. Design vapour pressure greater than 70 kN/m^2 may be accepted on a case-by-case basis

Tanque de lastre:

$$Pls - 1 = \rho \times g \times (Ztop - Z) = 1{,}025 \times 9{,}81 \times (2{,}5 - 0)$$

$P_{ls\text{-}1}$ = 25,2 KN/m^2

Presión dinámica:

(Pt3 Ch4 Sec6 pag80)

1.3 Dynamic liquid pressure

1.3.1 The dynamic pressure due to liquid in tanks and ballast holds, in kN/m^2 shall be taken as:

$$P_{\ell d} = f_{cd}\,\rho_L\left[a_Z(z_0 - z) + f_{ull-\ell}\,a_X(x_0 - x) + f_{ull-t}\,a_Y(y_0 - y)\right]$$

where:

$f_{ull\text{-}\ell}$ = longitudinal acceleration correction factor for the ullage space above the liquid in tanks and ballast holds, taken as:

for strength assessment:

$f_{ull\text{-}\ell}$ = 0.62 for cargo tanks filled with any liquids inclusive water ballast

$f_{ull\text{-}\ell}$ = 1.0 for other cases

for fatigue assessment:

$$f_{ull-\ell} = 0.5 + \frac{|z_0 - z|}{\ell_{fs}}\frac{180}{\varphi\pi} \quad \text{for cargo tanks and ballast holds}$$

$f_{ull\text{-}\ell}$ = 1.0 for other cases

$f_{ull\text{-}\ell}$ shall not be less than 0.0 nor greater than 1.0

ℓ_{fs} = cargo tank length at the top of the tank or length of the ballast hold hatch coaming, in m

$f_{ull\text{-}t}$ = transverse acceleration correction factor to account for the ullage space above the liquid in tanks and ballast holds, taken as:

for strength assessment:

$f_{ull\text{-}t}$ = 0.67 for cargo tanks filled with any liquids inclusive water ballast

$f_{ull\text{-}t}$ = 1.0 for other cases

for fatigue assessment:

$$f_{ull-t} = 0{,}5 + \frac{|z_0 - z|}{b_{top}}\frac{180}{\theta\pi} \quad \text{for cargo tanks and ballast holds}$$

$f_{ull\text{-}t}$ = 1.0 for other cases

b_{top} = cargo tank breadth at the top of the tank or breadth of the ballast hold hatch coaming, in m determined at mid length of the tank or ballast hold hatch coaming

x_0 = *X* coordinate, in m, of the reference point

y_0 = *Y* coordinate, in m, of the reference point

z_0 = *Z* coordinate, in m, of the reference point.

$$Pld = 1 \times 1{,}025 \times [1{,}5 \times (1{,}25 - (-5{,}15) + 0{,}62 \times 0{,}2635 \times (24{,}8 - 13) + 0{,}67 \times 0 \times (0 - 0)]$$

P_{ld} = 7,96 KN/m^2

Presión de los tanques de lastre:

Pld + Pls-1 = 7,96 + 25,2 =33,16 KN/m^2

<u>Presión de los TEUS sobre el doble fondo:</u>

Teniendo en cuenta que la sección que estamos estudiando es la correspondiente a la bodega 9 el resultado de la presión ejercida por los TEUs será:

A = Superficie de la bodega = 12,6*45 = 567 m^2

Peso de un TEU = 23 t

Número de TEUS = 384 TEUS

m = Peso total = 384 * 23 = 8832 t

F = m * g = 8832 * 9,81 = 86641,92 KN

$$P = F/A = 86641,92/567 = 152,8\ KN/m^2$$

$$P_{TEUS} = 152,8\ KN/m^2$$

Observamos que la presión debida a los TEUS sobre la cara superior de la chapa es muy superior a la que ejercen los tanques de lastre, por lo que en la formula del espesor en función a la presión emplearemos la presión mayor, que en este caso es la P_{TEUS} = 152,8 KN/m^2.

Ahora calcularemos el espesor en función de la presión:

(Pt3 Ch6 Sec4 pag16)

SECTION 4 PLATING

Symbols

For symbols not defined in this section, see Ch.1 Sec.4.

α_p = correction factor for the panel aspect ratio to be taken as follows but not to be taken greater than 1.0:

$$\alpha_p = 1{,}2 - \frac{b}{2{,}1\,a}$$

a = length of plate panel, in mm, as defined in Ch.3 Sec.7 [2.1.1]

b = breadth of plate panel, in mm, as defined in Ch.3 Sec.7 [2.1.1]

P = design pressure for the considered design load set, see Sec.2 [2], calculated at the load calculation point defined in Ch.3 Sec.7 [2.2], in kN/m^2

σ_{hg} = hull girder longitudinal stress, in N/mm^2, as defined in Sec.2 [1], calculated at the load calculation point as defined in Ch.3 Sec.7 [2.2].

1 Plating subjected to lateral pressure

1.1 General

1.1.1 Plating

The net thickness, in mm, shall not be taken less than the greatest value for all applicable design load sets, as defined in Sec.2 [2.1.3], given by:

$$t = 0{,}0158\alpha_p b\sqrt{\frac{|P|}{C_a R_{eH}}}$$

where:

C_a = permissible bending stress coefficient for plate taken equal to:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{R_{eH}}$$ not to be taken greater than $C_{a\text{-}max}$

β_a = coefficient as defined in Table 1

α_a = coefficient as defined in Table 1

$C_{a\text{-}max}$ = maximum permissible bending stress coefficient as defined in Table 1.

Donde:

b = lado corto de la chapa = 900 mm

a = lado largo de la chapa = 2700 mm

R_{eh} = 235 MPa

σ_{Hg} = 205 N/mm^2

(Pt3 Ch6 Sec4 pag17)

Acceptance criteria	Structural member		β_a	α_a	$C_{a\text{-}max}$
AC-II	Longitudinal members	Longitudinal stiffened plating	1.05	0.50	0.95
		Transverse stiffened plating	1.05	1.00	0.95
	Other members		0.95	0.00	0.95

$\beta_a = 1{,}05$

$\alpha_a = 0{,}5$

$C_{a\text{-}max} = 0{,}95$

Obtenemos los siguientes resultados:

$C_a = 0{,}61 < C_{a\text{-}max} = 0{,}95$

$\alpha_p = 1$

P = presión mas alta que deberá soportar la chapa. De las presiones obtenidas anteriormente la mayor correspondía a las ejercida por los TEUS, con un valor de **152,8 KN/m²**.

$$t = 0{,}0158 \times 1 \times 900 \times \sqrt{\frac{152{,}8}{0{,}61 \times 235}}$$

t = 14,68 mm

Como t min = 11 mm (calculado anteriormente), vemos que cumple el espesor mínimo.

4.6 Chapa del costado

Para el cálculo de las presiones en el costado se distinguirán dos secciones

1. Presión externa debida al mar, hasta el calado de verano
2. Presión interna debida al tanque de lastre situado en el doble casco

Presión externa debida al mar:

(Pt3 Ch4 Sec5 pag48)

1.2 Hydrostatic pressure

1.2.1 The hydrostatic pressure, P_S at any load point, in kN/m^2, is obtained from Table 1. See also Figure 1.

Table 1 Hydrostatic pressure, PS

Location	Hydrostatic pressure, P_S, in kN/m^2
$z \le T_{LC}$	$\rho g\ (T_{LC}-z)$
$z > T_{LC}$	0

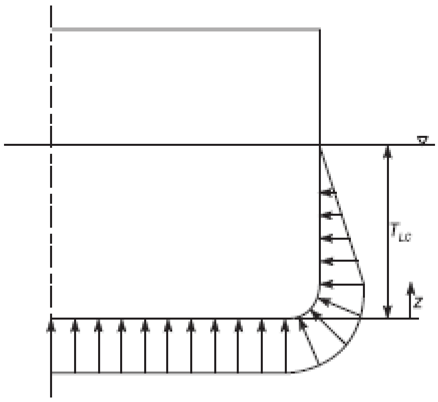


Figure 1 Transverse distribution of hydrostatic pressure Ps

(Pt3 Ch4 Sec3 pag27)

T_{LC} = draught, in m, amidships for the considered loading condition. In case loading condition is not defined, $T_{LC} = T_{SC}$ shall be applied

$$Ps = 1{,}025 \times 9{,}81 \times (16 - 2{,}5)$$

Ps = 135,74 KN/m^2

Presión inercial debida al mar:

(Pt3 Ch4 Sec5 pag49)

Table 2 Hydrodynamic pressures for HSM load cases

	Wave pressure, in kN/m²		
Load case	$z \le T_{LC}$	$T_{LC} < z \le h_W + T_{LC}$	$z > h_W + T_{LC}$
HSM-1	$P_W = \max\left(-P_{HS};\rho g(z - T_{LC})\right)$	$P_W = P_{W,WL} - \rho g(z - T_{LC})$	$P_W = 0.0$
HSM-2	$P_W = \max\left(P_{HS};\rho g(z - T_{LC})\right)$		

where:

$$P_{HS} = C_{f_T} f_{ps} f_{nl} f_h k_a k_p f_{yz} C_W \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

C_{fT} = $f_T + 0.5 - (0.7f_T - 0.2)C_B$

f_{nl} = coefficient considering non-linear effects, to be taken as:
for extreme sea loads design load scenario:
$f_{nl} = 0.7$ at $f_{xL} = 0$
$f_{nl} = 0.9$ at $f_{xL} = 0.3$
$f_{nl} = 0.9$ at $f_{xL} = 0.7$
$f_{nl} = 0.6$ at $f_{xL} = 1$
for ballast water exchange design load scenario:
$f_{nl} = 0.85$ at $f_{xL} = 0$
$f_{nl} = 0.95$ at $f_{xL} = 0.3$
$f_{nl} = 0.95$ at $f_{xL} = 0.7$
$f_{nl} = 0.80$ at $f_{xL} = 1$
Intermediate values are obtained by linear interpolation

f_{yz} = girth distribution coefficient, to be taken as:

$$f_{yz} = C_x \cdot \frac{z}{T_{LC}} + \left(2 - C_x\right) f_{yB} + 1$$

C_x = coefficient to be taken as:

$$C_x = 1.5 - \frac{|x - 0.5L|}{L}$$

f_h = coefficient to be taken as:

$$f_h = 3{,}0\left(1{,}21 - 0{,}66 f_T\right)$$

k_a = amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$$k_a = (0.5 + f_T)\left[\left(3 - 2\sqrt{f_{yB}}\right) - \frac{20}{9} f_{xL}\left(7 - 6\sqrt{f_{yB}}\right)\right] + \frac{2}{3}(1 - f_T) \quad \text{for } f_{xL} < 0.15$$

$$k_a = 1.0 \quad \text{for } 0.15 \le f_{xL} < 0.7$$

$$k_a = 1 + (f_{xL} - 0{,}7)\left[\left(\frac{40}{3} f_T - 5\right) + 2\left(1 - f_{yB}\right)\left[\frac{10}{C_B} f_T (f_{xL} - 0{,}7) - 0{,}25(2 - f_T)\right]\right] \quad \text{for } f_{xL} \ge 0.7$$

λ = wave length of the dynamic load case, in m, to be taken as: $\lambda = 0.6(1 + f_T)L$

Cálculo de P_{HS}:

C_{fT} = $f_T + 0.5 - (0.7f_T - 0.2)C_B$

$C_{fT} = 1{,}1783$

f_T = ratio between draught at a loading condition and scantling draught, shall be taken as:

$f_T = \frac{T_{LC}}{T_{SC}}$, but shall not be taken less than 0.5

$f_T = 1$

f_{ps} = coefficient for strength assessments which is dependant on the applicable design load scenario specified in Sec.7, and shall be taken as:

f_{ps} = 1.0 for extreme sea loads design load scenario
f_{ps} = f_r for extreme sea loads design load scenario for vessels with service restriction
f_{ps} = 0.8 for the ballast water exchange design load scenario
f_{ps} = $0.8 \cdot f_r$ for the ballast water exchange design load scenario for vessels with service restriction

$f_{PS} = 1$

f_h = coefficient to be taken as:

$f_h = 3.0(1.21 - 0.66 f_T)$

$f_h = 1{,}65$

f_{xL} = ratio between X-coordinate of the load point and L, to be taken as:

$f_{xL} = \frac{x}{L}$, but shall not be taken less than 0.0 or greater than 1.0

$f_{XL} = 0{,}52$ (x = 170 m)

$f_{n\ell}$ = coefficient considering non-linear effects, to be taken as:
for extreme sea loads design load scenario:
f_{nl} = 0.7 at f_{xL} = 0
f_{nl} = 0.9 at f_{xL} = 0.3
f_{nl} = 0.9 at f_{xL} = 0.7
f_{nl} = 0.6 at f_{xL} = 1
for ballast water exchange design load scenario:
f_{nl} = 0.85 at f_{xL} = 0
f_{nl} = 0.95 at f_{xL} = 0.3
f_{nl} = 0.95 at f_{xL} = 0.7
f_{nl} = 0.80 at f_{xL} = 1
Intermediate values are obtained by linear interpolation

$f_{nl} = 0{,}9$

k_a = amplitude coefficient in the longitudinal direction of the ship, to be taken as:

$$k_a = (0.5 + f_T)\left[\left(3 - 2\sqrt{f_{yB}}\right) - \frac{20}{9} f_{xL}\left(7 - 6\sqrt{f_{yB}}\right)\right] + \frac{2}{3}(1 - f_T) \quad \text{for } f_{xL} < 0.15$$

$$k_a = 1.0 \quad \text{for } 0.15 \le f_{xL} < 0.7$$

$$k_a = 1 + (f_{xL} - 0.7)\left\{\left(\frac{40}{3} f_T - 5\right) + 2\left(1 - f_{yB}\right)\left[\frac{18}{C_B} f_T (f_{xL} - 0.7) - 0.25(2 - f_T)\right]\right\} \quad \text{for } f_{xL} \ge 0.7$$

$K_a = 1$ ($0{,}15 < f_{XL} < 0{,}7$)

(Pt3 Ch4 Sec5 pag 47)

f_{yB} = ratio between Y-coordinate of the load point and B_x, to be taken as:

$$f_{yB} = \frac{|2y|}{B_x} \quad \text{but not greater than 1.0}$$

$f_{yB} = 1$ when $B_x = 0$

$F_{yB} = 0$ (y = 0 m)

Table 3 Definition of phase coefficient K_p

f_{xL}	0	$0.3 - 0.1\ f_T$	$0.35 - 0.1\ f_T$	$0.8 - 0.2\ f_T$	$0.9 - 0.2\ f_T$	1.0
k_p	$-0.25\ f_T(1 + f_{yB})$	−1	1	1	−1	−1

$K_p = 1$

C_x = coefficient to be taken as:

$$C_x = 1.5 - \frac{|x - 0.5L|}{L}$$

$C_x = 1,48$

f_{yz} = girth distribution coefficient, to be taken as:

$$f_{yz} = C_x \cdot \frac{z}{T_{LC}} + \left(2 - C_x\right) f_{yB} + 1$$

Donde:

z = 2,5 m

$f_{yz} = 1,23$

λ = wave length of the dynamic load case, in m, to be taken as: $\lambda = 0.6(1 + f_T)L$

λ = 392,268 m

$$P_{HS} = C_{f_T} f_{ps} f_{n\ell} f_h k_a k_p f_{yz} C_w \sqrt{\frac{L_0 + \lambda - 125}{L}}$$

$P_{HS} = 25,35\ KN/m^2$

Recordando la tabla obtenemos el valor de P_w en la condición HSM-2:

Table 2 Hydrodynamic pressures for HSM load cases

	Wave pressure, in kN/m^2		
Load case	$z \le T_{LC}$	$T_{LC} < z \le h_W + T_{LC}$	$z > h_W + T_{LC}$
HSM-1	$P_W = \max\{-P_{HS}; \rho g(z - T_{LC})\}$	$P_W = P_{W,WL} - \rho g(z - T_{LC})$	$P_W = 0.0$
HSM-2	$P_W = \max\{P_{HS}; \rho g(z - T_{LC})\}$		

$$\rho \times g \times (z - Tlc) = 1{,}025 \times 9{,}81 \times (2{,}5 - 16) = -135{,}74\ KN/m^2$$

P_w = máx{25,35 ; -135,74} = 25,35 KN/m²

La presión debida al mar será:

Ps + Pw = 135,74 + 25,35 = **161,09 KN/m²**

Presión debida al tanque de lastre:

(Pt3 Ch6 Sec2 pag 9)

Boundaries of water ballast tanks and ballast holds	WB-1[5)]	2[5)]	$P_{ls\text{-}1} + P_{ld} - (P_S + P_W)^{1)}$	T_{BAL}	AC-II	Normal ballast condition
	WB-2	3	$P_{ls\text{-}2} + P_{ld} - (P_S + P_W)^{1)}$	T_{BAL}	AC-II	Normal ballast condition
	WB-3	4	$\max(P_{ls\text{-}4}; P_{ls\text{-}ST}) - P_S^{1)}$	$\min(T_{BAL}; 0.25T_{SC})$	AC-III	-
	WB-4[5)]	1[5)]	$P_{ls\text{-}3} - P_S^{1)}$	T_{BAL}	AC-I	-

(Pt3 Ch4 Sec6 pag 77)

1.2 Static liquid pressure

1.2.1 Normal operations at sea

The static pressure, in kN/m², in tanks and ballast holds for normal operations at sea, shall be taken as:

$$P_{ls\text{-}1} = f_{cd}\,\rho_L\, g\left(z_{top} - z\right) + P_{PV}$$ for tanks arranged with pressure relief valves

$$P_{ls\text{-}1} = \rho_L\, g\left(z_{top} - z\right)$$ for other cases.

$$Pls - 1 = \rho \times g \times (Ztop - Z) = 1{,}025 \times 9{,}81 \times (16 - 2{,}5)$$

$P_{ls\text{-}1}$ = 135,746 KN/m²

Obtenemos las coordenadas de referencia para los tanques de agua de lastre.

xj1 = 6,3 + 0,5*12,6 = 12,6 m

xj1 = 6,3 - 0,5*12,6 = 0 m

yj1 = 1,25 + 0,5*2,5 = 2,5 m

yj1 = 1,25 - 0,5*2,5 = 0 m

(Pt3 Ch4 Sec6 pag 80)

$$V_j = a_X\left(x_j - x_G\right) + a_Y\left(y_j - y_G\right) + \left(a_Z + g\right)\left(z_j - z_G\right)$$

Recordando los valores de las aceleraciones obtenidas anteriormente:

a_x = 0,2935 m/s²

a_y = 0 m/s²

a_z = 1,5 m/s²

V_{j1} = 1,66

V_{j2} = -1,66

Por lo que el valor de P_{ld} será:

(Pt3 Ch4 Sec6 pag80)

1.3 Dynamic liquid pressure

1.3.1 The dynamic pressure due to liquid in tanks and ballast holds, in kN/m² shall be taken as:

$$P_{\ell d} = f_{cd}\,\rho_L\left[a_Z\left(z_0 - z\right) + f_{ull-\ell}\,a_X\left(x_0 - x\right) + f_{ull-t}\,a_Y\left(y_0 - y\right)\right]$$

where:

$f_{ull\text{-}\ell}$ = longitudinal acceleration correction factor for the ullage space above the liquid in tanks and ballast holds, taken as:

for strength assessment:

$f_{ull\text{-}\ell}$ = 0.62 for cargo tanks filled with any liquids inclusive water ballast

$f_{ull\text{-}\ell}$ = 1.0 for other cases

for fatigue assessment:

$$f_{ull-\ell} = 0.5 + \frac{\left|z_0 - z\right|}{\ell_{fs}}\frac{180}{\varphi\pi}$$ for cargo tanks and ballast holds

$f_{ull\text{-}\ell}$ = 1.0 for other cases

$f_{ull\text{-}\ell}$ shall not be less than 0.0 nor greater than 1.0

ℓ_{fs} = cargo tank length at the top of the tank or length of the ballast hold hatch coaming, in m

$f_{ull\text{-}t}$ = transverse acceleration correction factor to account for the ullage space above the liquid in tanks and ballast holds, taken as:

for strength assessment:

$f_{ull\text{-}t}$ = 0.67 for cargo tanks filled with any liquids inclusive water ballast

$f_{ull\text{-}t}$ = 1.0 for other cases

for fatigue assessment:

$$f_{ull-t} = 0.5 + \frac{\left|z_0 - z\right|}{b_{top}}\frac{180}{\theta\pi}$$ for cargo tanks and ballast holds

$f_{ull\text{-}t}$ = 1.0 for other cases

b_{top} = cargo tank breadth at the top of the tank or breadth of the ballast hold hatch coaming, in m determined at mid length of the tank or ballast hold hatch coaming

x_0 = X coordinate, in m, of the reference point

y_0 = Y coordinate, in m, of the reference point

z_0 = Z coordinate, in m, of the reference point.

$$Pld = 1 \times 1{,}025 \times [1{,}5 \times (16 - (-5{,}15) + 0{,}62 \times 0{,}2635 \times (24{,}8 - 13) + 0{,}67 \times 0 \times (0 - 0)]$$

P_{ld} = 34,48 KN/m²

Por lo que la presión que ejerce el interior del tanque será:

$P = P_{ls\text{-}1} + P_{ld} - P_{mar}$ = 135,746 + 34,48 – 161,09

P = 9,135 KN/m²

Recordando que la expresión que definía el espesor de la chapa en función de la presión es:

(Pt3 Ch6 Sec4 pag 16)

1.1 General

1.1.1 Plating

The net thickness, in mm, shall not be taken less than the greatest value for all applicable design load sets, as defined in Sec.2 [2.1.3], given by:

$$t = 0.0158\alpha_p b \sqrt{\frac{|P|}{C_a R_{eH}}}$$

where:

C_a = permissible bending stress coefficient for plate taken equal to:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{R_{eH}}$$ not to be taken greater than $C_{a\text{-}max}$

β_a = coefficient as defined in Table 1

α_a = coefficient as defined in Table 1

$C_{a\text{-}max}$ = maximum permissible bending stress coefficient as defined in Table 1.

Donde:

b = lado corto de la chapa = 900 mm

a = lado largo de la chapa = 2700 mm

R_{eh} = 235 MPa

σ_{Hg} = 205 N/mm^2

Acceptance criteria	Structural member		β_a	α_a	$C_{a\text{-}max}$
AC-II	Longitudinal members	Longitudinal stiffened plating	1.05	0.50	0.95
		Transverse stiffened plating	1.05	1.00	0.95
	Other members		0.95	0.00	0.95

β_a = 1,05

α_a = 0,5

$C_{a\text{-}max}$ = 0,95

Obtenemos los siguientes resultados:

C_a = 0,61 < $C_{a\text{-}max}$ = 0,95

α_p = 1

P = presión más alta que deberá soportar la chapa. De las presiones obtenidas anteriormente la mayor correspondía a las ejercida por el mar, con un valor de **161,09 KN/m²**.

$$t = 0{,}0158 \times 1 \times 900 \times \sqrt{\frac{161{,}09}{0{,}61 \times 235}}$$

t = 15 mm

Como t min = 7,2689 mm (calculado anteriormente), vemos que cumple el espesor mínimo.

En la zona del costado por el interior del tanque de lastre tenemos:

P = presión más alta que deberá soportar la chapa, con un valor de **(135,746 + 34,48) = 170,226 KN/m²**.

$$t = 0{,}0158 \times 1 \times 900 \times \sqrt{\frac{170{,}226}{0{,}61 \times 235}}$$

t = 15,5 mm

Como t min = 7,2689 mm (calculado anteriormente), vemos que cumple el espesor mínimo.

4.7 Mamparos

(Pt3 Ch6 Sec2 pag 9)

Boundaries of water ballast tanks and ballast holds	WB-1[5)]	2[5)]	$P_{ls\text{-}1} + P_{ld} - (P_S + P_W)$[1)]	T_{BAL}	AC-II	Normal ballast condition
	WB-2	3	$P_{ls\text{-}2} + P_{ld} - (P_S + P_W)$[1)]	T_{BAL}	AC-II	Normal ballast condition
	WB-3	4	$\max(P_{ls\text{-}4}; P_{ls\text{-}ST}) - P_S$[1)]	$\min(T_{BAL}; 0.25T_{SC})$	AC-III	-
	WB-4[5)]	1[5)]	$P_{ls\text{-}3} - P_S$[1)]	T_{BAL}	AC-I	-

(Pt3 Ch4 Sec6 pag 77)

1.2 Static liquid pressure

1.2.1 Normal operations at sea

The static pressure, in kN/m², in tanks and ballast holds for normal operations at sea, shall be taken as:

$P_{ls\text{-}1} = f_{cd}\,\rho_L\, g(z_{top} - z) + P_{PV}$ for tanks arranged with pressure relief valves

$P_{ls\text{-}1} = \rho_L\, g(z_{top} - z)$ for other cases.

$$Pls - 1 = \rho \times g \times (Ztop - Z) = 0{,}93 \times 9{,}81 \times (30{,}5 - 2{,}5)$$

$P_{ls\text{-}1} = 255{,}45$ KN/m²

Obtenemos las coordenadas de referencia para los tanques de agua de lastre.

xj1 = 6,3 + 0,5*12,6 = 12,6 m

xj1 = 6,3 - 0,5*12,6 = 0 m

yj1 = 1,25 + 0,5*2,5 = 2,5 m

yj1 = 1,25 - 0,5*2,5 = 0 m

(Pt3 Ch4 Sec6 pag 80)

$$V_j = a_X(x_j - x_G) + a_Y(y_j - y_G) + (a_Z + g)(z_j - z_G)$$

Recordando los valores de las aceleraciones obtenidas anteriormente:

$a_x = 0{,}2935$ m/s²

$a_y = 0$ m/s²

$a_z = 1{,}5$ m/s²

$V_{j1} = 1{,}66$

$V_{j2} = -1{,}66$

Por lo que el valor de P_{ld} será:

(Pt3 Ch4 Sec6 pag80)

1.3 Dynamic liquid pressure

1.3.1 The dynamic pressure due to liquid in tanks and ballast holds, in kN/m² shall be taken as:

$$P_{\ell d} = f_{cd}\,\rho_L\left[a_Z\left(z_0 - z\right) + f_{ull-\ell}\,a_x\left(x_0 - x\right) + f_{ull-t}\,a_y\left(y_0 - y\right)\right]$$

where:

$f_{ull-\ell}$ = longitudinal acceleration correction factor for the ullage space above the liquid in tanks and ballast holds, taken as:

for strength assessment:

$f_{ull-\ell}$ = 0.62 for cargo tanks filled with any liquids inclusive water ballast

$f_{ull-\ell}$ = 1.0 for other cases

for fatigue assessment:

$$f_{ull-\ell} = 0.5 + \frac{|z_0 - z|}{\ell_{fs}}\frac{180}{\varphi\pi}$$ for cargo tanks and ballast holds

$f_{ull-\ell}$ = 1.0 for other cases

$f_{ull-\ell}$ shall not be less than 0.0 nor greater than 1.0

ℓ_{fs} = cargo tank length at the top of the tank or length of the ballast hold hatch coaming, in m

f_{ull-t} = transverse acceleration correction factor to account for the ullage space above the liquid in tanks and ballast holds, taken as:

for strength assessment:

f_{ull-t} = 0.67 for cargo tanks filled with any liquids inclusive water ballast

f_{ull-t} = 1.0 for other cases

for fatigue assessment:

$$f_{ull-t} = 0.5 + \frac{|z_0 - z|}{b_{top}}\frac{180}{\theta\pi}$$ for cargo tanks and ballast holds

f_{ull-t} = 1.0 for other cases

b_{top} = cargo tank breadth at the top of the tank or breadth of the ballast hold hatch coaming, in m determined at mid length of the tank or ballast hold hatch coaming

x_0 = X coordinate, in m, of the reference point

y_0 = Y coordinate, in m, of the reference point

z_0 = Z coordinate, in m, of the reference point.

$$Pld = 1 \times 1{,}025 \times [1{,}5 \times (30{,}5 - 2{,}5) + 0{,}62 \times 0{,}2935 \times (24{,}8 - 13) + 0{,}67 \times 0 \times (0 - 0)]$$

P_{ld} = 45 KN/m²

Por lo que la presión que ejerce el interior del tanque será:

$P = P_{ls-1} + P_{ld}$ = 255,45 + 45

P = 300,47 KN/m²

Recordando que la expresión que definía el espesor de la chapa en función de la presión es:

(Pt3 Ch6 Sec4 pag 16)

1.1 General

1.1.1 Plating

The net thickness, in mm, shall not be taken less than the greatest value for all applicable design load sets, as defined in Sec.2 [2.1.3], given by:

$$t = 0.0158\alpha_p b\sqrt{\frac{|P|}{C_a R_{eH}}}$$

where:

C_a = permissible bending stress coefficient for plate taken equal to:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{R_{eH}}$$ not to be taken greater than $C_{a\text{-}max}$

β_a = coefficient as defined in Table 1

α_a = coefficient as defined in Table 1

$C_{a\text{-}max}$ = maximum permissible bending stress coefficient as defined in Table 1.

Donde:

b = lado corto de la chapa = 900 mm

a = lado largo de la chapa = 2700 mm

R_{eh} = 235 MPa

σ_{Hg} = 205 N/mm^2

Acceptance criteria	*Structural member*		β_a	α_a	$C_{a\text{-}max}$
AC-II	Longitudinal members	Longitudinal stiffened plating	1.05	0.50	0.95
		Transverse stiffened plating	1.05	1.00	0.95
	Other members		0.95	0.00	0.95

β_a = 1,05

α_a = 0,5

$C_{a\text{-}max}$ = 0,95

Obtenemos los siguientes resultados:

C_a = 0,61 < $C_{a\text{-}max}$ = 0,95

α_p = 1

Por tanto, el espesor de la zona del mamparo, en la zona del costado 2 será:

$$t = 0{,}0158 \times 1 \times 900 \times \sqrt{\frac{300{,}47}{0{,}61 \times 235}}$$

t = 20,6 mm

Como t min = 9,4 mm (calculado anteriormente), vemos que cumple el espesor mínimo.

En la zona del costado 1 será:

$$t = 0{,}0158 \times 1 \times 900 \times \sqrt{\frac{255{,}45}{0{,}61 \times 235}}$$

t = 19 mm

Como t min = 9,4 mm (calculado anteriormente), vemos que cumple el espesor mínimo.

4.8 Longitudinales del mamparo

(Pt3 Ch6 Sec3 pag 14)

Table 2 Minimum net thickness for stiffeners and tripping brackets

Element	*Location*	*Net thickness*
Stiffeners and attached end brackets	Tank boundary, boundary of cargo holds for dry bulk cargo, single strength deck and shell up to freeboard deck	4.5 + 0.01 L_1
	Structures in deckhouse and superstructure and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.0
	Other structure	4.5 + 0.005 L_1
Tripping brackets		4.5 + 0.01 L_1

3 Primary supporting members

3.1 Minimum thickness requirements

3.1.1 The net thickness of web plating and flange of primary supporting members in mm, shall not be taken less than:

$$t = a + bL_2\sqrt{k}$$

where:

a = coefficient as defined in Table 3

b = coefficient as defined in Table 3.

Table 3 Minimum net thickness for primary supporting members

Element	*a*	*b*
Bottom centreline girder and lower strake of centreline wash bulkhead	5.0	0.03
Other bottom girders	5.0	0.017
Floors	5.0	0.015
PSM at tank boundaries, boundaries of holds intended for cargo in bulk, single strength deck and shell up to freeboard deck	4.5	0.015[2)]
PSM in deckhouses and superstructures and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.5	0.01[3)]
Other PSM	4.5	0.01
PSM in peak tanks	5.0	0.025[1)]

1) $bL_2 \leq 5.0$

2) $bL_2 \leq 2.5$ for stringers in double side next to dry space not intended for cargo in bulk.

3) $bL_2 \leq 2{,}0$

L_1 = eslora de escantillonado, L_1 = 323 m

$$t = 4{,}5 + 0{,}01 \times 323 \times \sqrt{1}$$

t = 7,8 mm

(Pt3 Ch6 Sec5 pag 22)

1 Stiffeners subject to lateral pressure

1.1 General

1.1.1 Web plating

The minimum net web thickness, in mm, shall not be taken less than the greatest value calculated for all applicable design load sets as defined in Sec.2 [2], given by:

$$t_w = \frac{f_{shr}|P|s\,\ell_{shr}}{d_{shr}C_t\tau_{eH}}$$

where:

f_{shr} = shear force distribution factor as defined in Table 1. For stiffeners with end fixity deviating from the ones included in Table 1, with complex load pattern, or being part of a grillage, the requirements given in [1.2] apply.

Table 1 Definition of f_{shr}

Coefficient	*For continuous stiffeners with fixed end*			*For non-continuous stiffeners with simply supported ends*
	Horizontal stiffeners	*Upper end of vertical stiffeners*	*Lower end of vertical stiffeners*	*All stiffeners*
f_{shr}	0.5	0.4	0.7	0.5

C_t = permissible shear stress coefficient for the acceptance criteria being considered, as defined in Table 2.

Table 2 Stiffeners, definition of C_t

Acceptance criteria	*Structural member*	C_t
AC-I	All stiffeners	0.75
AC-II	All stiffeners	0.90
AC-III	All stiffeners	0.95

Donde:

- f_{shr} = factor de distribución de la fuerza cortante. f_{shr} = 0,5
- P = presión máxima establecida en el costado. P = 300,47 KN/m^2.
- s = separación propuesta para los refuerzos secundarios del mamparo. s = 900 mm
- l_{shr} = tramo cortante efectivo del refuerzo, donde se tomará:

(Pt3 Ch3 Sec7 pag 61)

1.1.4 Effective shear span of stiffeners

The effective shear span, ℓ_{shr} in m, of stiffeners shall be measured as shown in Figure 4 for single skin structures and Figure 5 for double skin structures.

Regardless of support detail, the full length of the stiffener shall be reduced by a minimum of $s/4000$ m at each end of the member, hence the effective shear span ℓ_{shr}, shall not be taken greater than:

$$\ell_{shr} \le \ell - \frac{s}{2000}$$

The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener.

If brackets are fitted at both the flange or free edge of the stiffener, and to the attached plating on the side opposite to the stiffener the effective shear span may be reduced using the longer effective bracket arm.

s = 900 mm

l = 900 mm

l_{shr} = 0,45

- d_{shr} = profundidad de corte efectiva expresado en milímetros, para los refuerzos perpendiculares a la chapa.
  (Pt3 Ch3 Sec7 pag 76)

1.4.3 Effective shear depth of stiffeners
The effective shear depth of stiffeners, in mm, shall be taken as:

$$d_{shr} = h_{stf} + t_p \qquad \text{for } 75° \le \varphi_w \le 90°$$

$$d_{shr} = (h_{stf} + t_p)\sin\varphi_w \qquad \text{for } \varphi_w < 75°$$

where:

h_{stf} = height of stiffener, in mm, as defined in Sec.2 Figure 1
t_p = net thickness of the attached plating, in mm, as defined in Sec.2 Figure 1
φ_w = angle, in deg, as defined in Figure 17.

Donde:
h_{stf} = altura de los refuerzos secundarios en milímetros que se establece en 45 mm para este cálculo
t_p = es el espesor añadido, el cual será de 1mm por la corrosión del agua salada a la que se exponen

$$d_{shr} = 45 + 1 = 46 \text{ mm}$$

- C_t = coeficiente de esfuerzo cortante permisible.
  (Pt3 Ch6 Sec5 pag 22)

C_t = permissible shear stress coefficient for the acceptance criteria being considered, as defined in Table 2.

Table 2 Stiffeners, definition of C_t

Acceptance criteria	Structural member	C_t
AC-I	All stiffeners	0.75
AC-II	All stiffeners	0.90
AC-III	All stiffeners	0.95

$$C_t = 0{,}9$$

- T_{eh} = esfuerzo limite cortante expresado en N/mm^2. En el caso del acero naval R_{eh} = 235 N/mm^2.
  (Pt3 Ch1 Sec4 pag 29)

τ_{eH}	specified shear yield stress, $\tau_{eH} = \frac{R_{eH}}{\sqrt{3}}$	N/mm^2

$$T_{eh} = 135{,}68 \text{ N/mm}^2$$

Recordando el valor del espesor era:

$$t_w = \frac{f_{shr}|P|s\,\ell_{shr}}{d_{shr}C_t\tau_{eH}}$$

$$\mathbf{t_w = 11\ mm}$$

4.9 Módulo mínimo de los refuerzos secundarios

(Pt3 Ch6 Sec5 pag 23)

1.1.2 Section modulus

The minimum net section modulus, in cm^3, shall not be taken less than the greatest value calculated for all applicable design load sets as defined in Sec.2 [2.1.3], given by:

$$Z = \frac{f_u |P| s \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

f_{bdg}	=	bending moment factor as defined in Table 5. For stiffeners with end fixity deviating from the ones included in Table 5, with complex load pattern, or being part of a grillage, the requirement given in [1.2] applies
f_m	=	bending moment ratio between end support and midspan as defined in Table 5
f_u	=	factor for unsymmetrical profiles, to be taken as:
	=	1.00 for flat bars and symmetrical profiles (T-profiles)
	=	1.03 for bulb profiles
	=	1.15 for unsymmetrical profiles (L-profiles)
C_s	=	permissible bending stress coefficient as defined in Table 3 for the acceptance criteria given in Table 4
$C_{s\text{-}max}$	=	coefficient, as defined in Table 4
α_s	=	coefficient, as defined in Table 4
β_s	=	coefficient, as defined in Table 4.

Donde:

- f_u = factor del perfil, que en nuestro caso emplearemos perfiles bulbo, con lo que f_u = 1,03

  (Pt3 Ch6 Sec5 pag 23)

f_u	=	factor for unsymmetrical profiles, to be taken as:
	=	1.00 for flat bars and symmetrical profiles (T-profiles)
	=	1.03 for bulb profiles
	=	1.15 for unsymmetrical profiles (L-profiles)

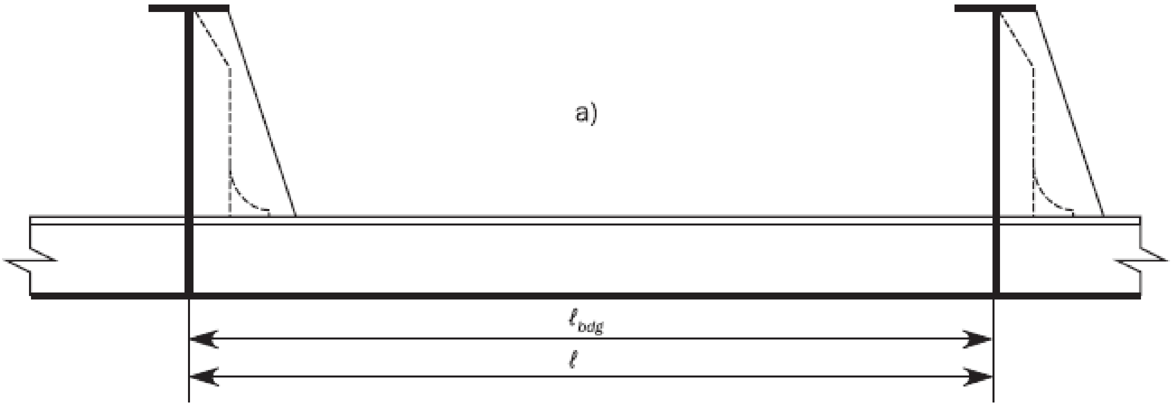
- f_{bdg} = factor del momento flector. fbdg = 12

  (Pt3 Ch6 Sec5 pag 24)

Table 5 Stiffeners, definition of f_{bdg} and f_m

Coefficient	Acceptance criteria	For continuous stiffeners with fixed ends		For continuous stiffeners with one fixed end and one simply supported end	For non-continuous stiffeners with simply supported ends
		Horizontal stiffeners and upper end of vertical stiffeners	Lower end of vertical stiffeners	Horizontal and vertical stiffeners	Horizontal and vertical stiffeners
f_{bdg}	AC-I, AC-II, AC-III	12.00	10.00	8.00	8.00
f_m	AC-I	2.00	2.33	1.77	-
	AC-II, AC-III	1.60	1.86	1.42	

- l_{bdg} = longitud o tramo de flexión efectivo en el refuerzo, el cual valdrá la separación entre bulárcamas establecidas en 3 claras de cuadernas (3*900 = 2700 mm). l_{bdg} = 2,7 m
  (Pt3 Ch3 Sec7 pag 59)



- Cs = coeficiente elástico permisible que vale 0,85 para la zona de actuación del doble casco referente a AC-II.

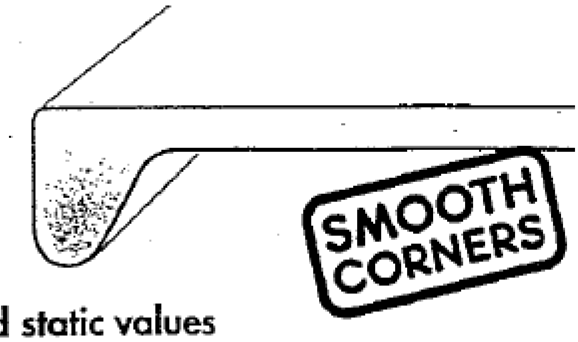
Recordando la formula del módulo:

$$Z = \frac{f_u |P| s\, \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

Z = 847,11 cm^3

A partir de este valor acudimos al catalogo de perfiles bulbo, donde seleccionaremos un perfil que tenga un módulo superior al calculado anteriormente, por lo que el perfil seleccionado será:

Bulb Flats



Dimension range, weight/m and static values

Width a mm	Thickness s mm	Height c mm	Radius r mm	Area A cm^2	Weight kg/m	e cm	I_x cm^4	W_x* cm^3
340	12	49	15	58.8	46.1	21.5	6760	947
	14	49	15	65.5	51.5	21.1	7540	1014

Perfil seleccionado: 340 x 12 de Z = 947 cm^3

4.10 Longitudinales del costado y del doble costado

(Pt3 Ch6 Sec3 pag 14)

Table 2 Minimum net thickness for stiffeners and tripping brackets

Element	*Location*	*Net thickness*
Stiffeners and attached end brackets	Tank boundary, boundary of cargo holds for dry bulk cargo, single strength deck and shell up to freeboard deck	$4.5 + 0.01\,L_1$
	Structures in deckhouse and superstructure and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.0
	Other structure	$4.5 + 0.005\,L_1$
Tripping brackets		$4.5 + 0.01\,L_1$

3 Primary supporting members

3.1 Minimum thickness requirements

3.1.1 The net thickness of web plating and flange of primary supporting members in mm, shall not be taken less than:

$$t = a + bL_2\sqrt{k}$$

where:

a = coefficient as defined in Table 3
b = coefficient as defined in Table 3.

Table 3 Minimum net thickness for primary supporting members

Element	*a*	*b*
Bottom centreline girder and lower strake of centreline wash bulkhead	5.0	0.03
Other bottom girders	5.0	0.017
Floors	5.0	0.015
PSM at tank boundaries, boundaries of holds intended for cargo in bulk, single strength deck and shell up to freeboard deck	4.5	0.015 2)
PSM in deckhouses and superstructures and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.5	0.01 3)
Other PSM	4.5	0.01
PSM in peak tanks	5.0	0.025 1)

1) $bL_2 \leq 5.0$
2) $bL_2 \leq 2.5$ for stringers in double side next to dry space not intended for cargo in bulk.
3) $bL_2 \leq 2{,}0$

L_1 = eslora de escantillonado, L_1 = 323 m

$$t = 4{,}5 + 0{,}01 \times 323 \times \sqrt{1}$$

t = 7,8 mm

(Pt3 Ch6 Sec5 pag 22)

1 Stiffeners subject to lateral pressure

1.1 General

1.1.1 Web plating

The minimum net web thickness, in mm, shall not be taken less than the greatest value calculated for all applicable design load sets as defined in Sec.2 [2], given by:

$$t_w = \frac{f_{shr} |P| s \ell_{shr}}{d_{shr} C_t \tau_{eH}}$$

where:

f_{shr} = shear force distribution factor as defined in Table 1. For stiffeners with end fixity deviating from the ones included in Table 1, with complex load pattern, or being part of a grillage, the requirements given in [1.2] apply.

Table 1 Definition of f_{shr}

Coefficient	*For continuous stiffeners with fixed end*			*For non-continuous stiffeners with simply supported ends*
	Horizontal stiffeners	*Upper end of vertical stiffeners*	*Lower end of vertical stiffeners*	*All stiffeners*
f_{shr}	0.5	0.4	0.7	0.5

C_t = permissible shear stress coefficient for the acceptance criteria being considered, as defined in Table 2.

Table 2 Stiffeners, definition of C_t

Acceptance criteria	*Structural member*	C_t
AC-I	All stiffeners	0.75
AC-II	All stiffeners	0.90
AC-III	All stiffeners	0.95

Donde:

- f_{shr} = factor de distribución de la fuerza cortante. f_{shr} = 0,5
- P = presión máxima establecida en el costado. P = 135 + 34,48 = 170,226 KN/m^2.
- s = separación propuesta para los refuerzos secundarios del mamparo. s = 900 mm
- l_{shr} = tramo cortante efectivo del refuerzo, donde se tomará:

(Pt3 Ch3 Sec7 pag 61)

1.1.4 Effective shear span of stiffeners

The effective shear span, ℓ_{shr} in m, of stiffeners shall be measured as shown in Figure 4 for single skin structures and Figure 5 for double skin structures.

Regardless of support detail, the full length of the stiffener shall be reduced by a minimum of s/4000 m at each end of the member, hence the effective shear span ℓ_{shr}, shall not be taken greater than:

$$\ell_{shr} \leq \ell - \frac{s}{2000}$$

The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener.

If brackets are fitted at both the flange or free edge of the stiffener, and to the attached plating on the side opposite to the stiffener the effective shear span may be reduced using the longer effective bracket arm.

s = 900 mm

l = 900 mm

l_{shr} = 0,45

- d_{shr} = profundidad de corte efectiva expresado en milímetros, para los refuerzos perpendiculares a la chapa.
  (Pt3 Ch3 Sec7 pag 76)

1.4.3 Effective shear depth of stiffeners

The effective shear depth of stiffeners, in mm, shall be taken as:

$$d_{shr} = h_{stf} + t_p \qquad \text{for } 75° \le \varphi_w \le 90°$$

$$d_{shr} = (h_{stf} + t_p)\sin\varphi_w \qquad \text{for } \varphi_w < 75°$$

where:

h_{stf} = height of stiffener, in mm, as defined in Sec.2 Figure 1

t_p = net thickness of the attached plating, in mm, as defined in Sec.2 Figure 1

φ_w = angle, in deg, as defined in Figure 17.

Donde:

h_{stf} = altura de los refuerzos secundarios en milímetros que se establece en 45 mm para este cálculo

t_p = es el espesor añadido, el cual será de 1mm por la corrosión del agua salada a la que se exponen

$$d_{shr} = 45 + 1 = 46 \text{ mm}$$

- C_t = coeficiente de esfuerzo cortante permisible.
  (Pt3 Ch6 Sec5 pag 22)

C_t = permissible shear stress coefficient for the acceptance criteria being considered, as defined in Table 2.

Table 2 Stiffeners, definition of C_t

Acceptance criteria	Structural member	C_t
AC-I	All stiffeners	0.75
AC-II	All stiffeners	0.90
AC-III	All stiffeners	0.95

$$C_t = 0{,}9$$

- T_{eh} = esfuerzo limite cortante expresado en N/mm^2. En el caso del acero naval R_{eh} = 235 N/mm^2.
  (Pt3 Ch1 Sec4 pag 29)

τ_{eH}	specified shear yield stress, $\tau_{eH} = \frac{R_{eH}}{\sqrt{3}}$	N/mm^2

$$T_{eh} = 135{,}68 \text{ N/mm}^2$$

Recordando el valor del espesor era:

$$t_w = \frac{f_{shr}|P|s\,\ell_{shr}}{d_{shr}C_t\tau_{eH}}$$

t_w = 6,2 mm

4.11 Módulo mínimo de los refuerzos secundarios

(Pt3 Ch6 Sec5 pag 23)

1.1.2 Section modulus

The minimum net section modulus, in cm^3, shall not be taken less than the greatest value calculated for all applicable design load sets as defined in Sec.2 [2.1.3], given by:

$$Z = \frac{f_u |P| s \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

f_{bdg} = bending moment factor as defined in Table 5. For stiffeners with end fixity deviating from the ones included in Table 5, with complex load pattern, or being part of a grillage, the requirement given in [1.2] applies

f_m = bending moment ratio between end support and midspan as defined in Table 5

f_u = factor for unsymmetrical profiles, to be taken as:

= 1.00 for flat bars and symmetrical profiles (T-profiles)

= 1.03 for bulb profiles

= 1.15 for unsymmetrical profiles (L-profiles)

C_s = permissible bending stress coefficient as defined in Table 3 for the acceptance criteria given in Table 4

$C_{s\text{-}max}$ = coefficient, as defined in Table 4

α_s = coefficient, as defined in Table 4

β_s = coefficient, as defined in Table 4.

Donde:

- f_u = factor del perfil, que en nuestro caso emplearemos perfiles bulbo, con lo que f_u = 1,03

  (Pt3 Ch6 Sec5 pag 23)

  f_u = factor for unsymmetrical profiles, to be taken as:

  = 1.00 for flat bars and symmetrical profiles (T-profiles)

  = 1.03 for bulb profiles

  = 1.15 for unsymmetrical profiles (L-profiles)

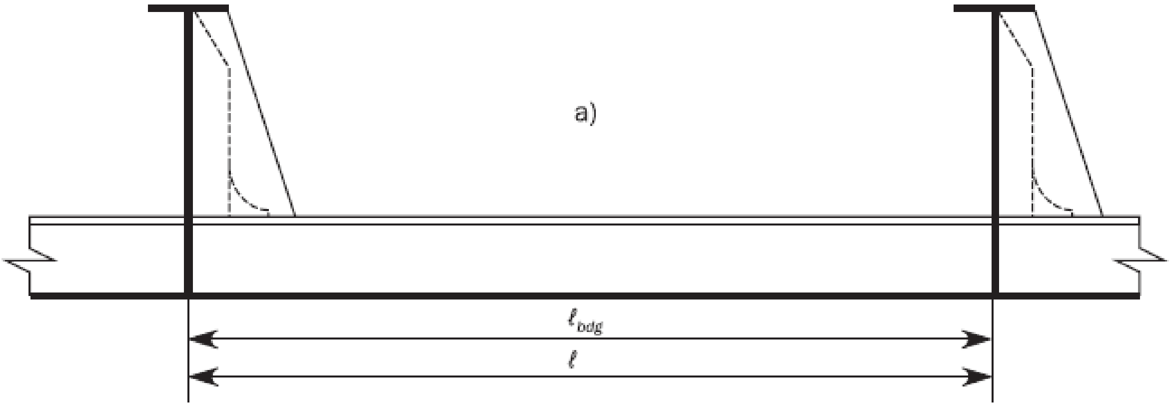
- f_{bdg} = factor del momento flector. f_{bdg} = 12

  (Pt3 Ch6 Sec5 pag 24)

Table 5 Stiffeners, definition of f_{bdg} and f_m

Coefficient	Acceptance criteria	For continuous stiffeners with fixed ends		For continuous stiffeners with one fixed end and one simply supported end	For non-continuous stiffeners with simply supported ends
		Horizontal stiffeners and upper end of vertical stiffeners	Lower end of vertical stiffeners	Horizontal and vertical stiffeners	Horizontal and vertical stiffeners
f_{bdg}	AC-I, AC-II, AC-III	12.00	10.00	8.00	8.00
f_m	AC-I	2.00	2.33	1.77	-
	AC-II, AC-III	1.60	1.86	1.42	

- l_{bdg} = longitud o tramo de flexión efectivo en el refuerzo, el cual valdrá la separación entre bulárcamas establecidas en 3 claras de cuadernas (3*900 = 2700 mm). l_{bdg} = 2,7 m
  (Pt3 Ch3 Sec7 pag 59)



- Cs = coeficiente elástico permisible que vale 0,85 para la zona de actuación del doble casco referente a AC-II.

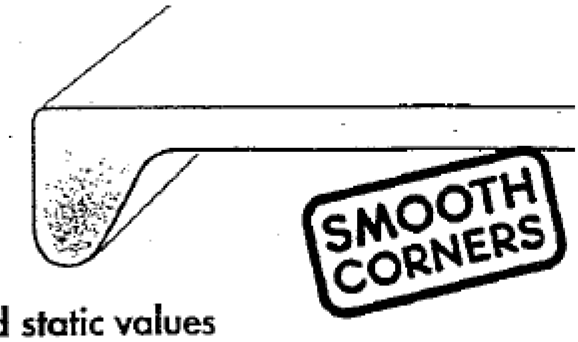
Recordando la formula del módulo:

$$Z = \frac{f_u |P| s \, \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

Z = 480 cm^3

A partir de este valor acudimos al catálogo de perfiles bulbo, donde seleccionaremos un perfil que tenga un módulo superior al calculado anteriormente, por lo que el perfil seleccionado será:

Bulb Flats



Dimension range, weight/m and static values

Width a mm	Thickness s mm	Height c mm	Radius r mm	Area A cm^2	Weight kg/m	e cm	I_x cm^4	W_x* cm^3
260	10	37	11	36.1	28.3	16.2	2477	455
	11	37	11	38.7	30.3	16.0	2610	474
	12	37	11	41.3	32.4	15.8	2770	493

Perfil seleccionado: 260 x 12 de Z = 493 cm^3

4.12 Longitudinales del fondo y doble fondo

(Pt3 Ch6 Sec3 pag 14)

Table 2 Minimum net thickness for stiffeners and tripping brackets

Element	*Location*	*Net thickness*
Stiffeners and attached end brackets	Tank boundary, boundary of cargo holds for dry bulk cargo, single strength deck and shell up to freeboard deck	$4.5 + 0.01\ L_1$
	Structures in deckhouse and superstructure and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.0
	Other structure	$4.5 + 0.005\ L_1$
Tripping brackets		$4.5 + 0.01\ L_1$

3 Primary supporting members

3.1 Minimum thickness requirements

3.1.1 The net thickness of web plating and flange of primary supporting members in mm, shall not be taken less than:

$$t = a + bL_2\sqrt{k}$$

where:

a = coefficient as defined in Table 3

b = coefficient as defined in Table 3.

Table 3 Minimum net thickness for primary supporting members

Element	*a*	*b*
Bottom centreline girder and lower strake of centreline wash bulkhead	5.0	0.03
Other bottom girders	5.0	0.017
Floors	5.0	0.015
PSM at tank boundaries, boundaries of holds intended for cargo in bulk, single strength deck and shell up to freeboard deck	4.5	0.015 2)
PSM in deckhouses and superstructures and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.5	0.01 3)
Other PSM	4.5	0.01
PSM in peak tanks	5.0	0.025 1)

1) $bL_2 \leq 5.0$

2) $bL_2 \leq 2.5$ for stringers in double side next to dry space not intended for cargo in bulk.

3) $bL_2 \leq 2{,}0$

L_1 = eslora de escantillonado, L_1 = 323 m

$$t = 4{,}5 + 0{,}01 \times 323 \times \sqrt{1}$$

t = 7,8 mm

(Pt3 Ch6 Sec5 pag 22)

1 Stiffeners subject to lateral pressure

1.1 General

1.1.1 Web plating

The minimum net web thickness, in mm, shall not be taken less than the greatest value calculated for all applicable design load sets as defined in Sec.2 [2], given by:

$$t_w = \frac{f_{shr}|P| s \ell_{shr}}{d_{shr} C_t \tau_{eH}}$$

where:

f_{shr} = shear force distribution factor as defined in Table 1. For stiffeners with end fixity deviating from the ones included in Table 1, with complex load pattern, or being part of a grillage, the requirements given in [1.2] apply.

Table 1 Definition of f_{shr}

Coefficient	*For continuous stiffeners with fixed end*			*For non-continuous stiffeners with simply supported ends*
	Horizontal stiffeners	*Upper end of vertical stiffeners*	*Lower end of vertical stiffeners*	*All stiffeners*
f_{shr}	0.5	0.4	0.7	0.5

C_t = permissible shear stress coefficient for the acceptance criteria being considered, as defined in Table 2.

Table 2 Stiffeners, definition of C_t

Acceptance criteria	*Structural member*	C_t
AC-I	All stiffeners	0.75
AC-II	All stiffeners	0.90
AC-III	All stiffeners	0.95

Donde:

- f_{shr} = factor de distribución de la fuerza cortante. f_{shr} = 0,5
- P = presión máxima establecida en el fondo. P = 152,8 KN/m^2.
- s = separación propuesta para los refuerzos secundarios del mamparo. s = 900 mm
- l_{shr} = tramo cortante efectivo del refuerzo, donde se tomará:

(Pt3 Ch3 Sec7 pag 61)

1.1.4 Effective shear span of stiffeners

The effective shear span, ℓ_{shr} in m, of stiffeners shall be measured as shown in Figure 4 for single skin structures and Figure 5 for double skin structures.

Regardless of support detail, the full length of the stiffener shall be reduced by a minimum of s/4000 m at each end of the member, hence the effective shear span ℓ_{shr}, shall not be taken greater than:

$$\ell_{shr} \leq \ell - \frac{s}{2000}$$

The effective shear span may be reduced for brackets fitted on either the flange or the free edge of the stiffener, or for brackets fitted to the attached plating on the side opposite to that of the stiffener.

If brackets are fitted at both the flange or free edge of the stiffener, and to the attached plating on the side opposite to the stiffener the effective shear span may be reduced using the longer effective bracket arm.

s = 900 mm

l = 900 x 3 = 2700 mm = 2,7 m

l_{shr} = 2,25

- d_{shr} = profundidad de corte efectiva expresado en milímetros, para los refuerzos perpendiculares a la chapa.
  (Pt3 Ch3 Sec7 pag 76)

1.4.3 Effective shear depth of stiffeners

The effective shear depth of stiffeners, in mm, shall be taken as:

$$d_{shr} = h_{stf} + t_p \quad \text{for } 75° \le \varphi_w \le 90°$$

$$d_{shr} = (h_{stf} + t_p)\sin\varphi_w \quad \text{for } \varphi_w < 75°$$

where:

h_{stf} = height of stiffener, in mm, as defined in Sec.2 Figure 1
t_p = net thickness of the attached plating, in mm, as defined in Sec.2 Figure 1
φ_w = angle, in deg, as defined in Figure 17.

Donde:

h_{stf} = altura de los refuerzos secundarios en milímetros que se establece en 260 mm para este cálculo

t_p = es el espesor añadido, el cual será de 1mm por la corrosión del agua salada a la que se exponen

$$d_{shr} = 260 + 1 = 261 \text{ mm}$$

- C_t = coeficiente de esfuerzo cortante permisible.
  (Pt3 Ch6 Sec5 pag 22)

C_t = permissible shear stress coefficient for the acceptance criteria being considered, as defined in Table 2.

Table 2 Stiffeners, definition of C_t

Acceptance criteria	Structural member	C_t
AC-I	All stiffeners	0.75
AC-II	All stiffeners	0.90
AC-III	All stiffeners	0.95

$$C_t = 0{,}9$$

- T_{eh} = esfuerzo limite cortante expresado en N/mm². En el caso del acero naval R_{eh} = 235 N/mm².
  (Pt3 Ch1 Sec4 pag 29)

τ_{eH}	specified shear yield stress, $\tau_{eH} = \frac{R_{eH}}{\sqrt{3}}$	N/mm²

$$T_{eh} = 135{,}68 \text{ N/mm}^2$$

Recordando el valor del espesor era:

$$t_w = \frac{f_{shr}|P|s\,\ell_{shr}}{d_{shr}C_t\tau_{eH}}$$

t_w = 4,85 mm, tomaremos **t_w = 5 mm**

4.13 Módulo mínimo de los refuerzos secundarios

(Pt3 Ch6 Sec5 pag 23)

1.1.2 Section modulus

The minimum net section modulus, in cm^3, shall not be taken less than the greatest value calculated for all applicable design load sets as defined in Sec.2 [2.1.3], given by:

$$Z = \frac{f_u |P| s\, \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

f_{bdg} = bending moment factor as defined in Table 5. For stiffeners with end fixity deviating from the ones included in Table 5, with complex load pattern, or being part of a grillage, the requirement given in [1.2] applies

f_m = bending moment ratio between end support and midspan as defined in Table 5

f_u = factor for unsymmetrical profiles, to be taken as:
= 1.00 for flat bars and symmetrical profiles (T-profiles)
= 1.03 for bulb profiles
= 1.15 for unsymmetrical profiles (L-profiles)

C_s = permissible bending stress coefficient as defined in Table 3 for the acceptance criteria given in Table 4

$C_{s\text{-}max}$ = coefficient, as defined in Table 4

α_s = coefficient, as defined in Table 4

β_s = coefficient, as defined in Table 4.

Donde:

- f_u = factor del perfil, que en nuestro caso emplearemos perfiles bulbo, con lo que f_u = 1,03

  (Pt3 Ch6 Sec5 pag 23)

  f_u = factor for unsymmetrical profiles, to be taken as:
  = 1.00 for flat bars and symmetrical profiles (T-profiles)
  = 1.03 for bulb profiles
  = 1.15 for unsymmetrical profiles (L-profiles)

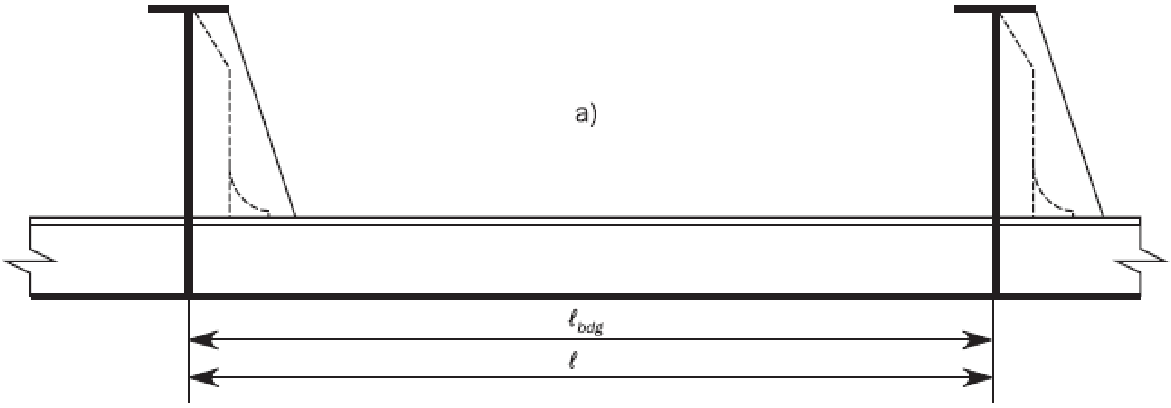
- f_{bdg} = factor del momento flector. fbdg = 12

  (Pt3 Ch6 Sec5 pag 24)

Table 5 Stiffeners, definition of f_{bdg} and f_m

Coefficient	*Acceptance criteria*	*For continuous stiffeners with fixed ends*		*For continuous stiffeners with one fixed end and one simply supported end*	*For non-continuous stiffeners with simply supported ends*
		Horizontal stiffeners and upper end of vertical stiffeners	*Lower end of vertical stiffeners*	*Horizontal and vertical stiffeners*	*Horizontal and vertical stiffeners*
f_{bdg}	AC-I, AC-II, AC-III	12.00	10.00	8.00	8.00
f_m	AC-I	2.00	2.33	1.77	-
	AC-II, AC-III	1.60	1.86	1.42	

- l_{bdg} = longitud o tramo de flexión efectivo en el refuerzo, el cual valdrá la separación entre bulárcamas establecidas en 3 claras de cuadernas (3*900 = 2700 mm). l_{bdg} = 2,7 m
  (Pt3 Ch3 Sec7 pag 59)



- Cs = coeficiente elástico permisible que vale 0,85 para la zona de actuación del doble casco referente a AC-II.

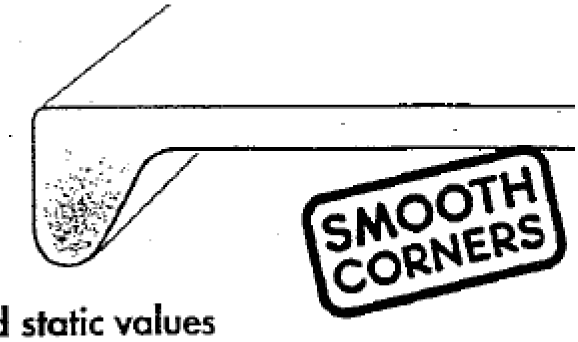
Recordando la formula del módulo:

$$Z = \frac{f_u |P| s \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

Z = 430,786 cm^3

A partir de este valor acudimos al catálogo de perfiles bulbo, donde seleccionaremos un perfil que tenga un módulo superior al calculado anteriormente, por lo que el perfil seleccionado será:

Bulb Flats



Dimension range, weight/m and static values

Width a mm	Thickness s mm	Height c mm	Radius r mm	Area A cm^2	Weight kg/m	e cm	I_x cm^4	W_x* cm^3
260	10	37	11	36.1	28.3	16.2	2477	455
	11	37	11	38.7	30.3	16.0	2610	474
	12	37	11	41.3	32.4	15.8	2770	493

Perfil seleccionado: 260 x 10 de Z = 455 cm^3

4.14 Baos

(Pt3 Ch6 Sec3 pag 14)

Table 2 Minimum net thickness for stiffeners and tripping brackets

Element	*Location*	*Net thickness*
Stiffeners and attached end brackets	Tank boundary, boundary of cargo holds for dry bulk cargo, single strength deck and shell up to freeboard deck	$4.5 + 0.01\,L_1$
	Structures in deckhouse and superstructure and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.0
	Other structure	$4.5 + 0.005\,L_1$
Tripping brackets		$4.5 + 0.01\,L_1$

3 Primary supporting members

3.1 Minimum thickness requirements

3.1.1 The net thickness of web plating and flange of primary supporting members in mm, shall not be taken less than:

$$t = a + bL_2\sqrt{k}$$

where:

a = coefficient as defined in Table 3
b = coefficient as defined in Table 3.

Table 3 Minimum net thickness for primary supporting members

Element	*a*	*b*
Bottom centreline girder and lower strake of centreline wash bulkhead	5.0	0.03
Other bottom girders	5.0	0.017
Floors	5.0	0.015
PSM at tank boundaries, boundaries of holds intended for cargo in bulk, single strength deck and shell up to freeboard deck	4.5	0.015 [2)]
PSM in deckhouses and superstructures and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.5	0.01 [3)]
Other PSM	4.5	0.01
PSM in peak tanks	5.0	0.025 [1)]

1) $bL_2 \leq 5.0$
2) $bL_2 \leq 2.5$ for stringers in double side next to dry space not intended for cargo in bulk.
3) $bL_2 \leq 2{,}0$

L_1 = eslora de escantillonado, L_1 = 323 m

$$t = 5 + 0{,}017 \times 323 \times \sqrt{1}$$

t = 10,6 mm

(Pt3 Ch6 Se4 pag 16)

1.1 General

1.1.1 Plating

The net thickness, in mm, shall not be taken less than the greatest value for all applicable design load sets, as defined in Sec.2 [2.1.3], given by:

$$t = 0{,}0158\alpha_p b\sqrt{\frac{|P|}{C_a R_{eH}}}$$

where:

C_a = permissible bending stress coefficient for plate taken equal to:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{R_{eH}}$$ not to be taken greater than $C_{a\text{-}max}$

β_a = coefficient as defined in Table 1

α_a = coefficient as defined in Table 1

$C_{a\text{-}max}$ = maximum permissible bending stress coefficient as defined in Table 1.

α_p = correction factor for the panel aspect ratio to be taken as follows but not to be taken greater than 1.0:

$$\alpha_p = 1{,}2 - \frac{b}{2.1\,a}$$

Donde:

a = 28000 mm

b = 900 mm

α_p = 1,18 > 1, por lo que α_p = 1

$$Ca = 1{,}05 - 1 \times \frac{205}{235}$$

Ca = 0,1776

P = presión máxima establecida en la cubierta. P = 34,3 KN/m^2.

$$t = 0.0158\alpha_p b\sqrt{\frac{|P|}{C_a R_{eH}}}$$

t = 12 mm

4.15 Módulo mínimo de los refuerzos secundarios

(Pt3 Ch6 Sec6 pag 27)

2 Primary supporting members

2.1 Scantling requirements

2.1.1 Section modulus

The section modulus, in cm^3, of primary supporting members subjected to lateral pressure shall not be taken less than the greatest value for all applicable design load sets defined in Sec.2 [2], given by:

$$Z = 1000\frac{|P| s \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

Z = Z_{n50}, required net section modulus in cm^3, only applicable for ships with class notation **ESP**

= Z_{gr}, required gross section modulus in cm^3, for other ships

f_{bdg} = bending moment distribution factor, as given in Table 1

C_s = permissible stress coefficient to be taken as:

C_s = 0.70 for AC-I

C_s = 0.85 for AC-II and AC-III.

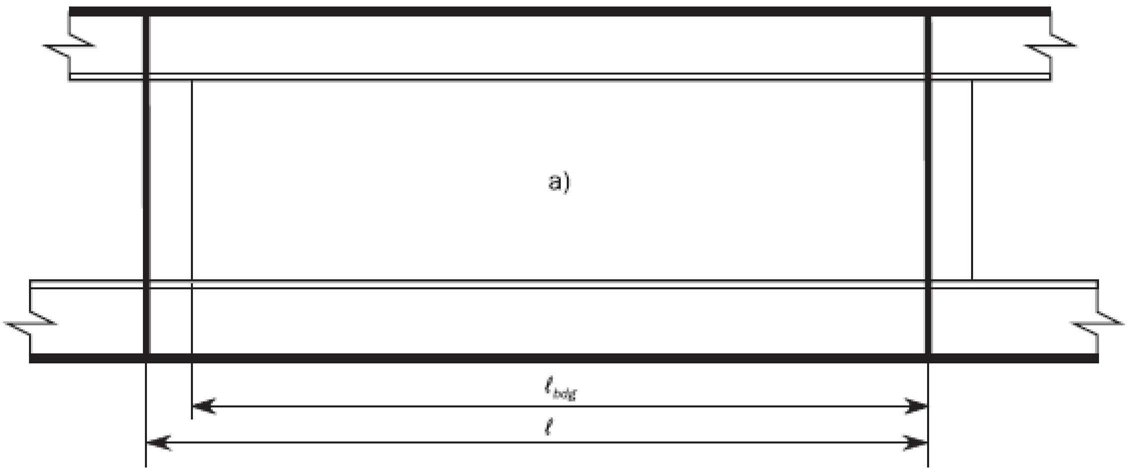
Donde:

- P = presión máxima establecida en la cubierta. P = 34,3 KN/m^2.
- s = separación entre refuerzos primarios, la cual para este elemento se dispondrá de una separación acorde con el espaciado comprendido de tres claras de cuaderna.
 s = 3 x 900 = 2700 mm
- f_{bdg} = factor del momento flector. fbdg = 12
 (Pt3 Ch6 Sec5 pag 24)

Table 5 Stiffeners, definition of f_{bdg} and f_m

Coefficient	*Acceptance criteria*	*For continuous stiffeners with fixed ends*		*For continuous stiffeners with one fixed end and one simply supported end*	*For non-continuous stiffeners with simply supported ends*
		Horizontal stiffeners and upper end of vertical stiffeners	*Lower end of vertical stiffeners*	*Horizontal and vertical stiffeners*	*Horizontal and vertical stiffeners*
f_{bdg}	AC-I, AC-II, AC-III	12.00	10.00	8.00	8.00
f_m	AC-I	2.00	2.33	1.77	-
	AC-II, AC-III	1.60	1.86	1.42	

- l_{bdg} = longitud o tramo de flexión efectivo en el refuerzo, el cual no será toda la longitud de separación entre refuerzos primarios. Se considerará un 95% de la longitud del elemento primario, el cual en elste caso en la varenga con una longitud en 3 claras de cuadernas valdrá (0,95*(3*900) = 2565 mm). l_{bdg} = 2,565 m
 (Pt3 Ch3 Sec7 pag 60)



- Cs = coeficiente elástico permisible que vale 0,85 para la zona de actuación del doble casco referente a AC-II.
- R_{eh} = limite elástico del acero naval normal. R_{eh} = 235 MPa

Recordando la formula del módulo:

$$Z = 1000 \frac{|P| S \, \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

Z = 254,2 cm^3

4.16 Varengas

(Pt3 Ch6 Sec3 pag 14)

Table 2 Minimum net thickness for stiffeners and tripping brackets

Element	*Location*	*Net thickness*
Stiffeners and attached end brackets	Tank boundary, boundary of cargo holds for dry bulk cargo, single strength deck and shell up to freeboard deck	$4.5 + 0.01\ L_1$
	Structures in deckhouse and superstructure and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.0
	Other structure	$4.5 + 0.005\ L_1$
Tripping brackets		$4.5 + 0.01\ L_1$

3 Primary supporting members

3.1 Minimum thickness requirements

3.1.1 The net thickness of web plating and flange of primary supporting members in mm, shall not be taken less than:

$$t = a + bL_2\sqrt{k}$$

where:

a = coefficient as defined in Table 3

b = coefficient as defined in Table 3.

Table 3 Minimum net thickness for primary supporting members

Element	*a*	*b*
Bottom centreline girder and lower strake of centreline wash bulkhead	5.0	0.03
Other bottom girders	5.0	0.017
Floors	5.0	0.015
PSM at tank boundaries, boundaries of holds intended for cargo in bulk, single strength deck and shell up to freeboard deck	4.5	0.015 2)
PSM in deckhouses and superstructures and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.5	0.01 3)
Other PSM	4.5	0.01
PSM in peak tanks	5.0	0.025 1)

1) $bL_2 \leq 5.0$

2) $bL_2 \leq 2.5$ for stringers in double side next to dry space not intended for cargo in bulk.

3) $bL_2 \leq 2{,}0$

L_1 = eslora de escantillonado, L_1 = 323 m

$$t = 5 + 0{,}03 \times 323 \times \sqrt{1}$$

t = 14,8 mm

(Pt3 Ch6 Se4 pag 16)

1.1 General

1.1.1 Plating

The net thickness, in mm, shall not be taken less than the greatest value for all applicable design load sets, as defined in Sec.2 [2.1.3], given by:

$$t = 0{,}0158\alpha_p b\sqrt{\frac{|P|}{C_a R_{eH}}}$$

where:

C_a = permissible bending stress coefficient for plate taken equal to:

$$C_a = \beta_a - \alpha_a\left|\frac{\sigma_{hg}}{R_{eH}}\right|$$ not to be taken greater than $C_{a\text{-}max}$

β_a = coefficient as defined in Table 1

α_a = coefficient as defined in Table 1

$C_{a\text{-}max}$ = maximum permissible bending stress coefficient as defined in Table 1.

α_p = correction factor for the panel aspect ratio to be taken as follows but not to be taken greater than 1.0:

$$\alpha_p = 1{,}2 - \frac{b}{2.1\,a}$$

Donde:

a = 2500 mm

b = 900 mm

α_p = 1,02 > 1, por lo que α_p = 1

$$Ca = 1{,}05 - 1 \times \frac{205}{235}$$

Ca = 0,177

P = presión máxima establecida en el doble fondo. P = 152,8 KN/m^2.

$$t = 0.0158\alpha_p b\sqrt{\frac{|P|}{C_a R_{eH}}}$$

t = 27,25 mm

4.17 Módulo mínimo de los refuerzos secundarios

(Pt3 Ch6 Sec6 pag 27)

2 Primary supporting members

2.1 Scantling requirements

2.1.1 Section modulus

The section modulus, in cm^3, of primary supporting members subjected to lateral pressure shall not be taken less than the greatest value for all applicable design load sets defined in Sec.2 [2], given by:

$$Z = 1000 \frac{|P| s \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

Z = Z_{n50}, required net section modulus in cm^3, only applicable for ships with class notation **ESP**
= Z_{gr}, required gross section modulus in cm^3, for other ships
f_{bdg} = bending moment distribution factor, as given in Table 1
C_s = permissible stress coefficient to be taken as:
C_s = 0.70 for AC-I
C_s = 0.85 for AC-II and AC-III.

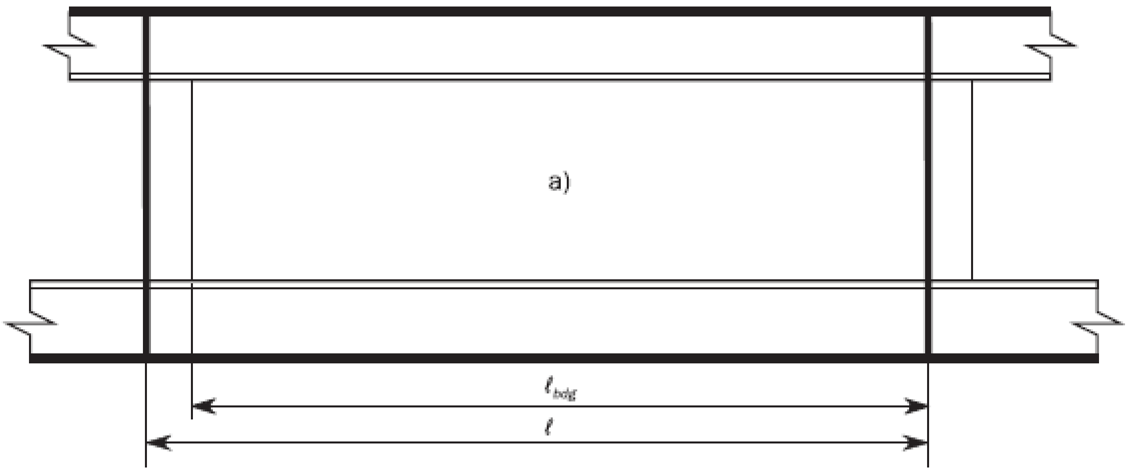
Donde:

- P = presión máxima establecida en el doble fondo. P = 152,8 KN/m^2.
- s = separación entre refuerzos primarios, la cual para este elemento se dispondráuna separación acorde con el espaciado comprendido de tres claras de cuaderna. s = 3 x 900 = 2700 mm
- f_{bdg} = factor del momento flector. f_{bdg} = 12
  (Pt3 Ch6 Sec5 pag 24)

Table 5 Stiffeners, definition of f_{bdg} and f_m

Coefficient	Acceptance criteria	For continuous stiffeners with fixed ends		For continuous stiffeners with one fixed end and one simply supported end	For non-continuous stiffeners with simply supported ends
		Horizontal stiffeners and upper end of vertical stiffeners	Lower end of vertical stiffeners	Horizontal and vertical stiffeners	Horizontal and vertical stiffeners
f_{bdg}	AC-I, AC-II, AC-III	12.00	10.00	8.00	8.00
f_m	AC-I	2.00	2.33	1.77	-
	AC-II, AC-III	1.60	1.86	1.42	

- l_{bdg} = longitud o tramo de flexión efectivo en el refuerzo, el cual no será toda la longitud de separación entre refuerzos primarios. Se considerará un 95% de la longitud del elemento primario, el cual en este caso en la varenga con una longitud en 3 claras de cuadernas valdrá (0,95*(3*900) = 2565 mm). l_{bdg} = 2,565 m
  (Pt3 Ch3 Sec7 pag 59)



- Cs = coeficiente elástico permisible que vale 0,85 para la zona de actuación del doble casco referente a AC-II.
- R_{eh} = limite elástico del acero naval normal. R_{eh} = 235 MPa

Recordando la formula del módulo:

$$Z = 1000 \frac{|P| S \, \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

Z = 1132,38 cm^3

4.18 Vagras

(Pt3 Ch6 Sec3 pag 14)

Table 2 Minimum net thickness for stiffeners and tripping brackets

Element	*Location*	*Net thickness*
Stiffeners and attached end brackets	Tank boundary, boundary of cargo holds for dry bulk cargo, single strength deck and shell up to freeboard deck	$4.5 + 0.01\, L_1$
	Structures in deckhouse and superstructure and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.0
	Other structure	$4.5 + 0.005\, L_1$
Tripping brackets		$4.5 + 0.01\, L_1$

3 Primary supporting members

3.1 Minimum thickness requirements

3.1.1 The net thickness of web plating and flange of primary supporting members in mm, shall not be taken less than:

$$t = a + bL_2\sqrt{k}$$

where:

a = coefficient as defined in Table 3
b = coefficient as defined in Table 3.

Table 3 Minimum net thickness for primary supporting members

Element	*a*	*b*
Bottom centreline girder and lower strake of centreline wash bulkhead	5.0	0.03
Other bottom girders	5.0	0.017
Floors	5.0	0.015
PSM at tank boundaries, boundaries of holds intended for cargo in bulk, single strength deck and shell up to freeboard deck	4.5	0.015 [2)]
PSM in deckhouses and superstructures and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.5	0.01 [3)]
Other PSM	4.5	0.01
PSM in peak tanks	5.0	0.025 [1)]

1) $bL_2 \le 5.0$
2) $bL_2 \le 2.5$ for stringers in double side next to dry space not intended for cargo in bulk.
3) $bL_2 \le 2,0$

L_1 = eslora de escantillonado, L_1 = 323 m

$$t = 4,5 + 0,01 \times 323 \times \sqrt{1}$$

t = 7,8mm

(Pt3 Ch6 Se4 pag 16)

1.1 General

1.1.1 Plating

The net thickness, in mm, shall not be taken less than the greatest value for all applicable design load sets, as defined in Sec.2 [2.1.3], given by:

$$t = 0{,}0158\alpha_p b\sqrt{\frac{|P|}{C_a R_{eH}}}$$

where:

C_a = permissible bending stress coefficient for plate taken equal to:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{R_{eH}}$$ not to be taken greater than $C_{a\text{-}max}$

β_a = coefficient as defined in Table 1

α_a = coefficient as defined in Table 1

$C_{a\text{-}max}$ = maximum permissible bending stress coefficient as defined in Table 1.

α_p = correction factor for the panel aspect ratio to be taken as follows but not to be taken greater than 1.0:

$$\alpha_p = 1{,}2 - \frac{b}{2.1\,a}$$

Donde:

a = 2700 mm

b = 2500 mm

$\alpha_p = 0{,}76$

$$Ca = 1{,}05 - 1 \times \frac{205}{235}$$

Ca = 0,177

P = presión máxima establecida en el doble fondo. P = 152,8 KN/m^2.

$$t = 0.0158\alpha_p b\sqrt{\frac{|P|}{C_a R_{eH}}}$$

t = 20,7 mm

4.19 Módulo mínimo de los refuerzos secundarios

(Pt3 Ch6 Sec6 pag 27)

2 Primary supporting members

2.1 Scantling requirements

2.1.1 Section modulus

The section modulus, in cm^3, of primary supporting members subjected to lateral pressure shall not be taken less than the greatest value for all applicable design load sets defined in Sec.2 [2], given by:

$$Z = 1000\frac{|P| s \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

Z = Z_{n50}, required net section modulus in cm^3, only applicable for ships with class notation **ESP**
= Z_{gr}, required gross section modulus in cm^3, for other ships
f_{bdg} = bending moment distribution factor, as given in Table 1
C_s = permissible stress coefficient to be taken as:
C_s = 0.70 for AC-I
C_s = 0.85 for AC-II and AC-III.

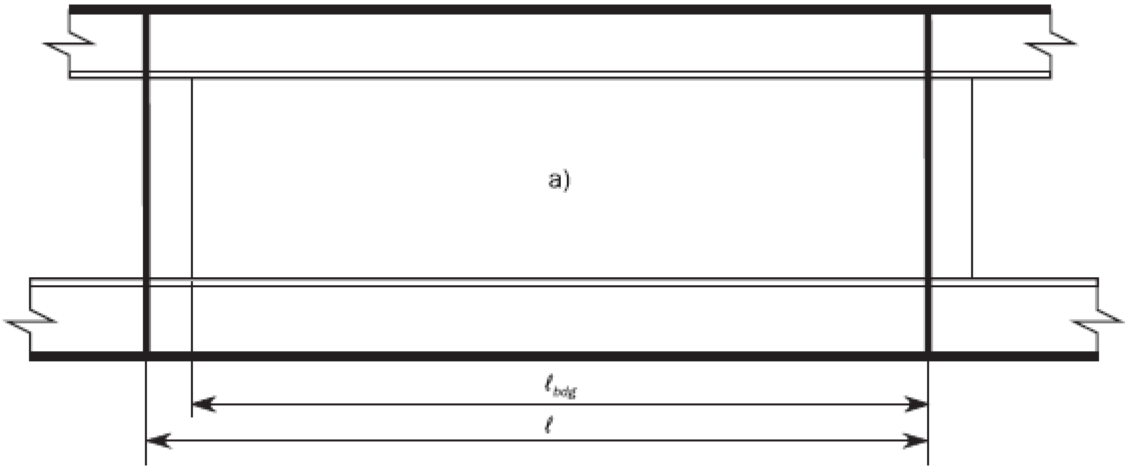
Donde:

- P = presión máxima establecida en el doble fondo. P = 152,8 KN/m^2.
- s = separación entre refuerzos primarios, la cual para este elemento se dispondrá de una separación acorde con el espaciado comprendido de tres claras de cuaderna.
  s = 3 x 900 = 2700 mm
- f_{bdg} = factor del momento flector. f_{bdg} = 12
  (Pt3 Ch6 Sec5 pag 24)

Table 5 Stiffeners, definition of f_{bdg} and f_m

Coefficient	*Acceptance criteria*	*For continuous stiffeners with fixed ends*		*For continuous stiffeners with one fixed end and one simply supported end*	*For non-continuous stiffeners with simply supported ends*
		Horizontal stiffeners and upper end of vertical stiffeners	*Lower end of vertical stiffeners*	*Horizontal and vertical stiffeners*	*Horizontal and vertical stiffeners*
f_{bdg}	AC-I, AC-II, AC-III	12.00	10.00	8.00	8.00
f_m	AC-I	2.00	2.33	1.77	-
	AC-II, AC-III	1.60	1.86	1.42	

- l_{bdg} = longitud o tramo de flexión efectivo en el refuerzo, el cual no será toda la longitud de separación entre refuerzos primarios. Se considerará un 95% de la longitud del elemento primario, el cual en este caso en la vagra con una longitud en 3 claras de cuadernas valdrá (0,95*(3*900) = 2565 mm). l_{bdg} = 2,565 m
  (Pt3 Ch3 Sec7 pag 59)



- Cs = coeficiente elástico permisible que vale 0,85 para la zona de actuación del doble casco referente a AC-II.
- R_{eh} = limite elástico del acero naval normal. R_{eh} = 235 MPa

Recordando la formula del módulo:

$$Z = 1000 \frac{|P| S \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

Z = 1132,4 cm^3

4.20 Bulárcamas

(Pt3 Ch6 Sec3 pag 14)

Table 2 Minimum net thickness for stiffeners and tripping brackets

Element	*Location*	*Net thickness*
Stiffeners and attached end brackets	Tank boundary, boundary of cargo holds for dry bulk cargo, single strength deck and shell up to freeboard deck	$4.5 + 0.01\ L_1$
	Structures in deckhouse and superstructure and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.0
	Other structure	$4.5 + 0.005\ L_1$
Tripping brackets		$4.5 + 0.01\ L_1$

3 Primary supporting members

3.1 Minimum thickness requirements

3.1.1 The net thickness of web plating and flange of primary supporting members in mm, shall not be taken less than:

$$t = a + bL_2\sqrt{k}$$

where:

a = coefficient as defined in Table 3
b = coefficient as defined in Table 3.

Table 3 Minimum net thickness for primary supporting members

Element	*a*	*b*
Bottom centreline girder and lower strake of centreline wash bulkhead	5.0	0.03
Other bottom girders	5.0	0.017
Floors	5.0	0.015
PSM at tank boundaries, boundaries of holds intended for cargo in bulk, single strength deck and shell up to freeboard deck	4.5	0.015 [2)]
PSM in deckhouses and superstructures and decks for vessels with more than 2 continuous decks above 0.7 *D* from baseline	4.5	0.01 [3)]
Other PSM	4.5	0.01
PSM in peak tanks	5.0	0.025 [1)]

1) $bL_2 \leq 5.0$
2) $bL_2 \leq 2.5$ for stringers in double side next to dry space not intended for cargo in bulk.
3) $bL_2 \leq 2{,}0$

L_1 = eslora de escantillonado, L_1 = 323 m

$$t = 4{,}5 + 0{,}01 \times 323 \times \sqrt{1}$$

t = 7,8mm

(Pt3 Ch6 Se4 pag 16)

1.1 General

1.1.1 Plating

The net thickness, in mm, shall not be taken less than the greatest value for all applicable design load sets, as defined in Sec.2 [2.1.3], given by:

$$t = 0{,}0158\alpha_p b\sqrt{\frac{|P|}{C_a R_{eH}}}$$

where:

C_a = permissible bending stress coefficient for plate taken equal to:

$$C_a = \beta_a - \alpha_a \frac{|\sigma_{hg}|}{R_{eH}}$$ not to be taken greater than $C_{a\text{-}max}$

β_a = coefficient as defined in Table 1

α_a = coefficient as defined in Table 1

$C_{a\text{-}max}$ = maximum permissible bending stress coefficient as defined in Table 1.

α_p = correction factor for the panel aspect ratio to be taken as follows but not to be taken greater than 1.0:

$$\alpha_p = 1{,}2 - \frac{b}{2.1\,a}$$

Donde:

a = 2700 mm

b = 900 mm

α_p = 1,04 > 1, por lo que α_p = 1

$$Ca = 1{,}25 - 0{,}5 \times \frac{205}{235}$$

Ca = 0,82

P = presión máxima establecida en el doble fondo. P = 152,8 KN/m^2.

$$t = 0.0158\alpha_p b\sqrt{\frac{|P|}{C_a R_{eH}}}$$

t = 12,7 mm

4.21 Módulo mínimo de los refuerzos secundarios

(Pt3 Ch6 Sec6 pag 27)

2 Primary supporting members

2.1 Scantling requirements

2.1.1 Section modulus

The section modulus, in cm^3, of primary supporting members subjected to lateral pressure shall not be taken less than the greatest value for all applicable design load sets defined in Sec.2 [2], given by:

$$Z = 1000\frac{|P|\, s\, \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

where:

Z = Z_{n50}, required net section modulus in cm^3, only applicable for ships with class notation **ESP**

= Z_{gr}, required gross section modulus in cm^3, for other ships

f_{bdg} = bending moment distribution factor, as given in Table 1

C_s = permissible stress coefficient to be taken as:

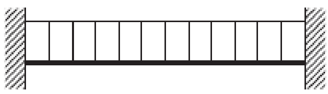
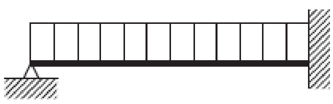
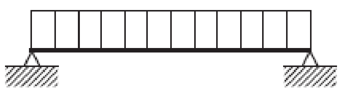
C_s = 0.70 for AC-I

C_s = 0.85 for AC-II and AC-III.

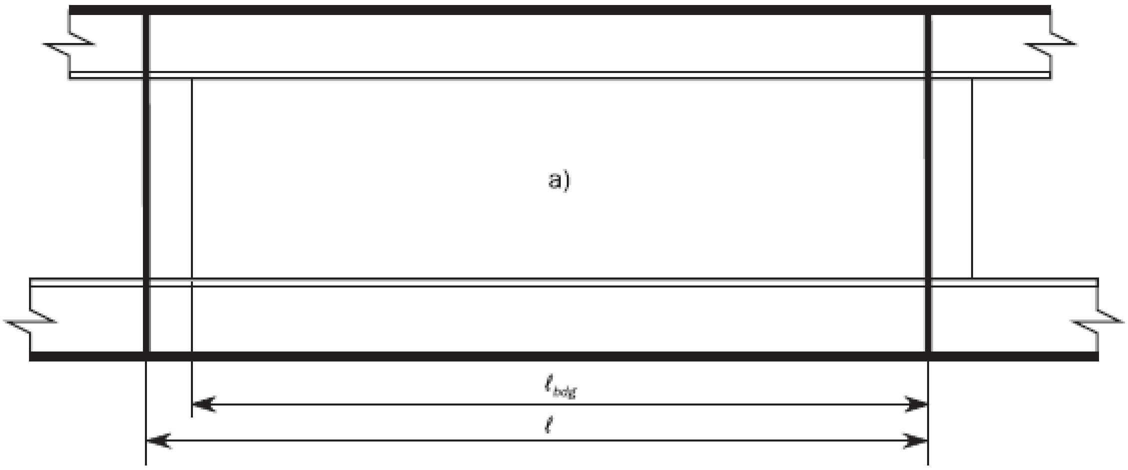
Donde:

- P = presión máxima establecida en el doble fondo. P = 152,8 KN/m^2.
- s = separación entre refuerzos primarios, la cual para este elemento se dispondrá de una separación acorde con el espaciado comprendido de tres claras de cuaderna.
  s = 3 x 900 = 2700 mm
- f_{bdg} = factor del momento flector. fbdg = 24
  (Pt3 Ch6 Sec5 pag 28)

Table 1 Definition of bending moment and shear force factors, f_{bdg} and f_{shr}

Load and boundary condition				Bending moment and shear force distribution factors (based on load at mid span, where load varies)		
	Position			1	2	3
Load model	1 Support	2 Field	3 Support	f_{bdg1} f_{shr1}	f_{bdg2} -	f_{bdg3} f_{shr3}
A				12.0 0.50	24.0 -	12.0 0.50
B				- 0.38	14.2 -	8.0 0.63
C				- 0.50	8.0 -	- 0.50

- l_{bdg} = longitud o tramo de flexión efectivo en el refuerzo, el cual no será toda la longitud de separación entre refuerzos primarios. Se considerará un 95% de la longitud del elemento primario, el cual en este caso será una longitud en 3 claras de cuadernas valdrá (0,95*(3*900) = 2565 mm). l_{bdg} = 2,565 m
  (Pt3 Ch3 Sec7 pag 59)



- Cs = coeficiente elástico permisible que vale 0,85 para la zona de actuación del doble casco referente a AC-II.
- R_{eh} = limite elástico del acero naval normal. R_{eh} = 235 MPa

Recordando la formula del módulo:

$$Z = 1000 \frac{|P| S \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

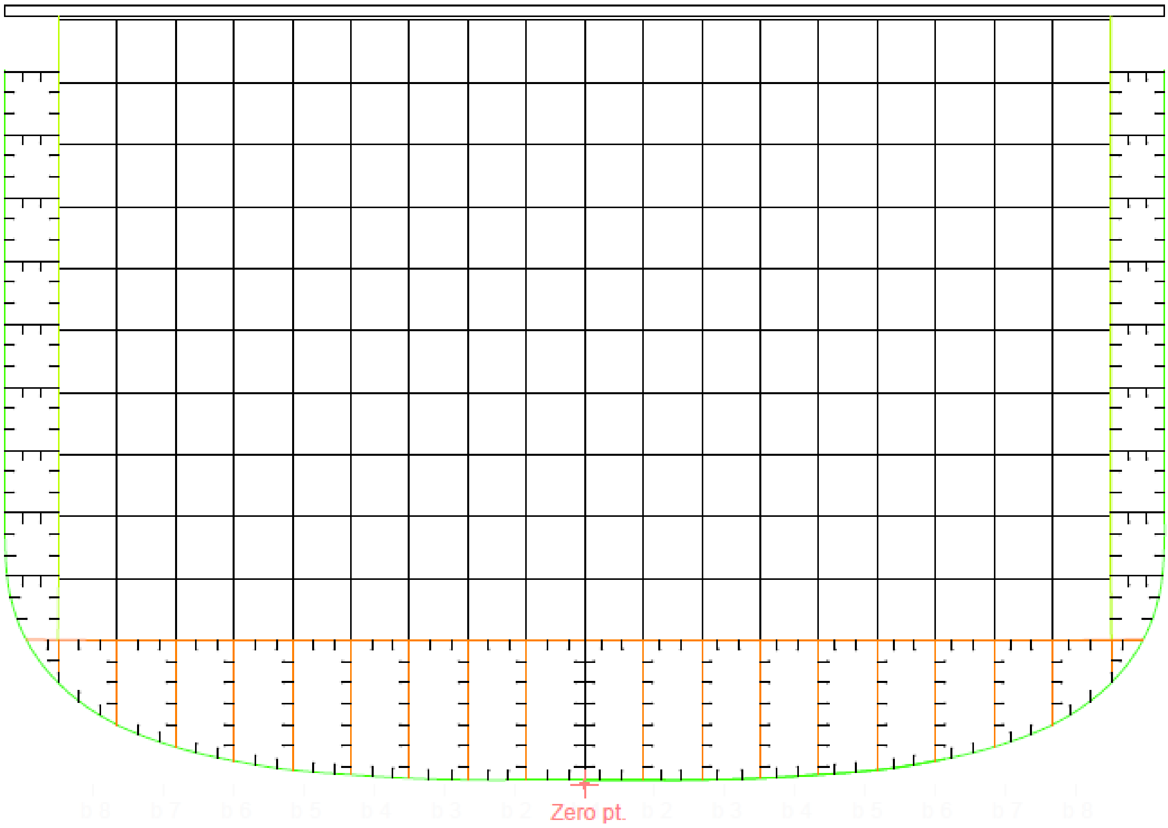
Z = 566,2 cm^3

5 TABLA RESUMEN DE ESPESORES Y MÓDULOS

Espesores en función de la presión	**t (mm)**
Chapa del fondo	16,2
Chapa del doble fondo	14,68
Chapa del costado	15,5
Mamparo	20,58

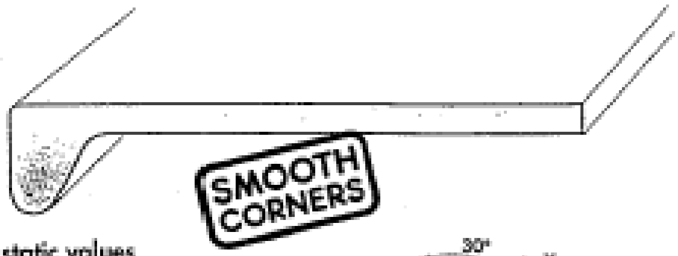
Refuerzos	**Espesor t_w (mm)**	**Módulo (cm^3)**
Longitudinales del mamparo	11	847,11
Long. del costado y doble costado	6,2	480
Long. del fondo y doble fondo	4,85	430,786
Baos	12	254,2
Varengas	27,25	1132,38
Vagras	20,7	1132,38
Bularcamas	12,7	566,2

6 CUADERNA MAESTRA

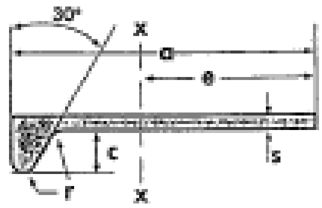


7 ANEXO: CATÁLOGO DE PERFILES BULBO

Bulb Flats



Dimension range, weight/m and static values



Width a mm	Thickness s mm	Height c mm	Radius r mm	Area A cm²	Weight kg/m	e cm	I_x cm⁴	W_x* cm³
60	4	13	3.5	3.58	2.81	3.82	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
		Delivery by special agreement. Standard lengths 6–12 m						
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
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	15.3	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
200	9	28	8	23.6	18.5	12.1	941	225
	10	28	8	25.6	20.1	11.9	1020	237
	11.5	28	8	28.6	22.5	11.7	1126	255
220	10	31	9	29.0	22.8	13.4	1400	302
	11.5	31	9	32.3	25.4	13.1	1550	323
240	10	34	10	32.4	25.4	14.7	1860	368
	11	34	10	34.9	27.4	14.6	2000	391
	12	34	10	37.3	29.3	14.4	2130	406
260	10	37	11	36.1	28.3	16.2	2477	455
	11	37	11	38.7	30.3	16.0	2610	474
	12	37	11	41.3	32.4	15.8	2770	493
280	11	40	12	42.6	33.5	17.4	3330	566
	12	40	12	45.5	35.7	17.2	3550	590
300	11	43	13	46.7	36.7	18.9	4190	671
	12	43	13	49.7	39.0	18.7	4460	701
	13	43	13	52.8	41.5	18.5	4720	728
320	12	46	14	54.2	42.5	20.1	5530	819
	13	46	14	57.4	45.0	19.9	5850	849
340	12	49	15	58.8	46.1	21.5	6760	947
	14	49	15	65.5	51.5	21.1	7540	1014
370	13	53.5	16.5	69.6	54.6	23.5	9470	1210
	15	53.5	16.5	77.0	60.5	23.0	10490	1278
400	14	58	18	81.4	63.9	25.5	12930	1580
	16	58	18	89.4	70.2	25.0	14220	1666
430	15	62.5	19.5	94.1	73.9	27.4	17260	1935
	17	62.5	19.5	103.0	80.6	26.9	18860	2036

* Inclusive plate as noted

Plate cross sectional area 60 cm² (widths 60–180)

Plate cross sectional area 100 cm² (widths 200–370)

Plate cross sectional area 150 cm² (widths 400–430)

Standard lengths
6–18 m.
Other lengths by special agreeme

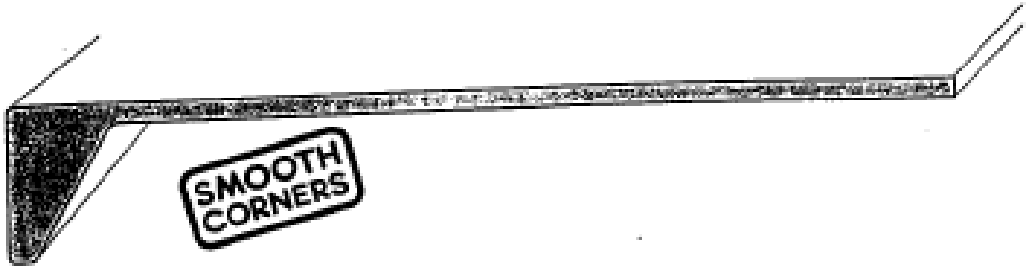
Orders
must include the following measurements:
a x s.

INEXA PROFIL

9

Jumbo Bulb Flats

Welded bulb flats, for very large and ultra large carrier/vessels



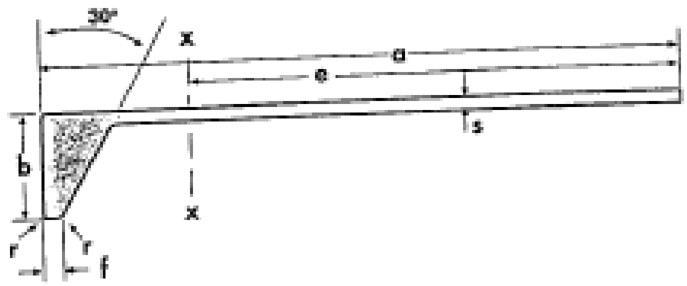
Dimension range, weight/m and static values

Width a mm	Thickness s mm	Height b mm	Bulb bottom f mm	Radius r mm	Area A cm²	Weight kg/m	e cm	I_x cm⁴	W_x * cm³
400	12	110	17	5.0	92.1	72.3	38.4	13530	2104
	14	110	17	5.0	98.7	77.5	37.6	14990	2144
450	12	110	17	5.0	98.1	77.0	31.5	18900	2457
	14	110	17	5.0	105.7	83.0	30.6	20920	2512
500	12	110	17	5.0	104.1	81.7	34.5	25440	2825
	14	110	17	5.0	112.7	88.5	33.5	28110	2897
550	12	110	17	5.0	110.1	86.4	37.5	33220	3208
	14	110	17	5.0	119.7	94.0	36.4	36670	3298
600	12	110	17	5.0	116.1	91.1	40.4	42340	3604
	14	110	17	5.0	126.7	99.5	39.3	46700	3714
650	12	110	17	5.0	122.1	[illegible]	43.3	52870	4014
	14	110	17	5.0	133.7	105.0	43.1	58290	4147

Plate cross sectional area 150 cm²

* Inclusive plate as noted

Other dimensions by special agreement.



Standard lengths

8 – 18 m.

Other lengths by special agreement.

Orders

must include the following measurements:

a x s.

INEXA PROFIL

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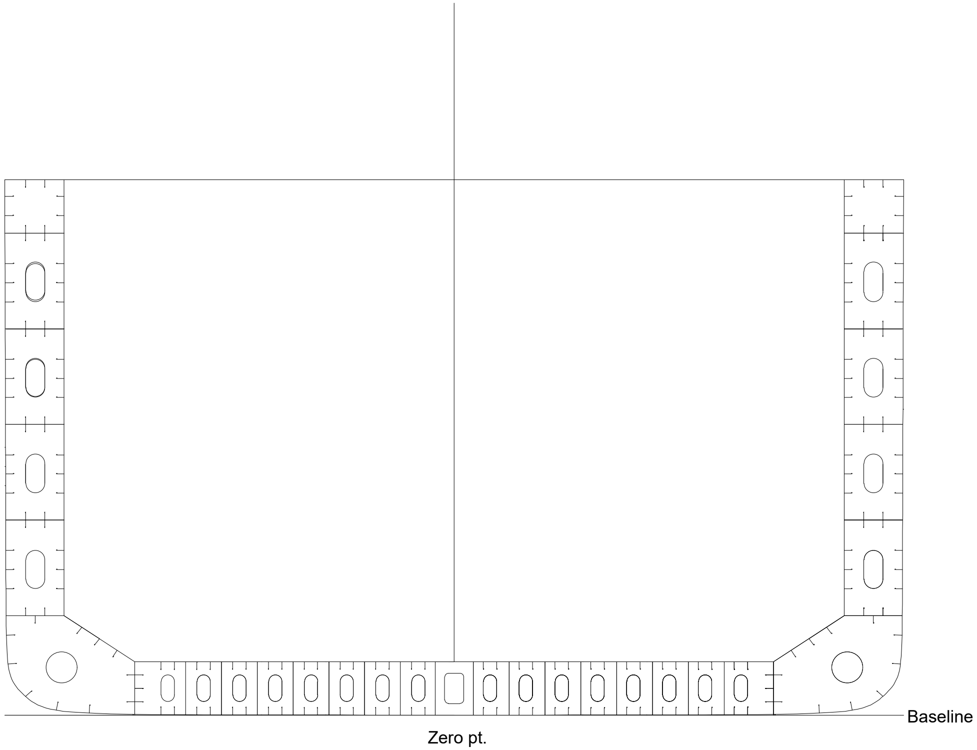

Espesores	t (mm)
Fondo	16,2
Doble fondo	14,68
Costado	15,5
Mamparo	20,58

Refuerzo	t (mm)	Módulo (cm3)
Long. mamparo	11	847,11
Long. costado y doble casco	6,2	480
Long. fondo y doble fondo	4,85	430,786
Baos	12	254,2
Varengas	27,25	1132,38
Vagras	20,7	1132,38
Bularcamas	12,7	566,2

TÍTULO:
BUQUE PORTACONTENEDORES POSTPANAMAX DE 1100 TEUS

PLANO:
CUADERNA MAESTRA

CUADERNO:
8

UNIVERSIDADE DA CORUÑA

AUTOR:
MANUEL GARCÍA PENSADO

ESCALA:
1:250