UNIVERSIDADE DA CORUÑA

Escola Politécnica Superior

TRABAJO FIN DE GRADO

CURSO 2017/18

Buque PSV. Buque de suministro a plataformas de 5000 TPM

Grado en Ingeniería Naval Oceánica

CUADERNO 8

Cuaderna maestra

Sandra Allegue García

PROYECTO 18-02

Escola Politécnica Superior
UNIVERSIDADE DA CORUÑA

GRADO EN INGENIERÍA NAVAL Y OCEÁNICA
TRABAJO DE FIN DE GRADO

CURSO 2.017-2018

PROYECTO NÚMERO 18-02

TIPO DE BUQUE: Buque PSV (Platform Vessel Supply). Buque de suministro a plataformas.

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

CARACTERÍSTICAS DE LA CARGA: Carga líquida y seca a granel para suministro a plataformas, 5000 TPM.

VELOCIDAD Y AUTONOMÍA: 13 nudos en condiciones de servicio al 85% de MCR y 15% de margen de mar. 6000 millas a la velocidad de servicio

SISTEMAS Y EQUIPOS DE CARGA / DESCARGA: Bombas para la carga y descarga de la carga líquida. Dos grúas.

PROPULSIÓN: Propulsión diésel-eléctrica. LNG para estancias en puerto

TRIPULACIÓN Y PASAJE: 35 personas.

OTROS EQUIPOS E INSTALACIONES: Sistema de posicionamiento dinámico con redundancia DP 3. FIFI

Ferrol, 2 Noviembre 2017

ALUMNO/A: **Dª Sandra Allegue García**

ÍNDICE

1 INTRODUCCIÓN

En este Cuaderno se realizarán todos los cálculos relacionados con la Cuaderna Maestra del buque, tanto el dimensionamiento como el cálculo del módulo. También se elegirá el tipo de estructura y el tipo de quilla que tendrá el buque

El plano usado no es el del buque proyecto, pero se asemeja bastante y por ello es el elegido como referencia, en el último apartado se harán las correcciones pertinentes al escantillonado con todas las diferencias entre el cálculo y el plano.

Las dimensiones del buque proyecto son las siguientes:

Lpp = 78,58 m
Loa = 85,78 m
B = 19,13 m
T = 6,58 m
D = 8,26 m
BHP = 1985 kW
Δ = 7.742 t
Fn = 0,241
Cb = 0,764
Cm = 0,989
Cp = 0,772
Cf = 0,925
Acubierta = 0,7·Lpp·0,9·B = 947 m^2

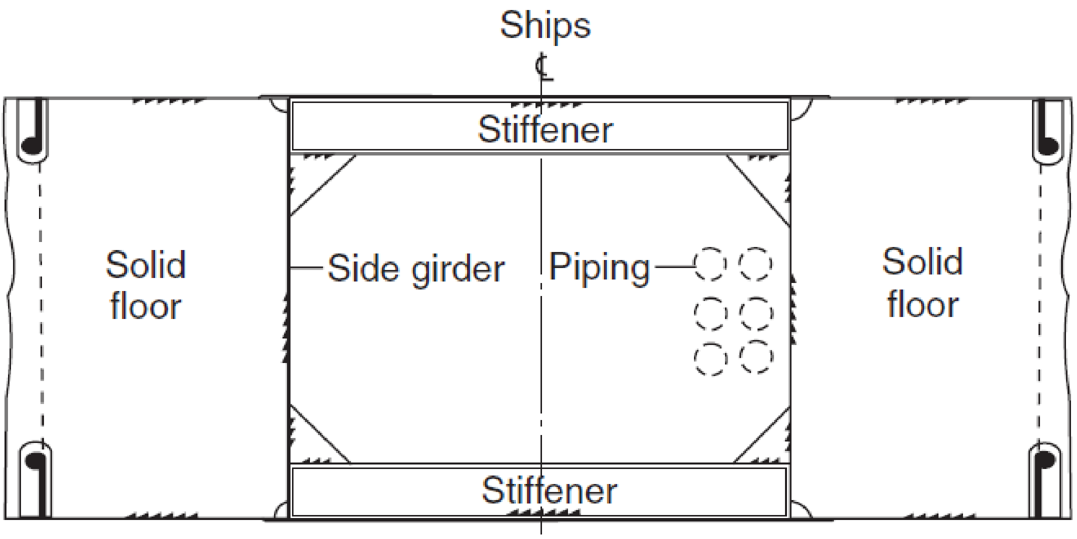
2 DISEÑO CONCEPTUAL DE LA CUADERNA MAESTRA

A continuación, se desarrollarán todas … antes de proceder al cálculo del escantillonado.

2.1 QUILLA

Se elige un tipo de quilla que es el túnel de quilla (duct keel). Este tipo de quilla se utiliza en algunos buques para que pasen todos los tubos y cables del doble fondo. Además, debido a que la cámara de máquinas se encuentra en proa, se usa para hacer la conexión desde los motores generados principales hasta el motor eléctrico que accionan los propulsores.

El túnel de quilla suele tener la siguiente estructura:



El túnel de quilla en el buque proyecto cuenta con una manga de 2 m y una altura, que corresponde a la altura del doble fondo, de 1,5 m y se extiende desde el mamparo de popa de la cámara de máquinas hacia la popa del buque.

2.2 TIPO DE ESTRUCTURA

Hay que definir el tipo de estructura que va a tener el buque proyecto, existen dos tipos:

- Estructura transversal
- Estructura longitudinal

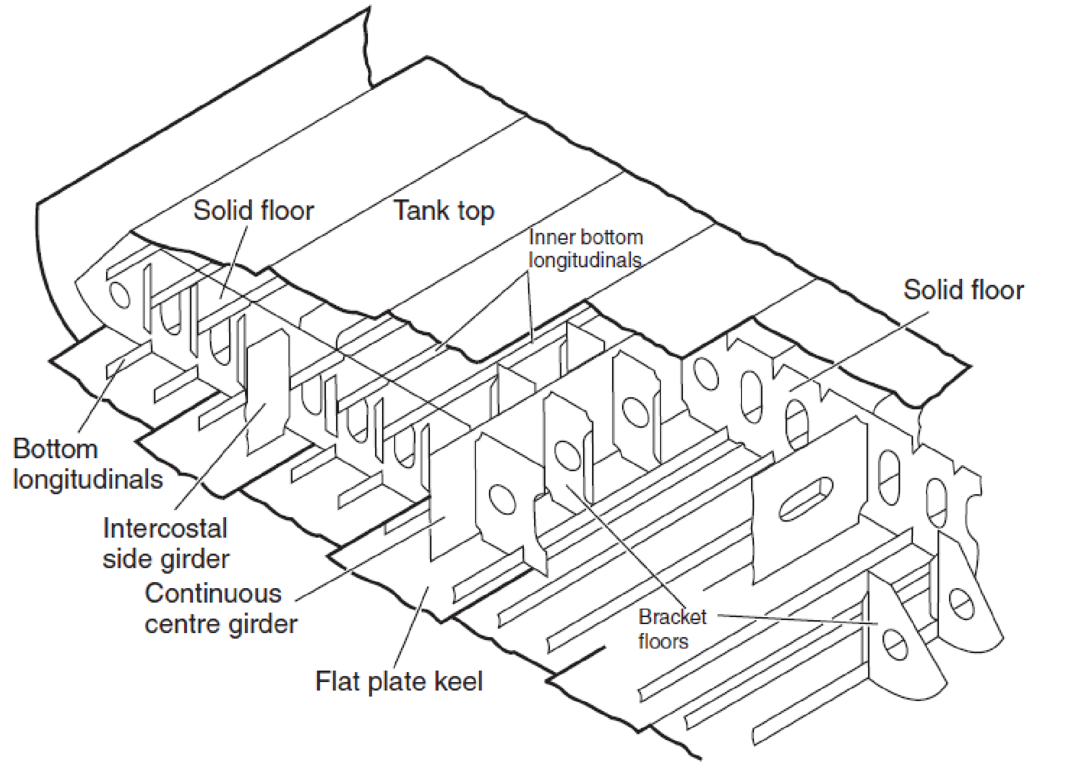
La principal diferencia entre estas dos disposiciones es la dirección en la cual estarán situados los refuerzos para que absorban las tensiones en sentido longitudinal o transversal.

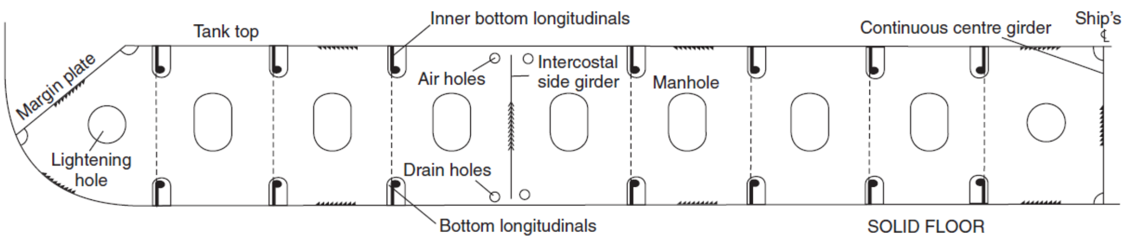
Normalmente, la estructura transversal se utiliza en buques de poca eslora. Esto es debido a que según aumenta la eslora aumentan las cargas en sentido longitudinal.

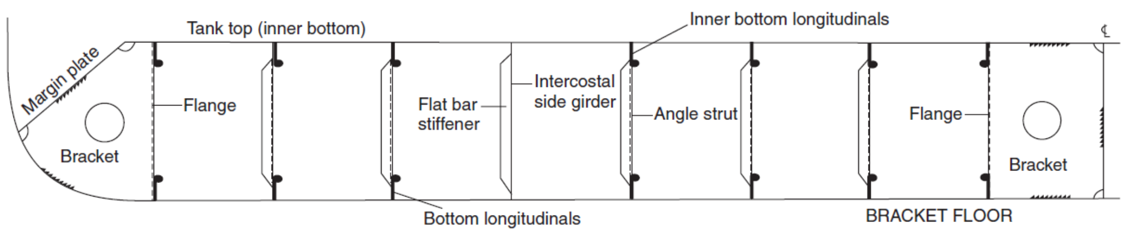
Como el buque tiene una eslora de 85 m y debido a las actividades que va a desempeñar el buque se van a crear más tensiones longitudinales, se opta por una estructura longitudinal.

2.3 DOBLE FONDO

El buque tendrá una estructura longitudinal, como ya se ha mencionado a continuación, por lo que la estructura del doble fondo tendrá la siguiente estructura:







2.4 PLANO DE REFERENCIA DE LA CUADERNA MAESTRA

Para el plano de referencia se ha escogido la siguiente imagen ya que se aproxima bastante al buque proyecto:

3 ESCANTILLONADO LOCAL DE LA CUADERNA MAESTRA

3.1 DIMENSIONES

3.1.1 Eslora de escantillonado

En buques que no tengan mecha del timón la eslora de escantillonado será igual 97% de la eslora tomada al calado de escantillonado:

$$L = 0{,}97 \cdot 83{,}4 = 80{,}90\ m$$

3.1.2 Calado de escantillonado

El calado de escantillonado será el francobordo máximo de verano:

$$T_{SC} = 6{,}593\ m \cong 6{,}59\ m$$

3.1.3 Manga de escantillonado

La mayor manga del buque, en m, mediad en el medio del buque al calado 6,59 m:

$$B = 19{,}13\ m$$

3.1.4 Puntal de escantillonado

Distancia vertical, en m, medido desde la línea base hasta la cubierta continua más alta:

$$D = 8{,}26\ m$$

3.1.5 Coeficiente de bloque

Coeficiente de bloque al calado Tsc:

$$C_B = \frac{\Delta\ (para\ T_{SC})}{1{,}025 \cdot L \cdot B \cdot T_{SC}}$$

De las hidrostáticas se saca el desplazamiento al calado de 6,59 m:

Draft Amidships m	6,590
Displacement t	**7667**
Heel deg	-0,5
Draft at FP m	6,841
Draft at AP m	6,339
Draft at LCF m	6,550
Trim (+ve by stern) m	-0,502
WL Length m	83,574
Beam max extents on WL m	19,131
Wetted Area m^2	2317,925
Waterpl. Area m^2	1382,196
Prismatic coeff. (Cp)	0,770
Block coeff. (Cb)	0,739
Max Sect. area coeff. (Cm)	0,982
Waterpl. area coeff. (Cwp)	0,919
LCB from zero pt. (+ve fwd) m	37,271
LCF from zero pt. (+ve fwd) m	33,004
KB m	3,576
KG fluid m	6,133
BMt m	5,002
BML m	87,131
GMt corrected m	2,444
GML m	84,573
KMt m	8,578
KML m	90,702
Immersion (TPc) tonne/cm	14,168
MTc tonne.m	82,521
RM at 1deg = GMt.Disp.sin(1) tonne.m	327,075
Max deck inclination deg	0,5937
Trim angle (+ve by stern) deg	-0,3658

Resolviendo:

$$C_B = \frac{7667}{1{,}025 \cdot 80{,}90 \cdot 19{,}13 \cdot 6{,}59} = 0{,}733$$

3.1.6 Claras entre cuadernas

El buque tiene la siguiente disposición de separación de cuadernas:

- De popa hasta la cuaderna 12 → s = 600 mm
- De la cuaderna 12 a la 110 → s = 700 mm
- De la cuaderna 110 a proa → s = 600 mm

A su vez se considera:

- Varengas dispuestas cada 3 claras de cuaderna

3.2 DIMENSIONAMIENTO DEL FONDO

3.2.1 Cálculo de parámetros básicos

En este apartado se calcularán los siguientes parámetros básicos:

C_w = wave coefficient, in m, shall be taken as:

$$C_w = 0.0856L \quad \text{for} \quad L < 90$$

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

$$C_w = 10.75 \quad \text{for} \quad 300 < L \leq 350$$

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

3.2.2 Coeficiente de ola C_w (Part 3, Ch.4, Sec. 4)

Como la eslora del buque es de 80,90 m:

$$C_w = 0{,}0856 \cdot 80{,}90 \longrightarrow \boldsymbol{C_w = 6,92}$$

C_V = $\frac{\sqrt{L}}{50}$, maximum 0.2

C_v

$$C_v = \frac{\sqrt{80{,}90}}{50} \longrightarrow \boldsymbol{C_v = 0,18}$$

3.2.2.1 Parámetro común de la aceleración, a_0 (Part 3, Ch. 4, Sec. 3)

a_0 = acceleration parameter, shall be taken as:

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

$$a_0 = (1{,}58 - 0{,}47 \cdot 0{,}733) \cdot \left(\frac{2{,}4}{\sqrt{80{,}90}} + \frac{34}{80{,}90} - \frac{600}{80{,}90^2}\right) \longrightarrow \boldsymbol{a_0 = 0,74}$$

3.2.2.2 Periodo de balance y ángulo de balance, T_θ y θ (Part 3, Ch. 4, Sec. 3)

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 $B \leq 32.2$ m
GM = 0.11 B for container ship with $B \geq 40.0$ m

$$T_\theta = \frac{2{,}3 \cdot \pi \cdot 0{,}39 \cdot 19{,}13}{\sqrt{9{,}81 \cdot 0{,}07 \cdot 19{,}13}} \longrightarrow \boldsymbol{T_\theta = 14{,}87\ s}$$

$$\theta = \frac{9000 \cdot (1{,}4 - 0{,}035 \cdot 14{,}87) \cdot 1 \cdot 1{,}2}{(1{,}15 \cdot 19{,}13 + 55) \cdot \pi} \longrightarrow \boldsymbol{\theta = 39{,}27^\circ}$$

3.2.2.3 Período de paso y ángulo de paso, φ (Part 3, Ch. 4, Sec. 3)

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

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

where:

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

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

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

where:

f_p = coefficient shall be taken as:
$f_p = f_{ps}$ for strength assessment
$f_p = f_R\left[\left(0.27 - 0.02 f_T\right) - \left(13 - 5 f_T\right) \cdot L \cdot 10^{-5}\right]$ for fatigue assessment.

$$T_\varphi = \sqrt{\frac{2 \cdot \pi \cdot 0{,}6 \cdot (1+1) \cdot 80{,}90}{9{,}81}} \longrightarrow \boldsymbol{T_\varphi = 7{,}88\ s}$$

$$\varphi = 920 \cdot 1 \cdot 80{,}90^{-0{,}84} \cdot \left\{1 + \left(\frac{2{,}57}{\sqrt{9{,}81 \cdot 80{,}90}}\right)^{1{,}2}\right\} \longrightarrow \boldsymbol{\varphi = 24{,}26^\circ}$$

3.2.2.4 Aceleración longitudinal (a_x), transversal (a_y) y vertical (a_z) (Part 3, Ch. 4, Sec. 3)

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:

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

Donde:

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.

$$a_{surge} = 0{,}2 \cdot \left(1{,}6 + \frac{1{,}5}{\sqrt{9{,}81 \cdot 80{,}90}}\right) \cdot 1 \cdot 0{,}74 \cdot 9{,}81 \longrightarrow a_{surge} = 2{,}39\ m/s^2$$

The transverse acceleration due to sway, in m/s^2, 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

$f_p = f_R\left[0.24 - \left(6 - 2f_T\right)B \cdot 10^{-4}\right]$ for fatigue assessment.

$$a_{sway} = 0{,}3 \cdot \left(2{,}25 - \frac{20}{\sqrt{9{,}81 \cdot 80{,}90}}\right) \cdot 1 \cdot 0{,}74 \cdot 9{,}81 \longrightarrow a_{sway} = 3{,}34\ m/s^2$$

The vertical acceleration due to heave, in m/s^2, 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.

$$a_{heave} = 0{,}8 \cdot (1 + 0{,}03 \cdot 0) \cdot \left(0{,}72 + \frac{2 \cdot 80{,}90}{700}\right) \cdot \left(1{,}15 - \frac{6{,}5}{\sqrt{9{,}81 \cdot 80{,}90}}\right) \cdot 1 \cdot 0{,}736 \cdot 9{,}81$$

$$a_{heave} = 5{,}05\ m/s^2$$

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

$f_p = f_R\left[0.28-(5+6f_T)L\cdot 10^{-5}\right]$ for fatigue assessment.

$$a_{pitch} = 0{,}8(1+0{,}05\cdot 0)1\left(0{,}72+\frac{2\cdot 80{,}90}{700}\right)\left(1{,}75-\frac{22}{\sqrt{9{,}81\cdot 80{,}90}}\right)24{,}26\frac{\pi}{180}\left(\frac{2\cdot\pi}{7{,}88}\right)^2$$

$$a_{pitch} = 0{,}198\ rad/s^2$$

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

$f_p = f_R\left[0.23-4f_TB\cdot 10^{-4}\right]$ for fatigue assessment.

$$a_{roll} = 1\cdot 39{,}27\cdot\frac{\pi}{180}\cdot\left(\frac{2\cdot\pi}{14{,}87}\right)^2 \longrightarrow a_{roll} = 0{,}122\ rad/s^2$$

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

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}	$-1.0f_{lp}$	$1.0f_{lp}$	$-0.6f_{lp}$	$0.6f_{lp}$	$-1.0f_{lp}$	$1.0f_{lp}$
	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}	$0.3 - 0.2f_T$	$0.2f_T - 0.3$	0.2	−0.2	$0.2 - 0.4f_T$	$0.4f_T - 0.2$
	$a_{pitch\text{-}x}$	C_{XP}	−0.7	0.7	−1.0	1.0	0.15	−0.15
	$g \sin\varphi$	C_{XG}	0.6	−0.6	$0.4f_T + 0.4$	$-0.4f_T - 0.4$	−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

$$C_{XG} = -0{,}6$$

$$C_{XS} = 0{,}2 \cdot \frac{6{,}59}{6{,}59} - 0{,}3 = -0{,}1$$

$$C_{XP} = 0{,}7$$

$$C_{YG} = 0$$

$$C_{YS} = 0$$

$$C_{YR} = 0$$

$$C_{ZH} = 0{,}15 - 0{,}5 \cdot 1 = -0{,}35$$

$$C_{ZR} = 0$$

$$C_{ZP} = 0{,}7$$

f_β = heading correction factor, shall be taken as:
for strength assessment:
$f_\beta = 1.0$ in general

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

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

$$\frac{8{,}26}{4} + \frac{6{,}59}{2} = 5{,}36\ m$$

$$\frac{8{,}26}{2} = 4{,}13\ m$$

$$R = \min(5{,}36{,}4{,}13) = 4{,}13\ m$$

Para hallar el valor de x y z, se toma como punto de referencia el centro de gravedad del buque:

$$XG = 39{,}29\ m\ , KG = 5{,}52\ m$$

El centro de gravedad de la cuaderna maestra es de:

$$XG_{maestra} = 27{,}5\ m\ , KG_{maestra} = 4{,}13\ m$$

Por lo tanto, la x y la z en este caso son:

$$x = -11{,}79\ m\ , z = -1{,}39\ m$$

Calculando ahora las aceleraciones:

$$a_x = 1 \cdot [(+0{,}6 \cdot 9{,}81 \cdot \sin(24{,}26)) - 0{,}1 \cdot 2{,}39 + 0{,}7 \cdot 0{,}198 \cdot (-1{,}39 - 4{,}13)]$$

$$\boldsymbol{a_x = 1{,}41\ m/s^2}$$

$$a_y = 1 \cdot [0 \cdot 9{,}81 \cdot sin(39{,}27) + 0 \cdot 3{,}34 - 0 \cdot 0{,}122 \cdot (-1{,}39 - 4{,}13)]$$

$$\boldsymbol{a_y = 0\ m/s^2}$$

$$a_z = 1 \cdot [-0{,}35 \cdot 5{,}05 + 0 \cdot 2{,}39 \cdot 0 - 0{,}7 \cdot 0{,}198 \cdot (-11{,}79 - 0{,}45 \cdot 80{,}9)]$$

$$\boldsymbol{a_z = 4{,}91\ m/s^2}$$

3.2.3 Cálculo de las presiones (Part 3, Ch. 6, Sec. 2)

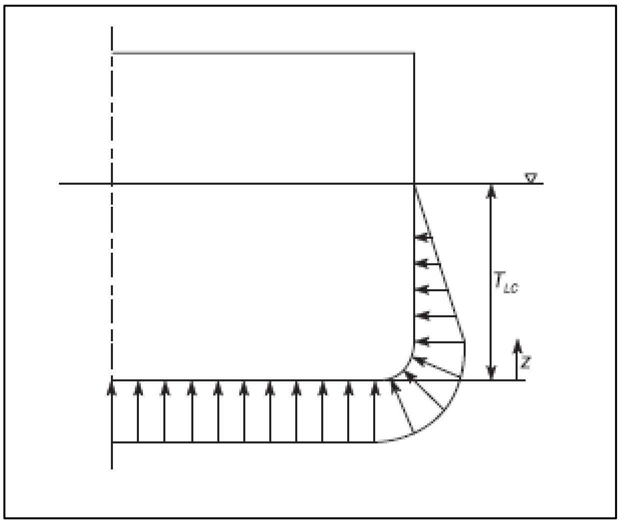
Para elegir la presión con la que dimensionar la chapa se calculará la presión que ejerce el agua de mar sobre el fondo:

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	2	$P_S + P_W, P_D$	T_{SC}	AC-II	Full load condition
Superstructure side			max(P_W;P_{SI})			
External shell	SEA-2	1	P_S	T_{SC}	AC-I	-

Siendo P_S:

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



Por lo tanto, la presión en el fondo debido al mar es de:

$$P_s = \rho \cdot g \cdot (T_{LC} - z)$$

Como se especifica en la tabla se usará $T_{LC}=T_{SC}$.

$$P_s = 1{,}025 \cdot 9{,}81 \cdot (6{,}59 - 0) \longrightarrow \boldsymbol{P_s = 66{,}26\ kN/m^2}$$

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	$P_W = \max\{P_{HS}; \rho g(z - T_{LC})\}$		

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:

$$f_h = 3.0(1.21 - 0.66 f_T)$$

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

$$k_a = (0{,}5 + f_T)\left[\left(3 - 2\sqrt{f_{yB}}\right) - \frac{20}{9} f_{xL}\left(7 - 6\sqrt{f_{yB}}\right)\right] + \frac{2}{3}(1 - f_T) \quad \text{for } f_{xL} < 0{,}15$$

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

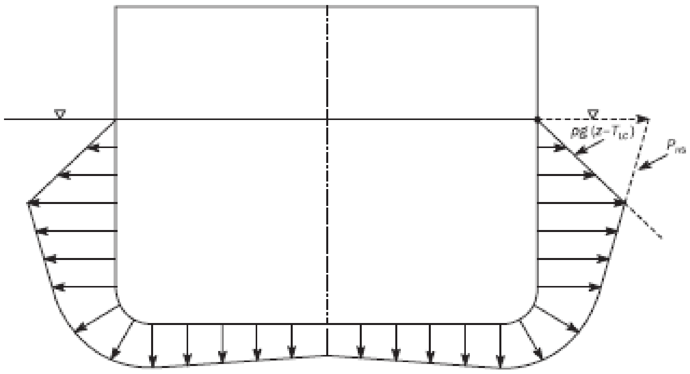
$$k_a = 1 + (f_{xL} - 0{,}7)\left\{\left(\frac{40}{3} f_T - 5\right) + 2\left(1 - f_{yB}\right)\left[\frac{18}{C_B} f_T (f_{xL} - 0{,}7) - 0{,}25(2 - f_T)\right]\right\} \quad \text{for } f_{xL} \ge 0.7$$

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

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



$$f_T = \frac{6,59}{6,59} = 1$$

$$C_{fT} = 1 + 0,5 - (0,7 \cdot 1 - 0,2) \cdot 0,733 \longrightarrow C_{fT} = 1,13$$

$$f_{ps} = 1$$

$$f_{xL} = \frac{27,5}{80,90} = 0,34$$

$f_{nl} = 0.9$ at $f_{xL} = 0.3$
$f_{nl} = 0.9$ at $f_{xL} = 0.7$

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

$$f_h = 3 \cdot (1,21 - 0,66 \cdot 1) \longrightarrow f_h = 1,65$$

$$k_a = 1$$

$$k_p = 1$$

$$C_x = 1,5 - \frac{|27,5 - 0,5 \cdot 80,90|}{80,90} \longrightarrow C_x = 1,34$$

$$f_{yB} = 0$$

$$f_{yz} = 1,34 \cdot \frac{0}{6,59} + (2 - 1,34) \cdot 0 + 1 \longrightarrow f_{yz} = 1$$

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

$$L_0 = 110\ m$$

$$\lambda = 0{,}63 \cdot (1 + 1) \cdot 80{,}90 \longrightarrow \lambda = 101{,}93\ m$$

$$P_{HS} = 1{,}13 \cdot 1 \cdot 0{,}9 \cdot 1{,}65 \cdot 1 \cdot 1 \cdot 1 \cdot 6{,}92 \cdot \sqrt{\frac{110 + 101{,}93 - 125}{80{,}90}} \longrightarrow P_{HS} = 12{,}04\ kN/m^2$$

$$1{,}025 \cdot 9{,}81 \cdot (0 - 6{,}59) = -66{,}26\ kN/m^2$$

$$P_W = máx(12{,}04, -66{,}26) = 12{,}04\ kN/m^2$$

La presión externa debida al mar será de:

$$P_S + P_W = 66{,}26 + 12{,}04 = \mathbf{78{,}30\ kN/m^2}$$

3.2.4 Cálculo del espesor de la chapa (Part 3, Ch. 6, Sec. 3)

En este apartado se calculará el espesor de la chapa del fondo y también el de la quilla, el material será de acero clase A de 235 N/mm².

Los espesores mínimos se calculan de la siguiente manera:

Table 2 Material factor, *k*

Specified minimum yield stress R_{eH}, in N/mm²	*k*
235	1.00
315	0.78
355	0.72
390	0.66
460	0.62

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)], strength deck[2),3)] and platform deck in machinery space		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 and machinery space end 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 la quilla:

$$t = 5 + 0,05 \cdot 80,90 \cdot \sqrt{1} = 9,05\ mm$$

Para el fondo:

$$t = 4,5 + 0,035 \cdot 80,90 \cdot \sqrt{1} = 7,33\ mm$$

El espesor de la chapa de fondo será de:

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.

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

$$\alpha_p = 1{,}2 - \frac{0{,}7}{2{,}1 \cdot 2{,}1} = 1$$

$$C_\alpha = 1{,}05 - 0{,}5 \cdot \frac{205}{235} = 0{,}61$$

$$t = 0{,}0158 \cdot 1 \cdot 700 \cdot \sqrt{\frac{78{,}30}{0{,}61 \cdot 235}} \longrightarrow t = 7{,}45\ mm$$

Comparándolo con el espesor mínimo es un valor mayor, por lo tanto, el valor de la chapa toma un valor de:

$$\underline{\boldsymbol{Espesor\ quilla}: \boldsymbol{t = 9{,}5\ mm}}$$

$$\underline{\boldsymbol{Espesor\ del\ fondo}: \boldsymbol{t = 7{,}5\ mm}}$$

3.2.5 Cálculo de las varengas (Part 3, Ch. 6, Sec. 6)

El módulo mínimo necesario de las varengas será de:

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:

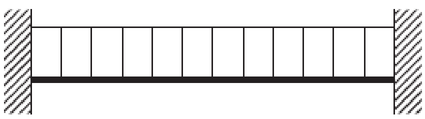
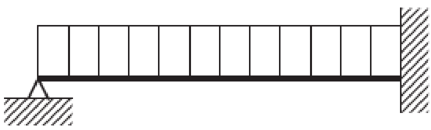
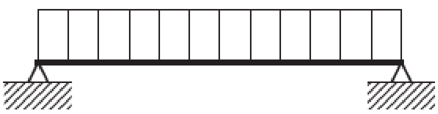
$$Z = 1000 \frac{|P|\, s\, \ell_{bdg}^2}{f_{bdg} C_s R_{eH}}$$

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.

La varenga se va a dimensionar suponiendo que los extremos se encuentran empotrados, es decir, no va a permitir el giro:

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

$$Z = 1000 \cdot \frac{78{,}30 \cdot 2{,}1 \cdot 3{,}9^2}{12 \cdot 0{,}85 \cdot 235} \longrightarrow Z = 1043{,}4\ cm^3$$

Se eligen perfiles llanta bulbo:

$$\underline{\boldsymbol{370\ x\ 13\ de\ Z = 1210\ cm^3}}$$

Se comprobará que este perfil adecuado comprobando que cumple con el espesor mínimo recomendado, que se calcula de la siguiente manera:

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.

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 supporting side shell, ballast tank, cargo tank and hold intended for cargo in bulk[2),3)]	4.5	0.015
Other PSM	4.5	0.01
PSM in peak tanks	5.0	0.025[1)]

1) The value of bL_2 does not need to be greater than 5.0.
2) For stringers in double side next to dry space not intended for cargo in bulk, the value of bL_2 does not need to be taken greater than 2.5.
3) Other specific requirements related to ship types are given in Pt.5.

$$t = 4{,}5 + 0{,}015 \cdot 80{,}90 \cdot \sqrt{1} \longrightarrow t = 5{,}7\ mm$$

Se observa que el perfil elegido cumple con el requisito del espesor mínimo, por lo tanto, la elección es válida.

3.2.6 Cálculo de los refuerzos secundarios (Part 3, Ch. 6, Sec. 5)

El módulo necesario será de:

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.

Table 3 Stiffeners, definition of C_s

Structural member	*Sign of hull girder stress, σ_{hg}*	*Lateral pressure acting on*	*Coefficient C_s*
For continuous stiffeners	Tension (positive)	Stiffener side	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
	Compression (negative)	Plate side	
	Tension (positive)	Plate side	$C_s = f_m\left(\beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}\right)$ but not to be taken greater than $C_{s\text{-}max}$
	Compression (negative)	Stiffener side	
For non-continuous stiffeners	Tension (positive)	Plate side	$C_s = \beta_s - \alpha_s \frac{\lvert\sigma_{hg}\rvert}{R_{eH}}$ but not to be taken greater than $C_{s\text{-}max}$
	Compression (negative)	Stiffener side	
	Tension (positive)	Stiffener side	$C_s = C_{s\text{-}max}$
	Compression (negative)	Plate side	

Table 4 Stiffeners, definition of β_s, α_s and $C_{s\text{-}max}$

Acceptance criteria	Structural member		β_s	α_s	$C_{s\text{-}max}$
AC-I	Longitudinal members		0.95	1.00	0.85
	Other members		0.85	0.00	0.85
AC-II	Longitudinal members		1.10	1.00	0.95
	Other members		0.95	0.00	0.95
AC-III	Longitudinal members	In general	1.20	1.00	1.00
		On watertight boundaries [1)]	1.20	1.00	1.15
	Other members	In general	1.00	0.00	1.00
		On watertight boundaries [1)]	1.15	0.00	1.15

1) Only applicable for flooding pressure

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	

$$C_S = 1{,}10 - 1 \cdot \frac{205}{235} = 0{,}23$$

$$Z = \frac{1{,}03 \cdot 78{,}30 \cdot 700 \cdot 2{,}1^2}{12 \cdot 0{,}23 \cdot 235} \longrightarrow Z = 383{,}85\ cm^3$$

Con este valor se entra en las tablas de perfiles comerciales y se elige un perfil llanta bulbo con chapa asociada de:

$$\underline{\mathbf{240\ x\ 11\ de\ Z = 391\ cm^3}}$$

Se comprobará que este perfil cumple con el espesor mínimo requerido mediante la fórmula:

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

También es necesario calcular la altura efectiva de los refuerzos:

1.4.3 Effective shear depth of stiffeners

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

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

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

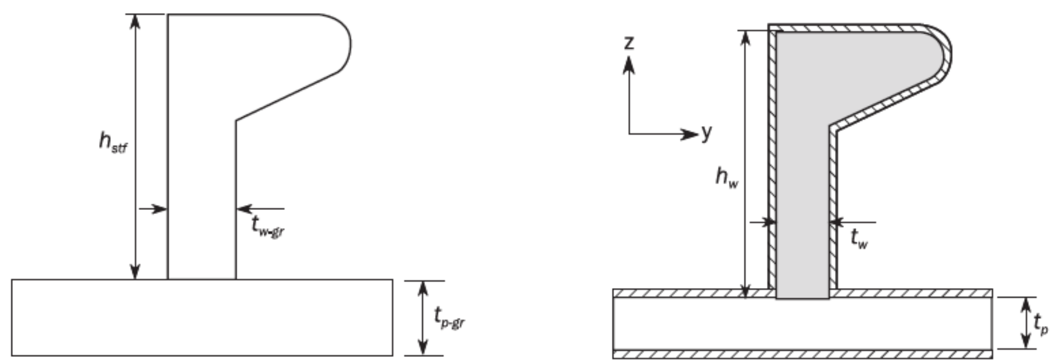
where:

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.

Para un perfil llanta bulbo:



Bulb and similar profiles

$$d_{shr} = 34 + 7{,}5 = 41{,}5\ mm$$

Ahora se puede calcular el espesor mínimo recomendado de los refuerzos:

$$t_w = \frac{0{,}5 \cdot 78{,}30 \cdot 700 \cdot 2}{41{,}5 \cdot 0{,}9 \cdot 135{,}7} \longrightarrow t_w = 10{,}8\ mm$$

Como se observa el perfil cumple con el espesor mínimo recomendado por lo tanto el perfil elegido es adecuado.

3.3 DIMENSIONAMIENTO DEL DOBLE FONDO

3.3.1 Cálculo de las presiones ((Part 3, Ch. 6, Sec. 2)

Se harán dos estudios de la presión para dimensionar el doble fondo: la presión de los tanques de agua de lastre situados en el mismo y la presión de los tanques de cemento situados encima.

Primero se calcularán la presión de los tanques de lastre:

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

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:

$$P_{in} = P_{\ell s} + P_{\ell d} \text{ but not less than 0}$$

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].

Siendo:

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:

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

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

Siendo:

ρ_L = 1,025 t/m^3

z_{top} = punto más alto del tanque en la coordenada Z, en m

Como en este caso el tanque no tiene una válvula de seguridad:

$$P_{ls-1} = 1{,}025 \cdot 9{,}81 \cdot (1{,}5 - 0) \longrightarrow P_{ls-1} = 15{,}08\ kN/m^2$$

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:

$f_{ull-\ell}$ = 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:

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

$f_{ull-\ell}$ = 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:

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

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.

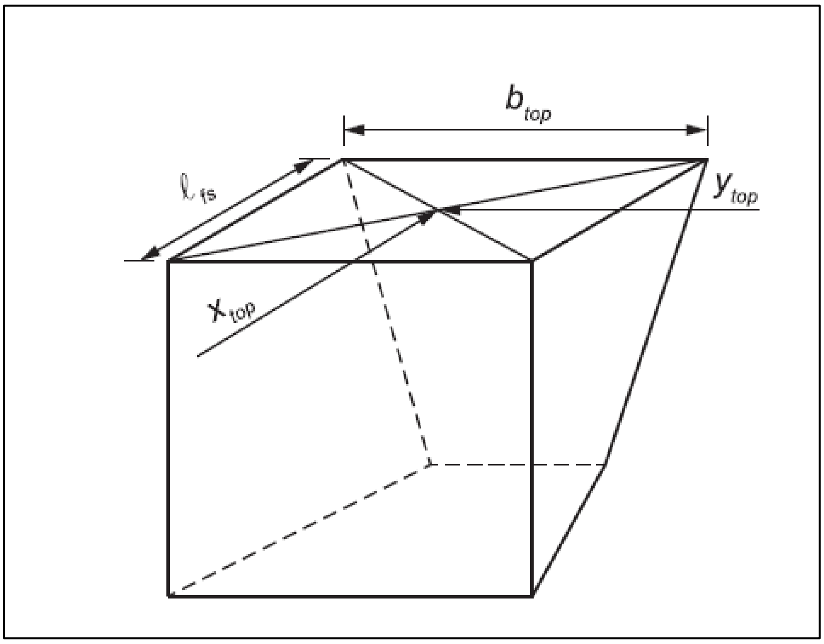
The following simplified method of determination of the reference point assuming a rectangular shape with area equal A_{top} of the top of the tank or the ballast hold hatch coaming is acceptable, see Figure 1:

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

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

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.



Se hallarán las coordenadas de referencia para los tanques de agua de lastre 4BR y 4ER, comparando los puntos y se elegirán en los que v_j tenga el mayor valor.

4BR

$$x_{j1} = 3{,}5 + 0{,}5 * 7 = 7\ m$$

$$x_{j2} = 3{,}5 - 0{,}5 * 7 = 0\ m$$

$$y_{j1} = 3{,}95 + 0{,}5 * 7{,}9 = 7{,}9\ m$$

$$y_{j2} = 3{,}95 - 0{,}5 * 7{,}9 = 0\ m$$

$$v_j = 1{,}41 \cdot (7 - 3{,}5) + 0 \cdot (7{,}9 - 0) + (4{,}91 + 9{,}81) \cdot (1{,}5 - 1{,}5) \longrightarrow v_j = 4{,}94$$

$$v_j = 1{,}41 \cdot (0 - 3{,}5) + 0 \cdot (0 - 0) + (4{,}91 + 9{,}81) \cdot (1{,}5 - 1{,}5) \longrightarrow v_j = -4{,}94$$

4ER

$$x_{j1} = 3{,}5 + 0{,}5 * 7 = 7\ m$$

$$x_{j2} = 3{,}5 - 0{,}5 * 7 = 0\ m$$

$$y_{j1} = -3{,}95 + 0{,}5 * 7{,}9 = 0\ m$$

$$y_{j2} = -3{,}95 - 0{,}5 * 7{,}9 = -7{,}9\ m$$

$$v_j = 1{,}41 \cdot (7 - 3{,}5) + 0 \cdot (0 - 0) + (4{,}91 + 9{,}81) \cdot (1{,}5 - 1{,}5) \longrightarrow v_j = 4{,}94$$

$$v_j = 1{,}41 \cdot (0 - 3{,}5) + 0 \cdot (-7{,}9 - 0) + (4{,}91 + 9{,}81) \cdot (1{,}5 - 1{,}5) \longrightarrow v_j = -4{,}94$$

Por lo tanto, los puntos de referencia de los tanques serán el x_{j1} y el y_{j1} en ambos casos.

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 $\rho_L \leq 1.025\ t/m^3$

$f_{ull-\ell}$	=	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: $f_{ull-\ell} = 0.5 + \frac{\lvert z_0 - z \rvert}{\ell_{fs}} \frac{180}{\varphi\pi}$ 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: $f_{ull-t} = 0.5 + \frac{\lvert z_0 - z \rvert}{b_{top}} \frac{180}{\theta\pi}$ for cargo tanks and ballast holds f_{ull-t} = 1.0 for other cases

Para el tanque situado a babor:

$$P_{ld} = 0{,}88 \cdot 1{,}025 \cdot [4{,}91 \cdot (1{,}5 + 1{,}39) + 0{,}62 \cdot 1{,}41 \cdot (7 + 11{,}79) + 0{,}67 \cdot 0 \cdot (7{,}9 - 0)]$$

$$P_{ld} = 27{,}62\ kN/m^2$$

Para el tanque situado a estribor:

$$P_{ld} = 0{,}88 \cdot 1{,}025 \cdot [4{,}91 \cdot (1{,}5 + 1{,}39) + 0{,}62 \cdot 1{,}41 \cdot (7 + 11{,}79) + 0{,}67 \cdot 0 \cdot (0 - 0)]$$

$$P_{ld} = 27{,}62\ kN/m^2$$

Calculando la presión interior total:

$$P_{ls-1} + 2 \cdot P_{ld} = 15{,}08 + 55{,}23$$

$$P_{in} = 70{,}31\ kN/m^2$$

A continuación, se calculará la presión ejercida por los tanques de cemento:

Boundaries of tanks other than ballast water tanks	TK-1	2	$P_{ls\text{-}1} + P_{ld} - (P_S + P_W)^{(1)}$	T_{BAL}	AC-II	Normal ballast condition
	TK-2	4	$P_{ls\text{-}ST} - P_S^{1)}$	max(T_{BAL}; $0.25T_{SC}$)	AC-III	
	TK-3	1	$P_{ls\text{-}3} - P_S^{1)}$	max(T_{BAL}; $0.25T_{SC}$)	AC-I	-

Siendo:

The tank testing pressure, in kN/m^2, shall be taken as:

$$P_{\ell s-ST} = 10(z_{ST} - z)$$

where:

z_{ST} = testing load height, in m, as defined in Table 1.

The actual tank testing shall be carried out in accordance with Pt.2 Ch.4 Sec.6.

Table 1 Design testing load height z_{ST}

Compartment	z_{ST}
Double bottom tanks	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{bd}$
Hopper side tanks[1)], topside tanks[1)], double side tanks[1)], fore and aft peaks used as tank	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{top} + 2.4$
Tanks[4)], deep tanks, fuel oil bunkers, cargo tanks[2)]	The greater of the following: z_{ST}[3)] $= z_{top} + h_{air}$ $z_{ST} = z_{top} + 2.4$ $z_{ST} = z_{top} + 0.1\ P_{PV}$
Ballast hold	$z_{ST} = z_h + 0.9$
Chain locker	$z_{ST} = z_c$
Independent tanks	The greater of the following: $z_{ST} = z_{top} + h_{air}$ $z_{ST} = z_{top} + 0.9$
Ballast ducts	Testing load height corresponding to ballast pump maximum pressure

where:
z_{bd} = Z coordinate, in m, of the bulkhead deck
z_h = Z coordinate, in m, of the top of hatch coaming
z_c = Z coordinate, in m, of the top of chain pipe.

1) Applicable to double bottom tank connected with hopper side tanks, topside tanks or double side tanks.
2) Tank test load is not applicable for cargo tanks carrying LNG.
3) Not applicable for cargo tanks.
4) Tank test load is not applicable for L.O. sump. tanks and other small tanks, e.g. in engine room.

$$z_{ST} = z_{top} + h_{air} = 5{,}5 + 0{,}5 = 6\ m$$

$$z_{ST} = z_{top} + 2{,}4 = 5{,}5 + 2{,}4 = 7{,}9\ m$$

$$z_{ST} = z_{top} + 0{,}1 \cdot P_{PV} = 5{,}5 + 0{,}1 \cdot 50 = 6\ m$$

Se tomará por lo tanto el segundo valor ya que es el mayor.

$$P_S = \rho \cdot g \cdot (T_{LC} - z) = 2{,}5 \cdot 9{,}81 \cdot (6{,}59 - 1{,}5) = 124{,}83\ kN/m^2$$

Por lo tanto, se dimensionará el doble fondo para la mayor presión de estas dos:

$$\boldsymbol{P = 124{,}83\ kN/m^2}$$

3.3.2 Cálculo del espesor de la chapa (Pt. 3 Ch. 6 Sec. 3)

El espesor mínimo de la chapa del doble fondo se halla según la fórmula:

Inner bottom	Cargo spaces loaded through cargo hatches except container holds	5.5	0.025
	Other spaces	4.5	0.02

$$t = a + b \cdot L_2 \cdot \sqrt{k}$$

$$t = 5{,}5 + 0{,}025 \cdot 80{,}90 \cdot \sqrt{1} = 7{,}53\ mm$$

El espesor de la chapa viene dado por la siguiente fórmula:

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

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

$$\alpha_p = 1{,}2 - \frac{0{,}7}{2{,}1 \cdot 2{,}1} = 1$$

$$C_\alpha = 0{,}9 - 0{,}5 \cdot \frac{205}{235} = 0{,}46$$

$$t = 0{,}0158 \cdot 1 \cdot 700 \cdot \sqrt{\frac{124{,}83}{0{,}46 \cdot 235}} \longrightarrow t = 11{,}9\ mm$$

Este espesor es mayor que el espesor mínimo, por lo que cumple. El espesor de la chapa será de:

$$\underline{\boldsymbol{Espesor\ del\ doble\ fondo}: \boldsymbol{t = 12\ mm}}$$

3.3.3 Cálculo de los refuerzos secundarios (Part 3, Ch. 6, Sec. 5)

El módulo de los longitudinales se obtiene mediante la siguiente fórmula:

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

Acceptance criteria	Structural member	β_s	α_s	$C_{s\text{-}max}$
AC-I	Longitudinal members	0.95	1.00	0.85
	Other members	0.85	0.00	0.85
AC-II	Longitudinal members	1.10	1.00	0.95
	Other members	0.95	0.00	0.95

$$C_S = 1{,}10 - 1 \cdot \frac{205}{235} = 0{,}23$$

$$Z = \frac{1{,}03 \cdot 124{,}83 \cdot 700 \cdot 2{,}1^2}{12 \cdot 0{,}23 \cdot 235} \longrightarrow Z = 612\ cm^3$$

Con este valor se entra en las tablas de perfiles comerciales y se elige un perfil llanta bulbo con chapa asociada de:

$$\underline{\boldsymbol{300\ x\ 11\ de\ Z = 671\ cm^3}}$$

3.4 DIMENSIONAMIENTO DEL COSTADO

3.4.1 Cálculo de las presiones (Part 3, Ch. 6, Sec. 2)

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 agua dulce situado en el doble caso.

Primero se calcula la presión estática externa debida al mar (la altura del punto para mediar la presión se sitúa a un tercio de la distancia del costado):

$$P_s = \rho \cdot g \cdot (T_{LC} - z)$$

$$P_s = 1{,}025 \cdot 9{,}81 \cdot (6{,}59 - 2{,}2) \longrightarrow P_s = 44{,}14\ kN/m^2$$

Y ahora la presión dinámica:

$$f_T = \frac{6{,}59}{6{,}59} = 1$$

$$C_{fT} = 1 + 0{,}5 - (0{,}7 \cdot 1 - 0{,}2) \cdot 0{,}733 \longrightarrow C_{fT} = 1{,}13$$

$$f_{ps} = 1$$

$$f_{xL} = \frac{27{,}5}{80{,}90} = 0{,}34$$

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

$$f_h = 3 \cdot (1{,}21 - 0{,}66 \cdot 1) \longrightarrow f_h = 1{,}65$$

$$k_a = 1$$

$$k_p = 1$$

$$C_x = 1{,}5 - \frac{|27{,}5 - 0{,}5 \cdot 80{,}90|}{80{,}90} \longrightarrow C_x = 1{,}34$$

$$f_{yB} = 0$$

$$f_{yz} = 1{,}34 \cdot \frac{2{,}2}{6{,}59} + (2 - 1{,}34) \cdot 0 + 1 \longrightarrow f_{yz} = 1{,}45$$

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

$$L_0 = 110\ m$$

$$\lambda = 0{,}63 \cdot (1 + 1) \cdot 80{,}90 \longrightarrow \lambda = 101{,}93\ m$$

$$P_{HS} = 1{,}13 \cdot 1{,}45 \cdot 0{,}9 \cdot 1{,}65 \cdot 1 \cdot 1 \cdot 1 \cdot 6{,}92 \cdot \sqrt{\frac{110 + 101{,}93 - 125}{80{,}90}}$$

$$P_{HS} = 17{,}45\ kN/m^2$$

$$1{,}025 \cdot 9{,}81 \cdot (2{,}2 - 6{,}59) = -44{,}14\ kN/m^2$$

$$P_W = máx(17{,}45, -44{,}14) = 17{,}45\ kN/m^2$$

La presión externa debida al mar será de:

$$P_S + P_W = 44{,}14 + 17{,}45 = \mathbf{61{,}59\ kN/m^2}$$

Ahora, la presión debida al tanque de agua dulce se calcula mediante la fórmula:

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

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:

$$P_{in} = P_{\ell s} + P_{\ell d} \text{ but not less than 0}$$

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].

$$P_{ls-1} = 1{,}025 \cdot 9{,}81 \cdot (8{,}26 - 6{,}59) \longrightarrow P_{ls-1} = 16{,}79\ kN/m^2$$

Para el cálculo de P_{ld} hay que hallar el punto de referencia del tanque:

$$x_{j1} = 2{,}1 + 0{,}5 * 4{,}2 = 4{,}2\ m$$

$$x_{j2} = 2{,}1 - 0{,}5 * 4{,}2 = 0\ m$$

$$y_{j1} = 0{,}5 + 0{,}5 * 1 = 1\ m$$

$$y_{j2} = 0{,}5 - 0{,}5 * 1 = 0\ m$$

$$v_j = 1{,}41 \cdot (4{,}2 - 2{,}1) + 0 \cdot (1 - 0) + (4{,}91 + 9{,}81) \cdot (8{,}26 - 8{,}26) \longrightarrow v_j = 2{,}96$$

$$v_j = 1{,}41 \cdot (0 - 2{,}1) + 0 \cdot (0 - 0) + (4{,}91 + 9{,}81) \cdot (8{,}26 - 8{,}26) \longrightarrow v_j = -2{,}96$$

Se coge como referencia os puntos x_{j1} e y_{j2}. Por lo tanto, el valor de Pld es:

$$P_{ld} = 0{,}88 \cdot 1{,}025 \cdot [4{,}91 \cdot (8{,}26 + 1{,}39) + 0{,}62 \cdot 1{,}41 \cdot (4{,}2 + 11{,}79) + 0{,}67 \cdot 0 \cdot (1 - 0)]$$

$$P_{ld} = 55{,}35\ kN/m^2$$

La presión que ejerce el interior del tanque es de:

$$P_{in} = 16{,}79 + 55{,}35 = 72{,}14\ kN/m^2$$

Se elige entre las dos la presión máxima para la cual se dimensionará la chapa y los longitudinales:

$$\mathbf{P = 72{,}14\ kN/m^2}$$

3.4.2 Cálculo del espesor de la chapa (Pt. 3 Ch. 6 Sec. 3)

El espesor mínimo de la chapa del costado se halla según la fórmula:

$$t = a + b \cdot L_2 \cdot \sqrt{k}$$

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

$$t = 4 + 0{,}01 \cdot 80{,}90 \cdot \sqrt{1} = 4{,}81\ mm$$

Ahora se calculará el espesor del costado, la separación de refuerzos en el costado se seguirá considerando 700 mm:

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

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

$$\alpha_p = 1{,}2 - \frac{0{,}6}{2{,}1 \cdot 1{,}8} = 1$$

$$C_\alpha = 1{,}05 - 0{,}5 \cdot \frac{205}{235} = 0{,}46$$

$$t = 0{,}0158 \cdot 1 \cdot 600 \cdot \sqrt{\frac{72{,}14}{0{,}46 \cdot 235}} \longrightarrow t = 7{,}74\ mm$$

Que es mayor que el espesor mínimo requerido, por lo tanto, se elige una chapa de:

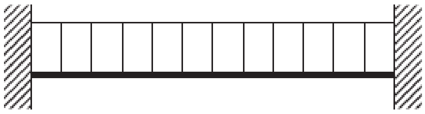
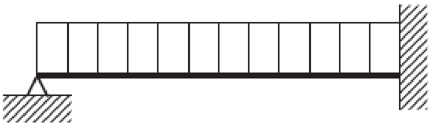
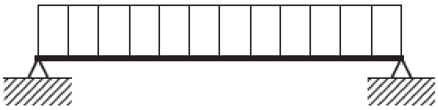
$$\underline{\textbf{\textit{Espesor del costado}}: \boldsymbol{t = 8\ mm}}$$

3.4.3 Cálculo de las cuadernas (Part 3, Ch. 6, Sec. 6)

El módulo de la cuaderna se obtiene mediante la siguiente formula:

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

La bulárcama se va a dimensionar suponiendo que los extremos se encuentran empotrados, es decir, no va a permitir el giro:

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

$$Z = 1000 \cdot \frac{72{,}14 \cdot 2{,}1 \cdot 5{,}8^2}{12 \cdot 0{,}85 \cdot 235} \longrightarrow Z = 2126{,}1\ cm^3$$

Se eligen perfiles llanta bulbo:

$$\underline{\boldsymbol{400\ x\ 14\ de\ Z = 2144\ cm^3}}$$

En este caso se hará la comprobación mediante el espesor mínimo recomendado y el área mínima recomendado, debido a que es un elemento sometido a presión lateral.

El espesor se calcula mediante la fórmula:

$$t = a + b \cdot L_2 \cdot \sqrt{k}$$

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 supporting side shell, ballast tank, cargo tank and hold intended for cargo in bulk 2),3)	4.5	0.015
Other PSM	4.5	0.01
PSM in peak tanks	5.0	0.025 1)

1) The value of bL_2 does not need to be greater than 5.0.
2) For stringers in double side next to dry space not intended for cargo in bulk, the value of bL_2 does not need to be taken greater than 2.5.
3) Other specific requirements related to ship types are given in Pt.5.

$$t = 4{,}5 + 0{,}015 \cdot 80{,}90 \cdot \sqrt{1} \longrightarrow t = 5{,}7\ mm$$

El área, por otro lado, se calcula de la siguiente manera:

The shear area, in cm[2], 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:

$$A_{shr} = 10\frac{f_{shr}|P|s\,\ell_{shr}}{C_t \tau_{eH}}$$

where:

A_{shr} = $A_{shr-n50}$, required net shear area in cm[2], only applicable for ships with class notation **ESP**
= A_{shr-gr}, required gross shear area in cm[2], for other ships
f_{shr} = shear force distribution factor, as given in Table 1
C_t = permissible shear stress coefficient to be taken as:

C_t = 0.70 for AC-I
C_t = 0.85 for AC-II and AC-III.

$$A_{shr} = 10 \cdot \frac{0{,}5 \cdot 72{,}14 \cdot 2{,}1 \cdot 2}{0{,}85 \cdot 135{,}7} \longrightarrow A_{shr} = 13{,}13\ cm^2$$

El área del perfil elegido es de 98,7 cm^2 por lo que cumple con este requerimiento. También cumple con el requerimiento del espesor, por lo tanto, el perfil elegido es válido.

3.4.4 Cálculo de los refuerzos secundarios (Part 3, Ch. 6, Sec. 5)

El módulo de los longitudinales se obtiene mediante la siguiente fórmula:

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

Acceptance criteria	Structural member	β_s	α_s	$C_{s\text{-}max}$
AC-I	Longitudinal members	0.95	1.00	0.85
	Other members	0.85	0.00	0.85
AC-II	Longitudinal members	1.10	1.00	0.95
	Other members	0.95	0.00	0.95

$$C_S = 1{,}10 - 1 \cdot \frac{205}{235} = 0{,}23$$

$$Z = \frac{1{,}03 \cdot 72{,}14 \cdot 600 \cdot 1{,}8^2}{12 \cdot 0{,}23 \cdot 235} \longrightarrow Z = 223\ cm^3$$

Con este valor se entra en las tablas de perfiles comerciales y se elige un perfil llanta bulbo con chapa asociada de:

$$\underline{\boldsymbol{200\ x\ 9\ de\ Z = 225\ cm^3}}$$

Se comprobará que este perfil cumple con el espesor mínimo requerido mediante la fórmula:

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

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

También es necesario calcular la altura efectiva de los refuerzos:

1.4.3 Effective shear depth of stiffeners

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

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

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

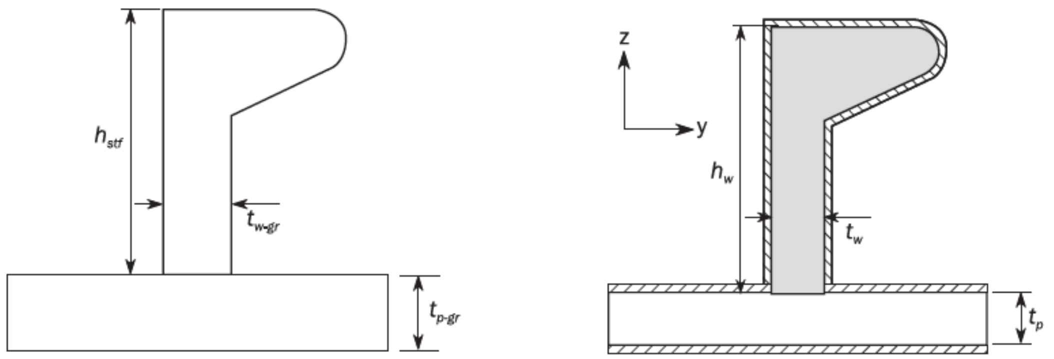
where:

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.

Para un perfil llanta bulbo:



Bulb and similar profiles

$$d_{shr} = 43 + 8 = 51\ mm$$

Ahora se puede calcular el espesor mínimo recomendado de los refuerzos:

$$t_w = \frac{0{,}4 \cdot 72{,}14 \cdot 600 \cdot 2}{51 \cdot 0{,}9 \cdot 135{,}7} \longrightarrow t_w = 5{,}56\ mm$$

Como se observa el perfil cumple con el espesor mínimo recomendado por lo tanto el perfil elegido es adecuado.

3.4.5 Cálculo de palmejares (Part 3, Ch. 6, Sec. 3)

Se estudiará el palmejar como elemento estructural de refuerzo del costado.

Se dispondrá un palmejar a una altura de 5 m sobre la línea base, la manga abarcará el doble costado del buque, 1 m.

El espesor mínimo viene dado por la fórmula:

Table 2 Minimum net thickness for stiffeners and tripping brackets

Element	*Location*	*Net thickness*
Stiffeners and attached end brackets	Tank boundary	$4.5 + 0.01\ L_1$
	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		$4.5 + 0.01\ L_1$

$$t = 4{,}5 + 0{,}01 \cdot 80{,}90 \longrightarrow t = 5{,}31\ mm$$

El módulo mínimo requerido se calcula mediante la fórmula:

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

Acceptance criteria	*Structural member*	β_s	α_s	$C_{s\text{-}max}$
AC-I	Longitudinal members	0.95	1.00	0.85
	Other members	0.85	0.00	0.85
AC-II	Longitudinal members	1.10	1.00	0.95
	Other members	0.95	0.00	0.95

$$C_S = 1{,}10 - 1 \cdot \frac{205}{235} = 0{,}23$$

En este caso, solamente se tiene un palmejar por lo tanto la separación entre palmejares será la distancia máxima entre la cubierta o el doble fondo:

$$Z = \frac{1{,}03 \cdot 72{,}14 \cdot 5000 \cdot 2{,}1^2}{12 \cdot 0{,}23 \cdot 235} \longrightarrow Z = \ 1856\ cm^3$$

Con este valor se entra en las tablas de perfiles comerciales y se elige un perfil llanta bulbo con chapa asociada de:

$$\underline{\mathbf{430\ x\ 15\ de\ Z = 1935\ cm^3}}$$

El espesor mínimo es de 5,31 mm por lo tanto este refuerzo se considera aceptable ya que cumple con el mínimo requerido.

3.5 DIMENSIONAMIENTO DE CUBIERTA

3.5.1 Cálculo de las presiones (Part 3, Ch. 6, Sec. 2)

Para el cálculo de las presiones en la cubierta se tiene en cuenta que es una cubierta expuesta y que además va a soportar cargas, se supondrán que las cargas son siempre distribuidas para el cálculo:

Exposed decks and non-exposed decks and platforms with distributed load	UDL-1 2)	2	$P_{dl-s} + P_{dl-d}$ $F_{U-s} + F_{U-d}$	T_{BAL} 3)	AC-II	Normal ballast condition3)
	UDL-2 2)	1	P_{dl-s} F_{U-s}	-	AC-I	-

The pressure, in kN/m², due to this distributed load for the static plus dynamic (S + D) design load scenario shall be derived for each dynamic load case and shall be taken as:

$$P_{dl} = P_{dl-s} + P_{dl-d}$$

where:

P_{dl-s} = static pressure, in kN/m², due to the distributed load, to be defined by the designer
P_{dl-d} = dynamic pressure, in kN/m², due to the distributed load
= $P_{dl-s} \cdot a_z/g$

Las cargas que pueden soportar las cubiertas en este tipo de buques van desde 5 t/m² a 10 t/m². En este caso se supondrá el caso extremo en el que se transporte 10 t/m², por lo tanto:

$$P_{dl-s} = 98{,}07\ kN/m^2$$

a_Z = vertical envelope acceleration, in m/s², as defined in Sec.3 [3.3.3]. Optionally, the acceleration for the considered dynamic load case, according to Sec.3 [3.2.3], may be applied.

Como también es posible hacer el cálculo con la aceleración vertical calculada anteriormente se utilizará este valor:

$$a_z = 4{,}91\ m/m_2$$

$$P_{dl-d} = 98{,}07 \cdot \frac{4{,}91}{9{,}81} = 49{,}08\ kN/m^2$$

La presión total que ha de soportar la cubierta será de:

$$P_{dl} = 98{,}07 + 49{,}08 \longrightarrow \boldsymbol{P_{dl} = 147{,}16\ kN/m^2}$$

3.5.2 Cálculo del espesor de la chapa (Pt. 3 Ch. 6 Sec. 3)

El espesor mínimo de la chapa del costado se halla según la fórmula:

$$t = a + b \cdot L_2 \cdot \sqrt{k}$$

Deck	Weather deck[1),2),3),4)], strength deck[2),3)] and platform deck in machinery space	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

$$t = 4 + 0{,}02 \cdot 80{,}90 \cdot \sqrt{1} = 5{,}62\ mm$$

Para el cálculo del espesor de la cubierta:

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

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

$$\alpha_p = 1{,}2 - \frac{0{,}7}{2{,}1 \cdot 2{,}1} = 1$$

$$C_\alpha = 1{,}05 - 0{,}5 \cdot \frac{205}{235} = 0{,}61$$

$$t = 0{,}0158 \cdot 1 \cdot 700 \cdot \sqrt{\frac{147{,}16}{0{,}61 \cdot 235}} \longrightarrow t = \ 11{,}21\ mm$$

Este espesor es mayor que el espesor mínimo, por lo que cumple. El espesor de la chapa será de:

$$\underline{\boldsymbol{Espesor\ de\ la\ cubierta}: \boldsymbol{t = 11,5\ mm}}$$

3.5.3 Puntales

Para dimensionar los baos de la cubierta se disponen de puntales, para que así estos actúen como soporte de los baos, disminuyendo su luz y así su tamaño.

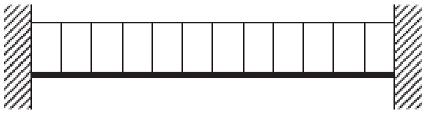
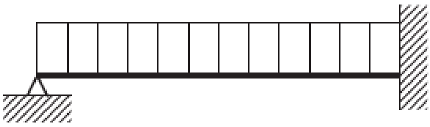
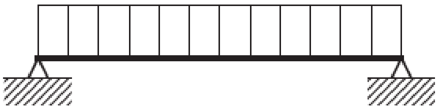
La separación de los puntales será de tres claras de cuaderna para que formen parte de los anillos transversales (bulárcamas) y la máxima distancia transversal será de 5,8 m, que corresponde a la máxima luz de los baos.

3.5.4 Cálculo de los baos (Part 3, Ch. 6, Sec. 6)

El módulo del bao se obtiene mediante la siguiente fórmula:

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

El bao se va a dimensionar suponiendo que los extremos se encuentran empotrados, es decir, no va a permitir el giro:

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

$$Z = 1000 \cdot \frac{147{,}13 \cdot 2{,}1 \cdot 5{,}8^2}{12 \cdot 0{,}85 \cdot 235} \longrightarrow Z = 4441{,}5\ cm^3$$

Para los baos se eligen perfiles en T:

$$\underline{\boldsymbol{630\ x\ 12\ de\ Z = 4636\ cm^3}}$$

Se comprobará que este perfil adecuado comprobando que cumple con el espesor mínimo recomendado, que se calcula de la siguiente manera:

$$t = a + b \cdot L_2 \cdot \sqrt{k}$$

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 supporting side shell, ballast tank, cargo tank and hold intended for cargo in bulk 2),3)	4.5	0.015
Other PSM	4.5	0.01
PSM in peak tanks	5.0	0.025 1)
1) The value of bL_2 does not need to be greater than 5.0. 2) For stringers in double side next to dry space not intended for cargo in bulk, the value of bL_2 does not need to be taken greater than 2.5. 3) Other specific requirements related to ship types are given in Pt.5.		

$$t = 4{,}5 + 0{,}01 \cdot 80{,}90 \cdot \sqrt{1} \longrightarrow t = 5{,}4\ mm$$

Como se observa el perfil cumple con el espesor mínimo recomendado por lo tanto el perfil elegido es adecuado.

3.5.5 Cálculo de las esloras (Part 3, Ch. 6, Sec. 3)

Encima de los puntales se situarán esloras para que hagan continuación con los puntales y soporten mejor las cargas.

El espesor mínimo viene dado por la fórmula:

Table 2 Minimum net thickness for stiffeners and tripping brackets

Element	*Location*	*Net thickness*
Stiffeners and attached end brackets	Tank boundary	$4.5 + 0.01\ L_1$
	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		$4.5 + 0.01\ L_1$

$$t = 4{,}5 + 0{,}01 \cdot 80{,}90 \longrightarrow t = 5{,}31\ mm$$

El módulo mínimo requerido se calcula mediante la fórmula:

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

Acceptance criteria	*Structural member*	β_s	α_s	$C_{s\text{-}max}$
AC-I	Longitudinal members	0.95	1.00	0.85
	Other members	0.85	0.00	0.85
AC-II	Longitudinal members	1.10	1.00	0.95
	Other members	0.95	0.00	0.95

$$C_S = 1{,}10 - 1 \cdot \frac{205}{235} = 0{,}23$$

La separación entre esloras es la misma que la separación entre puntales, 5,8 m:

$$Z = \frac{1{,}03 \cdot 147{,}13 \cdot 5800 \cdot 2{,}1^2}{12 \cdot 0{,}23 \cdot 235} \longrightarrow Z = \ 5976\ cm^3$$

Con este valor se entra en las tablas de perfiles comerciales y se elige un perfil en forma de T con chapa asociada de:

$$\underline{\boldsymbol{735\ x\ 12\ de\ Z = 6319\ cm^3}}$$

El espesor mínimo es de 5,31 mm por lo tanto este refuerzo se considera aceptable ya que cumple con el mínimo requerido.

3.5.6 Cálculo de los refuerzos secundarios (Part 3, Ch. 6, Sec. 5)

El módulo de los longitudinales se obtiene mediante la siguiente fórmula:

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

AC-II	Longitudinal members	1.10	1.00	0.95
	Other members	0.95	0.00	0.95

$$C_S = 1{,}10 - 1 \cdot \frac{205}{235} = 0{,}23$$

$$Z = \frac{1{,}03 \cdot 147{,}13 \cdot 700 \cdot 2{,}1^2}{12 \cdot 0{,}23 \cdot 235} \longrightarrow Z = 721{,}27\ cm^3$$

Con este valor se entra en las tablas de perfiles comerciales y se elige un perfil llanta bulbo con chapa asociada de:

$$\underline{\mathbf{300\ x\ 13\ de\ Z = 728\ cm^3}}$$

Se comprobará que este perfil cumple con el espesor mínimo requerido mediante la fórmula:

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

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

También es necesario calcular la altura efectiva de los refuerzos:

1.4.3 Effective shear depth of stiffeners

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

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

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

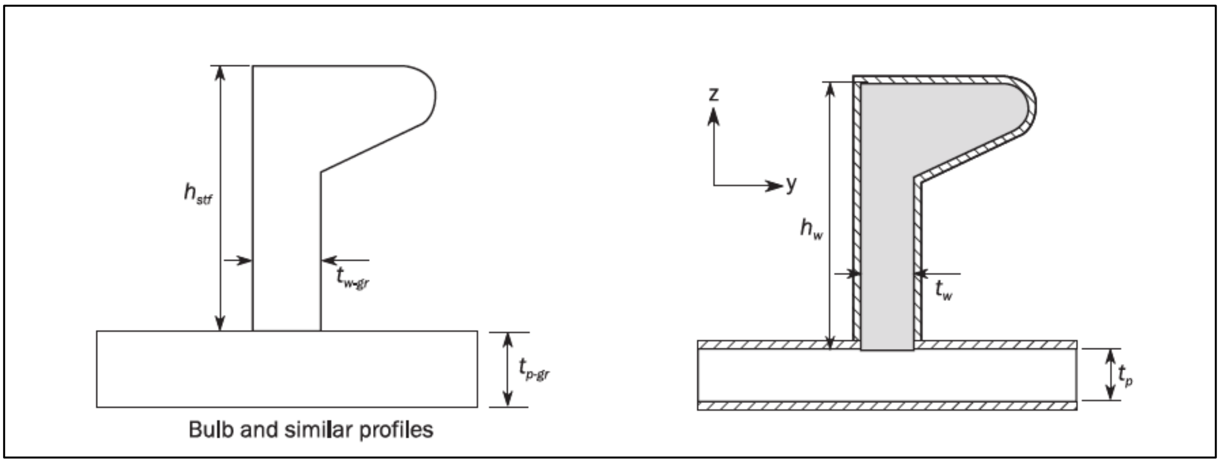
where:

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.

Para un perfil llanta bulbo:



$$d_{shr} = 43 + 11{,}5 = 54{,}5\ mm$$

Ahora se puede calcular el espesor mínimo recomendado de los refuerzos:

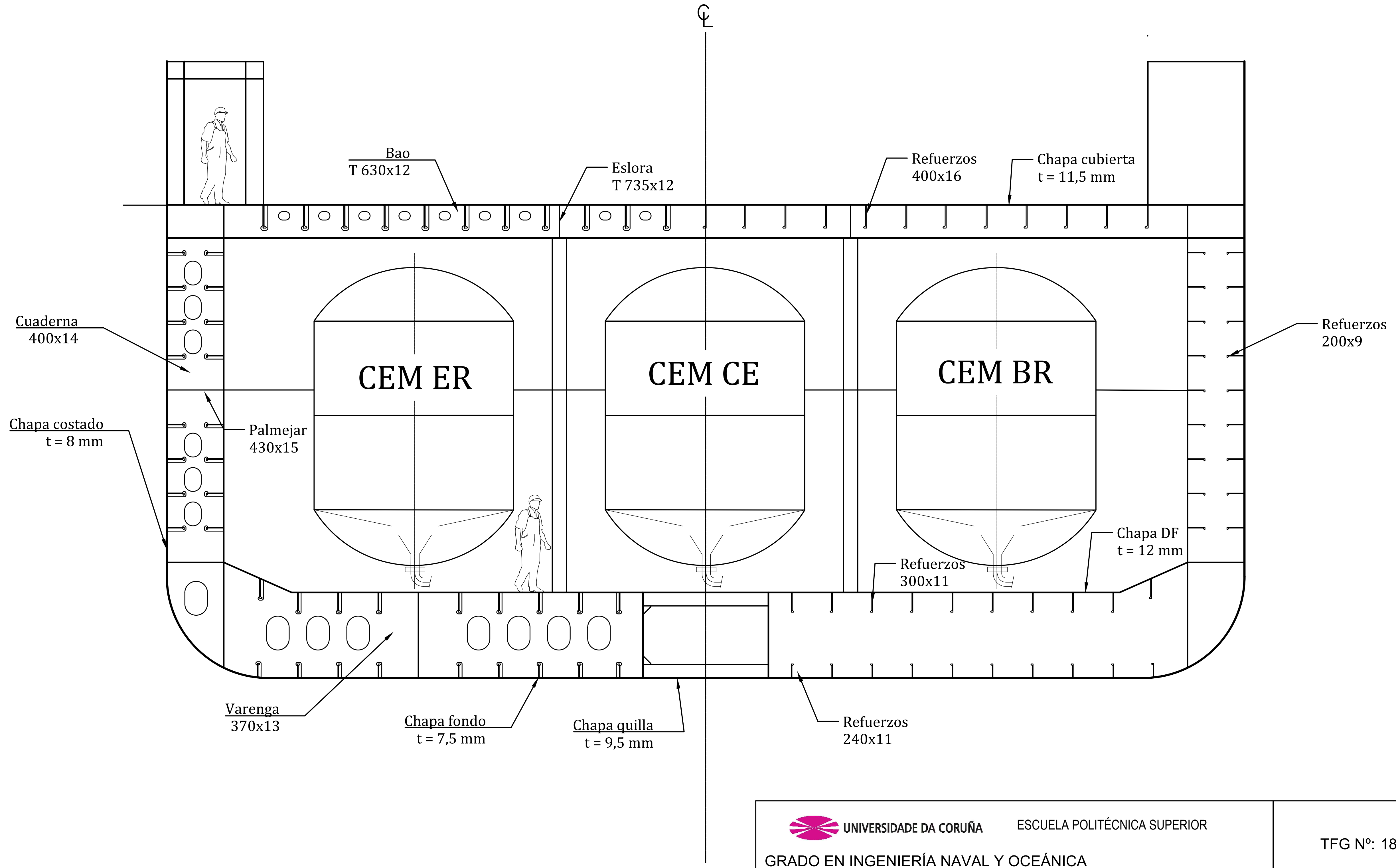
$$t_w = \frac{0{,}5 \cdot 147{,}16 \cdot 700 \cdot 2}{54{,}5 \cdot 0{,}9 \cdot 135{,}7} \longrightarrow t_w = 15{,}5\ mm$$

Como se observa el espesor mínimo es mayor que el espesor que tiene el perfil que se ha seleccionado, por lo tanto, se elegirá un perfil que cumpla con el requerimiento:

$$\underline{\boldsymbol{400\ x\ 16\ de\ Z = 1666\ cm^3}}$$

4 PLANO DE LA CUADERNA MAESTRA

A cotninuación se muestra un plano de la cuaderna mastre, indicando todos los valor calculados a lo largo de este Cuaderno.



UNIVERSIDADE DA CORUÑA ESCUELA POLITÉCNICA SUPERIOR

GRADO EN INGENIERÍA NAVAL Y OCEÁNICA

TFG Nº: 18-02

TÍTULO DEL PLANO:

CUADERNA MAESTRA

AUTOR:

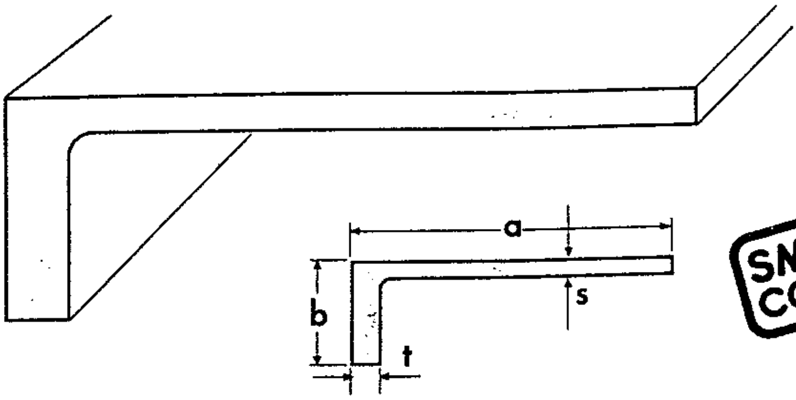
SANDRA ALLEGUE GARCÍA

ESCALA: 1:75

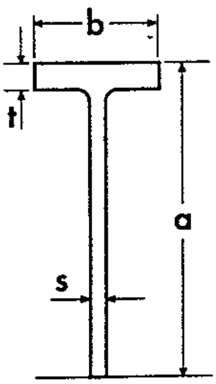
PLANO Nº: 01

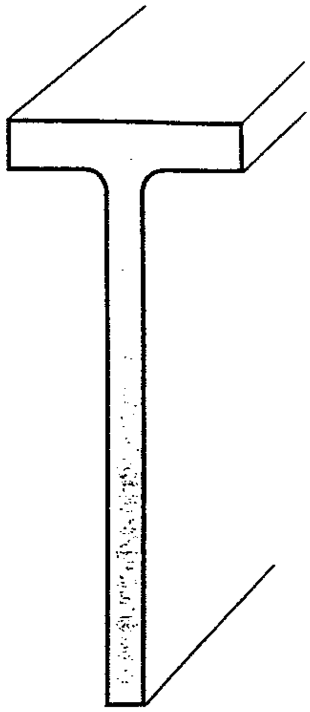
ANEXO: CATÁLOGO DE PERFILES

Welded Angles and T-Sections



SMOOTH CORNERS





Dimension range, weight/m and static values

Section	Width a mm	Height b mm	Thickness s mm	Thickness t mm	Area A cm²	Weight kg/m	e cm	I_x cm⁴	W* cm³	Plate
T-Sections	315	100	12	15	51.0	40.8	19.6	5329	764	Plate cross sectional area 100 cm²
	340	120	12	15	57.0	45.6	21.6	6995	946	
	370	120	12	20	66.0	52.8	24.2	9523	1235	
	395	120	12	20	69.0	55.2	25.6	11387	1350	
	425	120	12	25	78.0	62.4	28.2	14750	1682	
Angles and T-Sections	450	120	12	25	81.0	64.8	29.6	17250	1885	Plate cross sectional area 150 cm²
	455	120	12	30	87.0	69.6	30.7	18630	2118	
	460	120	12	35	93.0	74.4	31.6	19900	2350	
	475	120	12	25	84.0	67.2	31.0	20010	2030	
	525	120	12	25	90.0	72.0	33.8	26300	2330	
	525	150	12	25	97.5	78.0	35.1	28420	2685	
	530	150	12	30	105.0	84.0	36.4	30590	3026	
	535	150	12	35	112.5	90.0	37.5	32590	3364	
	575	150	12	25	103.5	82.8	37.9	36420	3033	
	585	150	12	35	118.5	94.8	40.5	41710	3775	
	625	150	12	25	109.5	87.6	40.7	45700	3395	
	630	150	12	30	117.0	93.6	42.1	49110	3799	
	635	150	12	35	124.5	99.6	43.4	52260	4200	
	625	200	12	25	122.0	97.6	42.8	50440	4096	
	630	200	12	30	132.0	105.6	44.3	54120	4636	
	635	200	12	35	142.0	113.6	45.7	57450	5172	
	675	200	12	25	128.0	102.4	45.7	62190	4602	Plate cross sectional area 175 cm²
	685	200	12	35	148.0	118.4	48.7	70810	5782	
	725	200	12	25	134.0	107.2	48.5	75510	5054	
	735	200	12	35	154.0	123.2	51.7	85940	6319	
	775	200	12	25	140.0	112.0	51.3	90480	5520	
	780	200	12	30	150.0	120.0	53.1	96990	6197	
	785	200	12	35	160.0	128.0	54.7	102920	6870	
	830	200	14	30	172.0	137.6	54.5	127070	7003	
	835	200	14	35	182.0	145.6	56.1	134890	7707	
	880	200	14	30	179.0	143.2	57.2	148920	7572	
	885	200	14	35	189.0	151.2	58.9	158020	8317	
	930	200	15	30	195.0	156.0	59.3	180990	8331	
	935	200	15	35	205.0	164.0	61.0	191950	9110	
	985	200	15	35	212.5	170.0	63.7	221100	9768	
	1035	200	15	35	220.0	176.0	66.5	252890	10440	

* Inclusive plate as noted

Butt /Fillet welded

Full penetration welds by special agreement.

Orders

must include the following measurements: a x b x s x t.

Standard lengths

8 – 18 m,

Other lengths by special agreement.

By special agreement other dimensions and combinations can be offered to satisfy required area and/or strength.

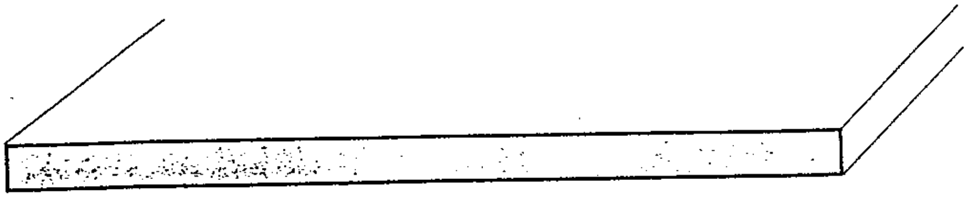
Heights up to 1500 mm can be offered.

Static values for required combination can be given.

Welded I-Sections are also available in heights from 350 – 1500 mm

INEXA PROFIL

Universals



SMOOTH CORNERS

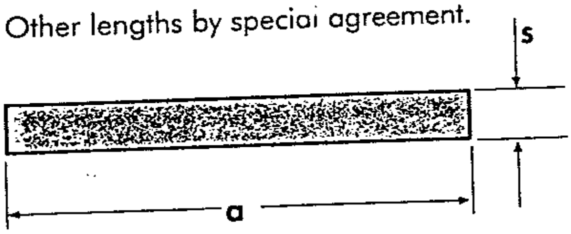
Dimension range and weight/m

Width a mm	Thickness s mm 12	14	15	20	25	30	35	40
150						35.3	41.2	47.1
175						41.2	48.1	55.0
200			23.6	31.4	39.3	47.1	55.0	62.8
225			26.5	35.3	44.2	53.0	61.8	70.7
250	23.6	27.5	29.4	39.3	49.1	58.9	68.7	78.5
275	25.9	30.2	32.4	43.2	54.0	64.8	75.6	86.4
300	28.3	33.0	35.3	47.1	58.9	70.7	82.4	94.2
325	30.6	35.7	38.3	51.0	63.8	76.5	89.3	102.1
350	33.0	38.5	41.2	55.0	68.7	82.4	96.2	109.9
375	35.3	41.2	44.2	58.9	73.6	88.3	103.0	117.8
400	37.7	44.0	47.1	62.8	78.5	94.2	109.9	125.6
425	40.0	46.7	50.0	66.7	83.4	100.1	116.8	133.5
450	42.4	49.5	53.0	70.7	88.3	106.0	123.6	141.3
475	44.7	52.2	55.9	74.6	93.2	111.9	130.5	149.2
500	47.1	55.0	58.9	78.5	98.1	117.8	137.4	157.0
525	49.5	57.7	61.8	82.4	103.0	123.6		
550	51.8	60.4	64.8	86.4	107.9	129.5		
575	54.2	63.2	67.7	90.3	112.8	135.4		
600	56.5	65.9	70.7	94.2	117.8	141.3		
625	58.9	68.7	73.6	98.1	122.7	147.2		
650	61.2	71.4	76.5	102.1	127.6	153.1		
700	65.9	76.9	82.4	109.9	137.4	164.9		
750	70.7	82.4	88.3	117.8				
800	75.4	87.9	94.2	125.6				
850	80.1	93.4	100.1	133.5				
900	84.8	98.9	106.0	141.3				
1000	94.2	109.9	117.8	157.0				
1035	97.5	113.7	121.9	162.5				

Other dimensions are rolled by special agreement.
Static values available upon request.

Standard lengths

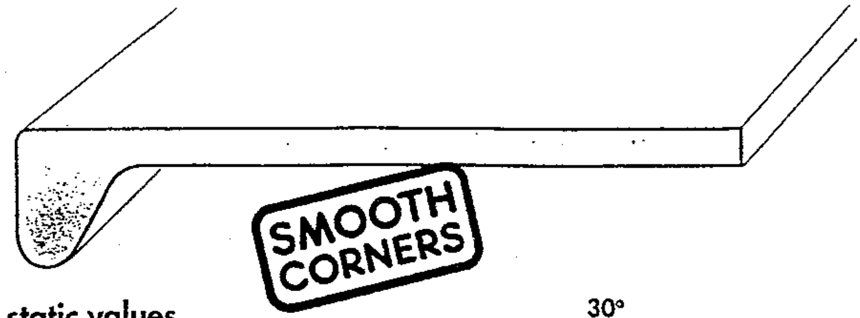
8 – 18 m.
Other lengths by speciai agreement.



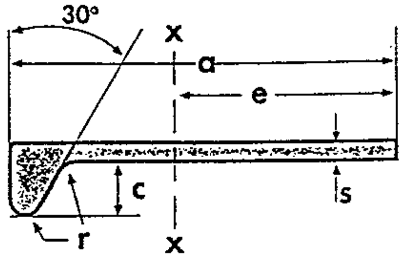
Orders

must include the following measurements:
a x s.

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	Plate cross sectional area 60 cm²
	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	15.2	11.9	8.07	291	93	
160	7	22	6	14.6	11.4	9.66	373	110	
	8	22	6	16.2	12.7	9.49	411	118	
	9	22	6	17.8	14.0	9.36	448	126	
180	8	25	7	18.9	14.8	10.9	609	157	
	9	25	7	20.7	16.2	10.7	663	166	
	10	25	7	22.5	17.6	10.6	717	177	
200	9	28	8	23.6	18.5	12.1	941	225	Plate cross sectional area 100 cm²
	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	Plate cross sectional area 150 cm²
	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

Standard lengths

6–18 m.

Other lengths by special agreeme

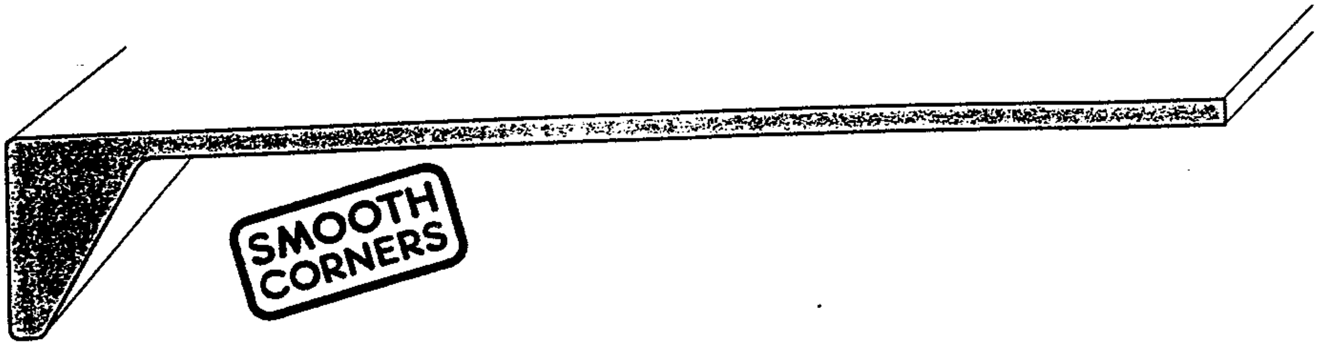
Orders

must include the following measurements: a x s.

INEXA PROFIL

Jumbo Bulb Flats

Welded bulb flats, for very large and ultra large carrier/vessels



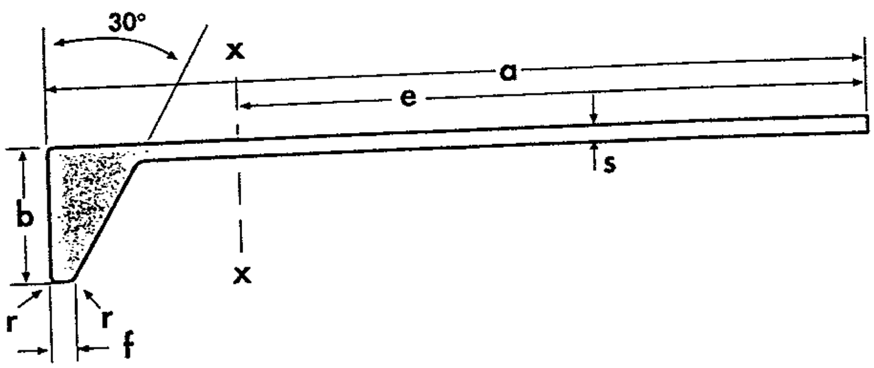
Dimension range, weight/m and static values

Width mm	Thickness s mm	Height b mm	Bulb bottom f mm	Radius r mm	Area A cm^2	Weight kg/m	e cm	I_x cm^4	W_x* cm^3
400	12	110	17	5.0	92.1	72.3	28.4	13530	2104
	14	110	17	5.0	98.7	77.5	27.6	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	95.9	43.3	52870	4014
	14	110	17	5.0	133.7	105.0	42.1	58290	4147

Plate cross sectional area 150 cm^2

* Inclusive plate as noted

Other dimensions by special agreement.



Standard lengths

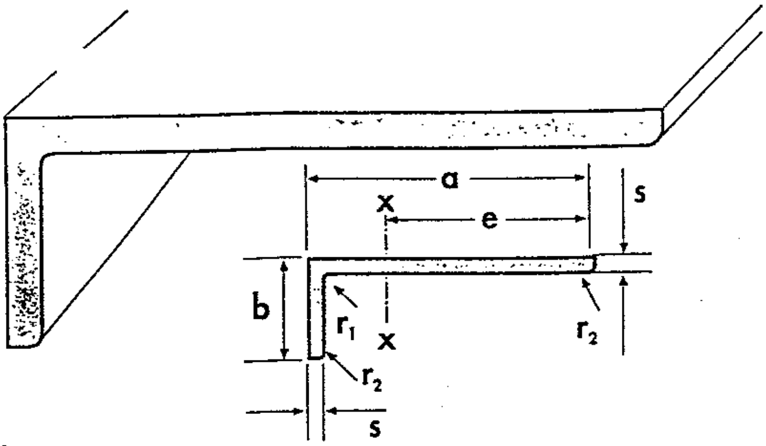
8 – 18 m.
Other lengths by special agreement.

Orders

must include the following measurements:
a x s.

Rolled Angles

SMOOTH CORNERS



Dimension range, weight/m and static values

Width a mm	Height b mm	Thickness s mm	r_1 mm	r_2 mm	Area cm^2	Weight kg/m	e cm	I_x cm^4	W_x* cm^3	
180	90	10	14	7	26.2	20.6	11.72	880	244	Plate cross sectional area 60 cm^2
180	90	12	14	7	31.2	24.5	11.63	1040	283	
180	90	14	14	7	36.1	28.3	11.54	1190	319	

* Inclusive plate as noted

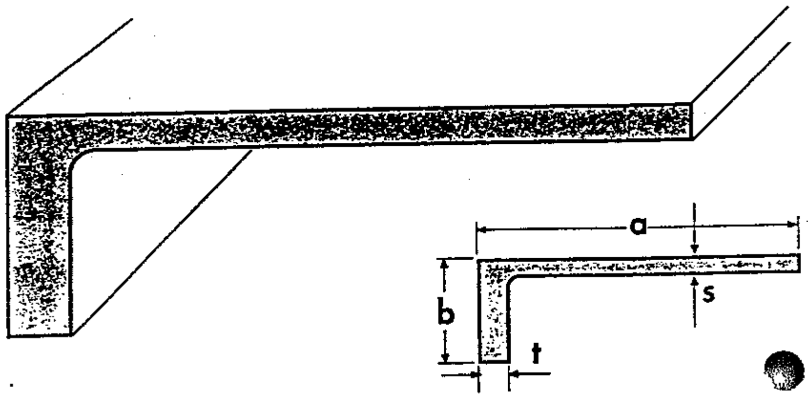
Standard lengths
8 – 18 m.
Other lengths by special agreement.

Orders
must include the following measurements:
a x b x s.

Welded Angles to NJA Standard

Butt/Fillet welded
Full penetration welds by special agreement.

SMOOTH CORNERS



Dimension range, weight/m and static values

Width a mm	Height b mm	Thickness s mm	Thickness t mm	Area A cm^2	Weight kg/m	e cm	I_x cm^4	W_x* cm^3	
200	90	9	12	27.7	21.8	13.3	1159	308	Plate cross sectional area 100 cm^2 (200–375)
250	90	9	13	33.0	25.9	16.3	2181	437	
250	90	10.5	15	38.2	30.0	16.2	2502	495	
250	90	11.5	16	41.3	32.4	16.1	2697	527	
300	100	10.5	15	44.9	35.3	19.3	4276	681	
300	100	11.5	16	48.7	38.2	19.1	4615	725	
325	120	10.5	14	49.5	38.8	21.1	5564	820	
325	120	11.5	15	53.7	42.1	21.0	6017	876	
350	120	10.5	16	54.3	42.6	22.9	7064	975	
350	120	11.5	18	59.8	46.9	22.9	7738	1068	
375	120	10.5	18	59.1	46.4	24.7	8805	1142	
375	120	11.5	20	64.8	50.9	24.7	9609	1242	
400	120	11.5	23	71.0	55.7	26.6	11893	1516	Plate cross sectional area 150 cm^2

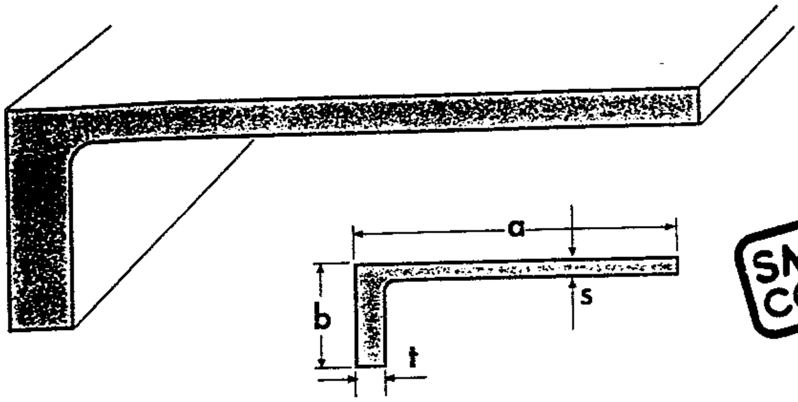
* Inclusive plate as noted

Standard lengths
8 –18 m.
Other lengths by special agreement.

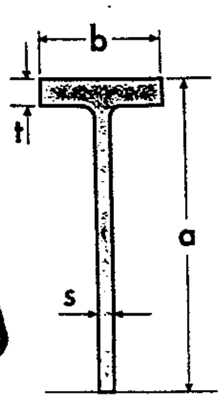
Orders
must include the following measurements:
a x b x s x t.

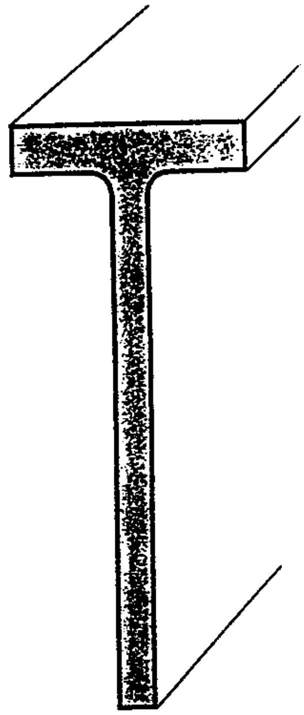
INEXA PROFIL

Welded Angles and T-Sections



SMOOTH CORNERS





Dimension range, weight/m and static values

Section	Width a mm	Height b mm	Thickness s mm	Thickness t mm	Area A cm^2	Weight kg/m	e cm	I_x cm^4	W* cm^3	Plate cross sectional area
T-Sections	315	100	12	15	51.0	40.8	19.6	5329	764	100 cm^2
T-Sections	340	120	12	15	57.0	45.6	21.6	6995	946	100 cm^2
T-Sections	370	120	12	20	66.0	52.8	24.2	9523	1235	100 cm^2
T-Sections	395	120	12	20	69.0	55.2	25.6	11387	1350	100 cm^2
T-Sections	425	120	12	25	78.0	62.4	28.2	14750	1682	100 cm^2
Angles and T-Sections	450	120	12	25	81.0	64.8	29.6	17250	1885	150 cm^2
Angles and T-Sections	455	120	12	30	87.0	69.6	30.7	18630	2118	150 cm^2
Angles and T-Sections	460	120	12	35	93.0	74.4	31.6	19900	2350	150 cm^2
Angles and T-Sections	475	120	12	25	84.0	67.2	31.0	20010	2030	150 cm^2
Angles and T-Sections	525	120	12	25	90.0	72.0	33.8	26300	2330	150 cm^2
Angles and T-Sections	525	150	12	25	97.5	78.0	35.1	28420	2685	150 cm^2
Angles and T-Sections	530	150	12	30	105.0	84.0	36.4	30590	3026	150 cm^2
Angles and T-Sections	535	150	12	35	112.5	90.0	37.5	32590	3364	150 cm^2
Angles and T-Sections	575	150	12	25	103.5	82.8	37.9	36420	3033	150 cm^2
Angles and T-Sections	585	150	12	35	118.5	94.8	40.5	41710	3775	150 cm^2
Angles and T-Sections	625	150	12	25	109.5	87.6	40.7	45700	3395	150 cm^2
Angles and T-Sections	630	150	12	30	117.0	93.6	42.1	49110	3799	150 cm^2
Angles and T-Sections	635	150	12	35	124.5	99.6	43.4	52260	4200	150 cm^2
Angles and T-Sections	625	200	12	25	122.0	97.6	42.8	50440	4096	150 cm^2
Angles and T-Sections	630	200	12	30	132.0	105.6	44.3	54120	4636	150 cm^2
Angles and T-Sections	635	200	12	35	142.0	113.6	45.7	57450	5172	150 cm^2
Angles and T-Sections	675	200	12	25	128.0	102.4	45.7	62190	4602	175 cm^2
Angles and T-Sections	685	200	12	35	148.0	118.4	48.7	70810	5782	175 cm^2
Angles and T-Sections	725	200	12	25	134.0	107.2	48.5	75510	5054	175 cm^2
Angles and T-Sections	735	200	12	35	154.0	123.2	51.7	85940	6319	175 cm^2
Angles and T-Sections	775	200	12	25	140.0	112.0	51.3	90480	5520	175 cm^2
Angles and T-Sections	780	200	12	30	150.0	120.0	53.1	96990	6197	175 cm^2
Angles and T-Sections	785	200	12	35	160.0	128.0	54.7	102920	6870	175 cm^2
Angles and T-Sections	830	200	14	30	172.0	137.6	54.5	127070	7003	175 cm^2
Angles and T-Sections	835	200	14	35	182.0	145.6	56.1	134890	7707	175 cm^2
Angles and T-Sections	880	200	14	30	179.0	143.2	57.2	148920	7572	175 cm^2
Angles and T-Sections	885	200	14	35	189.0	151.2	58.9	158020	8317	175 cm^2
Angles and T-Sections	930	200	15	30	195.0	156.0	59.3	180990	8331	175 cm^2
Angles and T-Sections	935	200	15	35	205.0	164.0	61.0	191950	9110	175 cm^2
Angles and T-Sections	985	200	15	35	212.5	170.0	63.7	221100	9768	175 cm^2
Angles and T-Sections	1035	200	15	35	220.0	176.0	66.5	252890	10440	175 cm^2

* Inclusive plate as noted

Butt /Fillet welded

Full penetration welds by special agreement.

Orders

must include the following measurements: a x b x s x t.

Standard lengths

8 – 18 m,

Other lengths by special agreement.

By special agreement other dimensions and combinations can be offered to satisfy required area and/or strength.

Heights up to 1500 mm can be offered.

Static values for required combination can be given.

Welded I-Sections are also available in heights from 350 – 1500 mm

INEXA PROFIL