Escola Politécnica Superior

**Trabajo Fin de Máster**
**CURSO 2016/2017**

# *BUQUE LNG DE MEMBRANA DE 145.000 m³*

**Máster en Ingeniería Naval y Oceánica**


**ALUMNA/O**

Ismael Grandal Mouriz

**TUTORAS/ES**

Vicente Díaz Casas


**FECHA**

SEPTIEMBRE DE 2017

# CUADERNO 8

En el presente cuaderno realizaremos el cálculo y diseño de la estructura del buque, así como el cálculo de la inercia y el  módulo y los momentos flectores y fuerzas cortantes.

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**CUADERNO 8**

## CUADERNA MAESTRA

Escola Politécnica Superior

UNIVERSIDADE DA CORUÑA

DEPARTAMENTO DE INGENIERÍA NAVAL Y OCEÁNICA

TRABAJO FIN DE MÁSTER

CURSO 2016-2017

**PROYECTO NÚMERO: 17-32 P**

**TIPO DE BUQUE:** Buque tanque LNG de membrana

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

**CARACTERÍSTICAS DE LA CARGA:** gas natural licuado con capacidad para 145.000 $m^3$.

**VELOCIDAD Y AUTONOMÍA:** 19,5 nudos a la velocidad de servicio, 85% MCR + 15% MM. 12.000 millas a la velocidad de servicio.

**SISTEMAS Y EQUIPOS DE CARGA / DESCARGA:** los habituales en este tipo de buque.

**PROPULSIÓN:** Propulsión Diesel eléctrico. Dos líneas de ejes

**TRIPULACIÓN Y PASAJE:** 35 tripulantes en camarotes individuales.

**OTROS EQUIPOS E INSTALACIONES:** Las habituales en este tipo de buque.

Ferrol, Abril de 2017

ALUMNO: D. Ismael Grandal Mouriz

ÍNDICE:

# 1. INTRODUCCIÓN

El objetivo de este cuaderno es realizar el escantillonado de diversos elementos del buque para de esta forma poder obtener el módulo resistente del buque en la cuaderna maestra y comprobar que resiste estructuralmente los momentos flectores máximos generados en las condiciones de arrufo y quebranto. Para ello será necesario escantillonar todos los elementos que participan en la resistencia longitudinal del buque.

En esta fase del proyecto se realizaran los cálculos del escantillonado tratando a nuestro buque como un buque tanque. En las siguientes fases del proyecto deberemos aplicar la sección específica para buques LNG de la Sociedad de Clasificación. Elegiremos DNV (revisión 2001). Todas las fórmulas utilizadas están copiadas directamente del reglamento y se indica la parte, el capítulo y la sección.

Adjuntamos los datos obtenidos en cuadernos anteriores ya que serán necesarios para la elaboración de este cuaderno.

| | |
|---|---|
| **L** | 269,7 |
| **B** | 43,2 |
| **D** | 26,3 |
| **T** | 11,5 |
| **Volumen** | 145.000 |
| **Δ** | 105.379 |
| **V** | 19,5 |
| **Fn** | 0,1950 |
| **Cb** | 0,7673 |
| **Cm** | 0,9971 |
| **Cp** | 0,7905 |

Las condiciones de carga definidas en el cuaderno 5 son:

a) Buque en la condición de **salida a plena carga**, distribuida esta de forma homogénea en todos los espacios de carga y con la totalidad de provisiones y combustible.

b) Buque en la condición de **llegada en plena carga**, distribuida esta de forma homogénea en todos los espacios de carga y con el 10 % de provisiones y combustibles.

c) Buque en condición de **salida, en lastre** sin carga, pero con la totalidad de provisiones y combustibles.

d) Buque en la condición de **llegada en lastre** sin carga, y con el 10% de provisiones y combustible

La cuaderna maestra que vamos a utilizar los detallamos a continuación:

Ahora vamos a ajustar la geometría de esta cuaderna maestra del buque base a nuestras condiciones de proyecto. Por tanto, vamos a tener las siguientes dimensiones y separaciones entre refuerzos:

- Separación horizontal entre longitudinales del doble fondo: 1 metro.
- Separación vertical entre longitudinales doble casco: 0.8 metros.
- Separación horizontal entre longitudinales cubierta principal: 1 metro.
- Separación horizontal entre longitudinales de los domos: 1 metros.

Los planos de diseño conceptual de la cuaderna maestra los adjuntamos como anexo.

## 2. DETERMINACIÓN DE LAS DIMENSIONES DE ESCANTILLONADO

Según el DNV Pt. 3 Ch. 1 Secc.1:

B.101

**Calado de escantillonado**

El reglamento nos lo define como el calado medio en la línea de verano. Debemos hacer una estimación del francobordo del buque y el calado máximo obtenido es el que se utilizará para realizar el diseño de la estructura del buque. En nuestro caso, como estamos penalizados por estabilidad, utilizaremos el calado a la condición de carga más desfavorable.

Podemos observar que la condición más desfavorable es la salida de puerto a plena carga (1). Por tanto, nuestro calado de escantillonado será la suma de este calado a plena carga más un margen de error, que será de medio metro: 12,34 + 0,5 = 12,84 m.

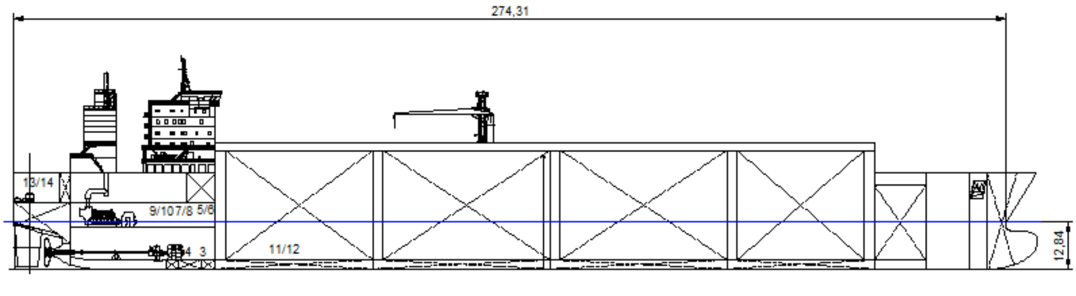
**Eslora de escantillonado**

Calcularemos la eslora de escantillonado siguiendo el siguiente criterio:

$$L = \max \begin{cases} 0.96 \cdot L_{WL} \\ \min \begin{cases} 0.97 \cdot L_{WL} \\ L_{PP} \end{cases} \end{cases}$$

Lpp = 269,7 m.

Lwl = 274,52 m.




Por otro lado: 0.97 · 274,52 = 266,08 m.

Por tanto, nuestra eslora de escantillonado será de 266.08 m.

$L_{escantillonado}$ = 266.08 m.

**Manga de escantillonado**

Se toma el valor de la manga máxima al calado de verano: 43.2 m

**Puntal de escantillonado**

Tomamos el valor de la distancia vertical desde la línea base a la cubierta continua más alta medida en el centro del buque. Coincide con el puntal de trazado: 26,3 m.

**Coeficiente de bloque de escantillonado**

Se obtiene con las dimensiones de escantillonado y el desplazamiento de escantillonado:

$$C_B = \frac{\Delta_s}{\rho L_s B_s T_s}$$

Donde:

Δ (escantillonado) = 117.658 t.

Tendremos, por tanto:

CB = 0,7777

**3-ESCANTILLONADO DE LOS ELEMENTOS ESTRUCTURALES DEL BUQUE**

**Márgenes de corrosión**

Deberemos añadir márgenes de corrosión a los espesores según la tabla D1 Pt. 3 Ch. 1 Secc. 2. Su valor dependerá del compartimento del que formen parte.

**Table D1 Corrosion addition $t_k$ in mm**

| *Internal members and plate boundary between spaces of the given category* | *Tank/hold region* | |
|---|---|---|
| | *Within 1,5 m below weather deck tank or hold top* | *Elsewhere* |
| Ballast tank 1) | 3,0 | 1,5 |
| Cargo oil tank only | 2,0 | 1,0 (0) 2) |
| Hold of dry bulk cargo carriers 4) | 1,0 | 1,0 (3) 5) |
| *Plate boundary between given space categories* | *Tank/hold region* | |
| | *Within 1,5 m below weather deck tank or hold top* | *Elsewhere* |
| Ballast tank 1)/Cargo oil tank only | 2,5 | 1,5 (1,0) 2) |
| Ballast tank 1)/Hold of dry bulk cargo carrier 4) | 2,0 | 1,5 |
| Ballast tank 1)/Other category space 3) | 2,0 | 1,0 |
| Cargo oil tank only/ Other cate-gory space 3) | 1,0 | 0,5 (0) 2) |
| Hold of dry bulk cargo carrier 4) /Other category space 3) | 0,5 | 0,5 |

1) The term ballast tank also includes combined ballast and cargo oil tanks, but not cargo oil tanks which may carry water ballast according to Regulation 13(3), of MARPOL 73/78, see Pt.7 Ch.4 App.B B100.

2) The figure in brackets refers to non-horizontal surfaces.

3) Other category space denotes the hull exterior and all spaces other than water ballast and cargo oil tanks and holds of dry bulk cargo carriers.

4) Hold of dry bulk cargo carriers refers to the cargo holds, including ballast holds, of vessels with class notations **Bulk Carrier** and **Ore Carrier**, see Pt.5 Ch.2 Sec.5.

5) The figure in brackets refers to webs and bracket plates in lower part of main frames in bulk carrier holds.

**Materiales**

Se utilizará acero de resistencia normal NV-NS con las siguientes características:

- Modulo de Young = $2.06 \cdot 10^5$ N/mm$^2$
- f1=1
- Tensión elástica mínima = 235 N/mm$^2$.

**Puntos de carga (load points)**

Pt.3 Ch. 1 Sec. 4

**A 200 Definitions**

**201** Symbols:

p = design pressure in kN/m$^2$
*r* = density of liquid or stowage rate of dry cargo in t/m$^3$.

**202** The load point for which the design pressure is to be calculated is defined for various strength members as follows:

a) For plates:
midpoint of horizontally stiffened plate field.
Half of the stiffener spacing above the lower support of vertically stiffened plate field, or at lower edge of plate when the thickness is changed within the plate field.

b) For stiffeners:
midpoint of span.
When the pressure is not varied linearly over the span the design pressure is to be taken as the greater of:

$$p_m \text{ and } \frac{p_a + p_b}{2}$$

$p_m$, $p_a$ and $p_b$ are calculated pressure at the midpoint and at each end respectively.

c) For girders:
midpoint of load area.

**Cálculo de los parámetros principales**

Pt. 3 Ch. 1 Sec. 4

**B 200 Basic parameters**

**201** The acceleration, sea pressures and hull girder loads have been related to a wave coefficient as given in Table B1.

**Table B1 Wave coefficient $C_W$**

| *L* | $C_W$ |
|---|---|
| $L \leq 100$ | 0,0792 L |
| $100 < L < 300$ | $10{,}75 - [(300-L)/100]^{3/2}$ |
| $300 \leq L \leq 350$ | 10,75 |
| $L > 350$ | $10{,}75 - [(L-350)/150]^{3/2}$ |

En nuestro caso tenemos que Cw = 10,55.

**203** A common acceleration parameter is given by:

$$a_0 = \frac{3C_W}{L} + C_V C_{V1}$$

$$C_V = \frac{\sqrt{L}}{50}, \quad \text{maximum } 0,2$$

$$C_{V1} = \frac{V}{\sqrt{L}}, \quad \text{minimum } 0,8$$

$$a_0 = \frac{3 \cdot 10,55}{266,08} + 0,2 \cdot 1,195 = 0,3579$$

$$C_V = \frac{\sqrt{266,08}}{50} = 0,326 \; Cogemos \; C_V = 0,2$$

$$C_{V1} = \frac{19,5}{\sqrt{266,08}} = 1,195$$

**B 600 Combined vertical acceleration**

**601** Normally the combined vertical acceleration (acceleration of gravity not included) may be approximated by:

$$a_v = \frac{k_v g_0 a_0}{C_B} \quad (m/s^2)$$

$k_v$ = 1,3 aft of A.P.
= 0,7 between 0,3 L and 0,6 L from A.P.
= 1,5 forward of F.P.

$$a_v = \frac{0,7 \cdot 9,81 \cdot 0,3579}{0,7777} = 3,1602 \; m/s^2$$

**C 200 Sea pressures**

**201** The pressure acting on the ship's side, bottom and weather deck is to be taken as the sum of the static and the dynamic pressure as:

— for load point below summer load waterline :

$p_1 = 10\, h_0 + p_{dp}$ 1) $(kN/m^2)$

— for load point above summer load waterline :

$p_2$ = a ( $p_{dp}$ – (4 + 0,2 $k_s$) $h_0$ ) [1] (kN/m²)
= minimum 6,25 + 0,025 $L_1$ for sides
= minimum 5 for weather decks.

The pressure $p_{dp}$ is taken as:

$$p_{dp} = p_l + 135\frac{y}{B+75} - 1,2(T - z) \qquad (kN/m^2)$$

$$p_l = k_s C_W + k_f$$

$$= (k_s C_W + k_f)\left(0,8 + 0,15\frac{V}{\sqrt{L}}\right) \text{ if } \frac{V}{\sqrt{L}} > 1,5$$

$$k_s = 3C_B + \frac{2,5}{\sqrt{C_B}} \quad \text{at AP and aft}$$

= 2 between 0,2 L and 0,7 L from AP

$$= 3C_B + \frac{4,0}{C_B} \quad \text{at FP and forward.}$$

Between specified areas $k_s$ is to be varied linearly.

a = 1,0 for ship's sides and for weather decks forward of 0,15L from FP, or forward of deckhouse front, whichever is the foremost position
= 0,8 for weather decks elsewhere
$h_0$ = vertical distance from the waterline at draught T to the load point (m)
z = vertical distance from the baseline to the load point, maximum T (m)
y = horizontal distance from the centre line to the load point, minimum B/4 (m)
$C_W$ = as given in B200
$k_f$ = the smallest of T and f
f = vertical distance from the waterline to the top of the ship's side at transverse section considered, maximum 0,8 $C_W$ (m)
$L_1$ = ship length, need not be taken greater than 300 (m).

1) For ships with service restrictions, $p_2$ and the last term in $p_1$ may be reduced by the percentages given in B202. $C_W$ should not be reduced.

Cw = 10,55

Kf = 8,424

f = 0,8 · 10,55 = 8,424 m., menor que 26,3 – 12,84 = 13,46 m.

Ks = 2

$$pl = 2 \cdot 10,55 + 8,424 = 29,484 \text{ kN/m}^2$$

**ESCANTILLONADO**

A continuación se presenta el cálculo de escantillones y módulos mínimos requeridos por el DNV. Una vez obtenidos los diferentes parámetros se deberá comprobar la validez de la estructura mediante el cálculo del módulo resistente de la cuaderna maestra.

En los cálculos en los que se precisen valores calculados con anterioridad, no los volveremos a presentar.

**Pt. 3 Ch. 1 Sec. 67**

**C200 Quilla plana**

**C 200 Keel plate**

**201** A keel plate is to extend over the complete length of the ship. The breadth is not to be less than:

$$b = 800 + 5\,L \quad (\text{mm}).$$

**202** The thickness is not to be less than:

$$t = 7,0 + \frac{0,05 L_1}{\sqrt{f_1}} + t_k \qquad (\text{mm})$$

The thickness is in no case to be less than that of the adjacent bottom plate.

b = 2.130,4 mm → 2.135 mm.

$$t = 7{,}0 + \frac{0{,}05 \cdot 266{,}08}{\sqrt{1}} + 2{,}5 = 22{,}804\ mm. \rightarrow 23mm.$$

**C300 Fondo y pantoque**

**302** The thickness requirement corresponding to lateral pressure is given by:

$$t = \frac{15,8 k_a s \sqrt{p}}{\sqrt{\sigma}} + t_k \qquad (\text{mm})$$

$p$ = $p_1$ to $p_3$ (when relevant) in Table B1

$\sigma$ = $175\ f_1 - 120\ f_{2b}$ , maximum $120\ f_1$ when transverse frames, within 0,4L

= $120\ f_1$ when longitudinals, within 0,4 L

= $160\ f_1$ within 0,1 L from the perpendiculars.

Between specified regions the $\sigma$-value may be varied linearly.

$f_{2b}$ = stress factor as given in A 200

Necesitamos el valor de ka de A201

$f_{2b}$ = stress factor below the neutral axis of the hull girder depending on surplus in midship section modulus and maximum value of the actual still water bending moments:

$$f_{2b} = \frac{5,7(M_S + M_W)}{Z_B}$$

$k_a$ = correction factor for aspect ratio of plate field

= $(1,1 - 0,25\ s/l)^2$

= maximum 1,0 for $s/l = 0,4$

= minimum 0,72 for $s/l = 1,0$

Y de la Sec. 4 C201

The pressure $p_{dp}$ is taken as:

$$p_{dp} = p_l + 135\frac{y}{B+75} - 1,2\,(T - z)$$

B201

| Table B1 Design loads | | |
|---|---|---|
| *Structure* | *Load type* | *p (kN/m²)* |
| Outer bottom | Sea pressure | $p_1 = 10\,T + p_{dp}$ (kN/m²) [1] |
| | Net pressure in way of cargo tank or deep tank | $p_2 = \rho(g_0 + 0{,}5\,a_v)\,h_s - 10\,T_M$<br>$p_3 = \rho g_0 h_s + p_0 - 10\,T_M$ |
| Inner bottom | Dry cargo in cargo holds | $p_4 = \rho(g_0 + 0{,}5\,a_v)\,H_C$ |
| | Ballast in cargo holds | $p_5 = (10 + 0,5a_v)h_s$<br>$p_6 = 6,7(h_s + \phi b) - 1,2\sqrt{H\phi b_t}$ [2]<br>$p_7 = 0,67(10h_p + \Delta p_{dyn})$<br>$p_8 = 10h_s + p_0$ |
| | Liquid cargo in tank above | $p_9 = \rho(g_0 + 0,5a_v)\,h_s$<br>$p_{10} = \rho g_0[0,67(h_s + \phi b) - 0,12\sqrt{H\phi b_t}]$ [2]<br>$p_{11} = 0,67(\rho g_0 h_p + \Delta p_{dyn})$<br>$p_{12} = \rho g_0 h_s + p_0$ |
| Inner bottom, floors and girders | Pressure on tank boundaries in double bottom | $p_{13} = 0{,}67\,(10\,h_p + \Delta\,p_{dyn})$<br>$p_{14} = 10\,h_s + p_0$ |
| | Minimum pressure | $p_{15} = 10\,T$ |
| 1) For ships with service restrictions the last term in $p_1$ may be reduced by the percentages given in Sec.4 B202.<br>2) $p_6$ and $p_{10}$ to be used in tanks/holds with largest breadth > 0,4 B. | | |

Y de la C304

**304** The thickness is not to be less than:

$$t = 5,0 + \frac{0,04L_1}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

Algunos parámetros que consideramos son:

-y: la distancia horizontal en metros, desde la línea de crujía al punto de cálculo considerado.

-z: distancia vertical en metros, desde la línea base hasta el punto de cálculo considerado.

-hs: distancia vertical en metros, desde el punto de cálculo a la parte superior del tanque.

-Tm = 2 + 0.02 · L = 2 + 0.02 · 266,28 = 7.321 m (calado)

-p0 = 25 kN/m$^2$

-pl = 29,484 kN/m$^2$

Según la tabla B201 tenemos:

$$p_{dp} = 29{,}484 + 135 \cdot \frac{10{,}8}{43{,}2 + 75} - 1{,}2 \cdot (12{,}84 - 0) = 26{,}41\ kN/m^2$$

$$p_1 = 10 \cdot 12{,}5 + 26{,}41 = 151{,}41 \frac{kN}{m^2}$$

$$p_2 = 1{,}025 \cdot (9{,}81 + 0{,}5 \cdot 3{,}1602) \cdot 26{,}3 - 10 \cdot (2 + 0{,}02 \cdot 266{,}08) = 236{,}63\ kN/m^2$$

$$p_3 = 1{,}025 \cdot 9{,}81 \cdot 26{,}3 + 25 - 10 \cdot (2 + 0{,}02 \cdot 266{,}08) = 216{,}24\ kN/m^2$$

Nos quedamos con el mayor valor, es decir p = p2

Definimos "s" como el espacio entre longitudinales del fondo, que será de 1000 mm. En el pantoque tenemos un espacio entre refuerzos de 775 mm, por lo que nos quedaremos con el valor de los del fondo para dimensionar el espesor tanto del fondo como del pantoque.

Definimos "l" como la distancia entre bulárcamas que es: 0,925·3 = 2,775 m.

$$ka = \left(1{,}1 - 0{,}25 \frac{1}{0{,}925 \cdot 3}\right)^2 = 1{,}02$$

Definiremos $Z_B$ como 1,2 veces $Z_0$. Por tanto: $Z_B$ =1,2·47681755 = 57218106 cm³.

De esta forma:

$$f_{2b} = \frac{5{,}7 \cdot 8344307}{57218106} = 0{,}8312$$

$$t_{requerido} = \frac{15{,}8 \cdot 1{,}02 \cdot 1 \cdot \sqrt{236{,}63}}{\sqrt{120 \cdot 1}} + 1{,}5 = 24{,}13\ mm. \rightarrow 25\ mm.$$

$$t_{mín} = 5 + \frac{0{,}04 \cdot 266{,}08}{\sqrt{1}} = 15{,}64\ mm. \rightarrow 16\ mm.$$

Tendremos un espesor tanto del fondo como del pantoque de 25 mm.

**C700 Longitudinales del fondo**

**C 700 Bottom longitudinals**

**701** The section modulus requirement is given by:

$$Z = \frac{83\, l^2 s\, p\, w_k}{\sigma} \quad (cm^3)$$

p = $p_1$ to $p_3$ (when relevant) as given in Table B1
$\sigma$ = allowable stress (maximum 160 $f_1$) given by:

— within 0,4 L:

| *Single bottom* | *Double bottom* |
|---|---|
| $225 f_1 - 130 f_{2b}$ | $225 f_1 - 130 f_{2b} - 0.7\, \sigma_{db}$ |

$\sigma_{db}$ = mean double bottom stress at plate flanges, normally not to be taken less than:
= 20 $f_1$ for cargo holds in general cargo vessels
= 50 $f_1$ for holds for ballast
= 85 $f_1$ b/B for tanks for liquid cargo

$$\sigma = 225 \cdot 1 - 130 \cdot f_{2b} - 0{,}7 \cdot \sigma_{db} = 225 \cdot 1 - 130 \cdot 0{,}8312 - 0{,}7 \cdot 50 \cdot 1 = 81{,}94$$

Cogemos p = p2 = 236,63 kN/m²

Para calcular wk: Pt 3 Ch. 1 Sec. 3 C.1000

**1004** For stiffeners and girders in tanks and in cargo holds of dry bulk cargo carriers, corrosion additions corresponding to the requirements given in Sec.2 D are to be applied. For built up sections the appropriate $t_k$-value may be added to the web and flange thickness after fulfilment of the modulus requirement.

For rolled sections the section modulus requirement may be multiplied by a corrosion factor $w_k$, given by the following approximation:

$w_k$ = $1 + 0{,}05\,(t_{kw} + t_{kf})$ for flanged sections
= $1 + 0{,}06\, t_{kw}$ for bulbs

$t_{kw}$ = corrosion addition $t_k$ as given in Sec.2 D200 with respect to the profile web
$t_{kf}$ = corrosion addition $t_k$ as given in Sec.2 D200 with respect to the profile flange.

For flat bars the corrosion addition $t_k$ may be added directly to the thickness.

$$wk = 1 + 0{,}06 \cdot 1{,}5 = 1{,}09$$

El valor utilizado para la separación entre bulárcamas es de 2,775 m. Lo definimos en el cuaderno 4, ya que 3·0,925 = 2,775 (→cofferdams).

$$Z = \frac{83 \cdot 2{,}775^2 \cdot 1 \cdot 236{,}63 \cdot 1{,}09}{81{,}94} = 2011{,}89\ cm^3$$

C730

$$t = 5,0 + \frac{k}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

$$= \frac{h}{g} + t_k$$

k = 0,02 $L_1$
= 5,0 maximum
h = profile height in m
g = 70 for flanged profile webs
= 20 for flat bar profiles.

El espesor es:

$$t = 5 + \frac{5}{\sqrt{1}} + 1,5 = 11,5\, mm. \rightarrow 12\, mm.$$

Para el valor del módulo obtenido Z = 2011,89 elegiremos un perfil con bulbo (tabla de perfiles anexada)

| | |
|---|---|
| Wx ($cm^3$) | 2036 |
| A ($cm^2$) | 103 |
| P (kg/m) | 80,6 |
| Width (mm) | 430 |
| Thickness (mm) | 17 |
| Inercia ($cm^4$) | 18860 |

**Doble fondo**

**Pt. 3 Ch. 1 Sec. 6**

A201

$$f_{2b} = \frac{5,7(M_S + M_W)}{Z_B}$$

$Ff_{2b}$ = 0,8312 (calculado anteriormente)

B201

**Table B1 Design loads**

| *Structure* | *Load type* | *p (kN/m²)* |
|---|---|---|
| Outer bottom | Sea pressure | $p_1 = 10\,T + p_{dp}$ (kN/m²) [1] |
| | Net pressure in way of cargo tank or deep tank | $p_2 = \rho\,(g_0 + 0{,}5\,a_v)\,h_s - 10\,T_M$<br>$p_3 = \rho\,g_0\,h_s + p_0 - 10\,T_M$ |
| Inner bottom | Dry cargo in cargo holds | $p_4 = \rho\,(g_0 + 0{,}5\,a_v)\,H_C$ |
| | Ballast in cargo holds | $p_5 = (10 + 0,5a_v)h_s$<br>$p_6 = 6,7(h_s + \phi b) - 1,2\sqrt{H\,\phi b_t}$ [2]<br>$p_7 = 0,67(10h_p + \Delta p_{dyn})$<br>$p_8 = 10h_s + p_0$ |
| | Liquid cargo in tank above | $p_9 = \rho\,(g_0 + 0,5a_v)\,h_s$<br>$p_{10} = \rho g_0[0,67(h_s + \phi b) - 0,12\sqrt{H\phi b_t}]$ [2]<br>$p_{11} = 0,67(\rho g_0 h_p + \Delta p_{dyn})$<br>$p_{12} = \rho g_0 h_s + p_0$ |
| Inner bottom, floors and girders | Pressure on tank boundaries in double bottom | $p_{13} = 0{,}67\,(10\,h_p + \Delta\,p_{dyn})$<br>$p_{14} = 10\,h_s + p_0$ |
| | Minimum pressure | $p_{15} = 10\,T$ |

1) For ships with service restrictions the last term in $p_1$ may be reduced by the percentages given in Sec.4 B202.
2) $p_6$ and $p_{10}$ to be used in tanks/holds with largest breadth > 0,4 B.

Vamos a definir algunos parámetros:

-Hc: la distancia vertical en metros, desde el punto de la línea base hasta el extremo superior de la brazola.

-hp: la distancia horizontal en metros, desde el punto de cálculo hasta el extremo superior de la tubería de aireación.

-hs: distancia vertical en metros, desde el punto de cálculo a la parte superior del tanque.

-la densidad de nuestra carga es de 0.43 t/m$^3$.

$$p_9 = 0{,}43 \cdot (9{,}81 + 0{,}5 \cdot 3{,}1602) \cdot 30{,}032 = 147{,}09\ kN/m^2$$

Para calcular el valor de ϕ vamos a Pt. 3 Ch.1 Sec. 4 B400:

**B 400 Roll motion and acceleration**

**401** The roll angle (single amplitude) is given by:

$$\phi = \frac{50c}{B+75} \quad \text{(rad)}$$

c = (1,25 – 0,025 $T_R$) k
k = 1,2 for ships without bilge keel
= 1,0 for ships with bilge keel
= 0,8 for ships with active roll damping facilities
$T_R$ = as defined in 402, not to be taken greater than 30.

**402** The period of roll is generally given by:

$$T_R = \frac{2k_r}{\sqrt{GM}} \quad \text{(s)}$$

$k_r$ = roll radius of gyration in m
GM = metacentric height in m.

The values of $k_r$ and GM to be used are to give the minimum realistic value of $T_R$ for the load considered.
In case $k_r$ and GM have not been calculated for such condition, the following approximate design values may be used:

$k_r$ = 0,39 B for ships with even transverse distribution of mass
= 0,35 B for tankers in ballast
= 0,25 B for ships loaded with ore between longitudinal bulkheads
GM = 0,07 B in general
= 0,12 B for tankers and bulk carriers.

Tenemos:

$$T_R = \frac{2 \cdot 0{,}35 \cdot 43{,}2}{\sqrt{0{,}12 \cdot 43{,}2}} = 13{,}28\ s$$

$$\phi = \frac{50 \cdot (1{,}25 - 0{,}025 \cdot 13{,}28) \cdot 1}{43{,}2 + 75} = 0{,}3883\ rad$$

$$p_{10} = 0{,}43 \cdot 9{,}81\left[0{,}67 \cdot (30{,}032 + 0{,}3883 \cdot 38{,}2) - 0{,}12 \cdot \sqrt{32{,}032 \cdot 0{,}3883 \cdot 19{,}836}\right] = 118{,}85\ kN/m^2$$

$$p_{11} = 0{,}67 \cdot (0{,}43 \cdot 9{,}81 \cdot 32{,}792 + 25) = 109{,}43\ kN/m^2$$

$$p_{12} = 0{,}43 \cdot 9{,}81 \cdot 30{,}032 + 25 = 151{,}68\ kN/m^2$$

$$p_{13} = 0{,}67 \cdot (10 \cdot 32{,}792 + 25) = 236{,}46\ kN/m^2$$

$$p_{15} = 10 \cdot 12{,}84 = 128{,}4\ kN/m^2$$

Cogemos el mayor valor de la presión, p = p13 = 236,46 kN/m²

$$ka = \left(1{,}1 - 0{,}25\frac{1}{0{,}925 \cdot 3}\right)^2 = 1{,}02$$

**C 400 Inner bottom plating**

**401** The thickness requirement corresponding to lateral pressure is given by:

$$t = \frac{15,8k_a s\sqrt{p}}{\sqrt{\sigma}} + t_k \quad \text{(mm)}$$

$$t_{req} = \frac{15{,}8 \cdot 1{,}02 \cdot 1 \cdot \sqrt{236{,}46}}{\sqrt{140 \cdot 1}} + 1{,}5 = 22{,}44\ mm. \rightarrow 23\ mm.$$

**402** The thickness is not to be less than:

$$t = t_0 + \frac{0,03L_1}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

$t_0$ = 7,0 in holds below dry cargo hatchway opening if ceiling is not fitted.
= 6,0 elsewhere in holds if ceiling is not fitted
= 5,0 in general if ceiling is fitted.
= 5,0 in void spaces, machinery spaces and tanks.

$$t_{mín} = 5 + \frac{0{,}03 \cdot 266{,}08}{\sqrt{1}} + 1{,}5 = 14{,}48\ mm. \rightarrow 15\ mm.$$

El doble fondo tendrá un espesor de 23 mm.

## C800 Longitudinales del doble fondo

**C 800 Inner bottom longitudinals**

**801** The section modulus requirement is given by:

$$Z = \frac{83\, l^2 s\, p\, w_k}{\sigma} \quad (\text{cm}^3)$$

Utilizaremos la tabla de B201. Los valores de las presiones están calculados en el apartado anterior. Cogemos el valor de la mayor presión. P = p13 = 236,46 kN/m².

$$wk = 1 + 0{,}06 \cdot 1{,}5 = 1{,}09$$

$$\sigma = 225 \cdot 1 - 130 \cdot f_{2b} - 0{,}7 \cdot \sigma_{db} = 225 \cdot 1 - 130 \cdot 0{,}8312 - 0{,}7 \cdot 50 \cdot 1 = 81{,}94$$

**802** The thickness of web and flange is not to be less than the larger of:

$$t = 5,0 + \frac{k}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

$$Z = \frac{83 \cdot 2{,}775^2 \cdot 1 \cdot 236{,}46 \cdot 1{,}09}{81{,}94} = 2010{,}44\ cm^3$$

$$t_{mín} = 5{,}0 + \frac{5}{1} + 1{,}5 = 11{,}5\ mm. \rightarrow 12\ mm.$$

Los refuerzos del doble fondo y de la tolva interior del tanque tendrán estas características.

El siguiente perfil es el que mejor se ajusta

| | |
|---|---|
| Wx ($cm^3$) | 2036 |
| A ($cm^2$) | 103 |
| P (kg/m) | 80,6 |
| Width (mm) | 430 |
| Thickness (mm) | 17 |
| Inercia ($cm^4$) | 18860 |

**C500 Vagras del fondo**

**C 500 Plating in double bottom floors and longitudinal girders**

**501** The thickness requirement of floors and longitudinal girders forming boundaries of double bottom tanks is given by:

$$t = \frac{15.8\, k_a s \sqrt{p}}{\sqrt{\sigma}} + t_k \quad \text{(mm)}$$

p = $p_{13}$ to $p_{15}$ (when relevant) as given in Table B1
p = $p_1$ for sea chest boundaries (including top and partial bulkheads)
$\sigma$ = allowable stress, for longitudinal girders within 0,4L given by:

| *Transversely stiffened* | *Longitudinally stiffened* |
|---|---|
| $190 f_1 - 120 f_{2b}$, maximum $130 f_1$ | $130 f_1$ |

$\sigma$ = $160 f_1$ within 0,1L from the perpendiculars and for floors in general
= $120 f_1$ for sea chest boundaries (including top and partial bulkheads)

Para nuestro caso utilizaremos 130 · f1 = 130 N/mm².

$$ka = \left(1{,}1 - 0{,}25 \cdot \frac{3}{0{,}925 \cdot 3}\right)^2 = 0{,}6884$$

P0 = 25 kN/m²

Calculamos p13, p14 y p15

-hp: distancia vertical en metros, desde el punto de cálculo hasta el extremo superior de la tubería de aireación.

-hs: distancia vertical en metros, desde el punto de cálculo a la parte superior del tanque.

-Para tanques de lastre cogemos Δpdyn = 25 kN/m² (Pt. 3 Ch. 1 Sec. 4 C300)

**Guidance note:**
If the pressure drop according to Pt.4 Ch.6 Sec.4 K201 is not available, $p_{dyn}$ may normally be taken as 25 kN/m², for ballast tanks and zero for other tanks. If arrangements for the prevention of overpumping of ballast tanks in accordance with Pt.4 Ch.6 Sec.4 K200 are fitted, $p_{dyn}$ may be taken as zero.

$$p_{13} = 0{,}67 \cdot \left(10h_p + \Delta p_{dyn}\right) = 0{,}67 \cdot (10 \cdot 25{,}81 + 25) = 189{,}68\ kN/m^2$$

$$p_{14} = 10 \cdot 25{,}05 + 25 = 275{,}5\ kN/m^2$$

$$p_{15} = 10 \cdot 12{,}84 = 128{,}4\ kN/m^2$$

Nos quedamos con el mayor valor, p = p14 = 275,5 kN/m².

$$t_{req} = \frac{15{,}8 \cdot 0{,}6884 \cdot \sqrt{275{,}5}}{\sqrt{130}} + 1{,}5 = 17{,}34\ mm. \rightarrow 18\ mm.$$

**502** The thickness of longitudinal girders, floors, supporting plates and brackets is not to be less than:

$$t = 6{,}0 + \frac{k}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

k = 0,04 $L_1$ for centre girder up to 2 m above keel plate
= 0,02 $L_1$ for other girders and remaining part of centre girder
= 0.05 $L_1$ for sea chest boundaries (including top and partial bulkheads).

Sustituyendo, tenemos:

$$t_{mín} = \frac{6 + 0{,}04 \cdot 266{,}08}{\sqrt{1}} + 1{,}5 = 18{,}14\ mm. \rightarrow 19\ mm.$$

Por tanto, las vagras no estancas tendrán un espesor de 19 mm.

**Varenga**

**Pt. 3 Ch. 1 Sec. 6**

Cálculo del módulo

$$Z = \frac{100\, l^2\, s\, p\, w_k}{\sigma} \quad (cm^3)$$

Nos quedamos con el mayor valor, p = p14 = 275,5 kN/m².

σ = 160

$$Z = 4010{,}67\ cm^3$$

El espesor:

$$t = 5.0 + \frac{k}{\sqrt{f_1}} + t_k \quad (mm)$$

$$t = 5 + \frac{0{,}02 \cdot 266{,}08}{\sqrt{1}} + 1{,}5 = 11{,}82\ mm. \rightarrow 12\ mm.$$

**Pt. 3 Ch. 1 Sec. 9**

**C101 Vagra estanca doble fondo**

**C 100 Bulkhead plating**

**101** The thickness requirement corresponding to lateral pressure is given by:

$$t = \frac{15.8 k_a s \sqrt{p}}{\sqrt{\sigma}} + t_k \quad (mm)$$

p = $p_1 - p_9$, whichever is relevant, as given in Table B1

σ = 160 $f_1$ for longitudinally stiffened longitudinal bulkhead plating at neutral axis irrespective of ship length

= 140 $f_1$ for transversely stiffened longitudinal bulkhead plating at neutral axis within 0.4 L amidships, may however be taken as 160 $f_1$ when $p_6$ or $p_7$ are used.

El valor más desfavorable de la presión lo obtenemos de p9:

$$p_9 = 1{,}025 \cdot (9{,}81 + 0{,}5 \cdot 3{,}1602) \cdot 25{,}81 = 301{,}33\ kN/m^2$$

$$ka = \left(1{,}1 - 0{,}25 \frac{0{,}625}{0{,}925 \cdot 3}\right)^2 = 1{,}09$$

$$t = \frac{15{,}8 \cdot 1{,}09 \cdot 0{,}625 \cdot \sqrt{301{,}33}}{\sqrt{140 \cdot 1}} + 1{,}5 = 17{,}29\ mm. \rightarrow 18\ mm.$$

Tomaremos un espesor de 18 mm.

**C900 Refuerzos de la vagra estanca**

**C 900 Stiffening of double bottom floors and girders**

**901** The section modulus requirement of stiffeners on floors and longitudinal girders forming boundary of double bottom tanks is given by:

$$Z = \frac{100\, l^2 s\, p\, w_k}{\sigma} \quad (cm^3)$$

Utilizaremos la tabla de B201. Los valores de las presiones están calculados en el apartado anterior. Cogemos el valor de la mayor presión. P = p9 = 301,33 kN/m².

$$wk = 1 + 0{,}06 \cdot 1{,}5 = 1{,}09$$

$$\sigma = 225 \cdot 1 - 110 \cdot f_{2b} = 225 \cdot 1 - 110 \cdot 0{,}831 = 133{,}59\ N/mm^2$$

$$Z = \frac{100 \cdot 2{,}775^2 \cdot 0{,}833 \cdot 301{,}33 \cdot 1{,}09}{133{,}59} = 1577{,}12\ cm^3$$

Escogemos el siguiente perfil:

| | |
|---|---|
| Wx (cm³) | 1580 |
| A (cm²) | 81,4 |
| P (kg/m) | 63,9 |
| Width (mm) | 400 |
| Thickness (mm) | 14 |
| Inercia (cm⁴) | 12930 |

**Pt. 3 Ch.1 Sec. 7**

**Costado**

**C 100 Side plating, general**

**101** The thickness requirement corresponding to lateral pressure is given by:

$$t = \frac{15{,}8 k_a\, s \sqrt{p}}{\sqrt{\sigma}} + t_k \quad (mm)$$

B.101

**Table B1 Design loads**

| *Load type* | | *P (kN/m²)* |
|---|---|---|
| External | Sea pressure below summer load waterline | $p_1 = 10\,h_0 + p_{dp}$ 1) |
| | Sea pressure above summer load waterline | $p_2 = (p_{dp} - (4 + 0{,}2\,k_s)\,h_0)$ 1) <br> minimum $6{,}25 + 0{,}025\,L_1$ |
| Internal | Ballast, bunker or liquid cargo in side tanks in general | $p_3 = \rho\,(g_0 + 0{,}5\,a_v)\,h_s - 10\,h_b$ <br> $p_4 = \rho\,g_0\,h_s - 10\,h_b + p_o$ <br> $p_5 = 0{,}67\,(\rho\,g_0\,h_p + \Delta p_{dyn} - 10\,h_b)$ |
| | Above the ballast waterline at ballast, bunker or liquid cargo tanks with a breadth > 0,4 B | $p_6 = \rho g_0[0,67(h_s + \phi b) - 0,12\sqrt{H \phi b_t}]$ |
| | Above the ballast waterline and towards ends of tanks for ballast, bunker or liquid cargo with length > 0,15 L | $p_7 = \rho g_0[0,67(h_s + \theta l) - 0,12\sqrt{H \theta\, l_t}]$ |
| | In tanks with no restriction on their filling height 2) | $p_8 = \rho\left[3 - \frac{B}{100}\right]b_b$ |

1) For ships with service restrictions, $p_2$ and the last term in $p_1$ may be reduced by the percentages given in Sec.4 B202.
2) For tanks with free breadth $b_s$ > 0,56 B the design pressure will be specially considered according to Sec.4 C305.

C.102

**102** The thickness is not for any region of the ship to be less than:

$$t = 5,0 + \frac{k\,L_1}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

Definimos algunos parámetros:

-y: distancia horizontal en metros, desde la línea de crujía al punto de cálculo considerado.

-z: distancia vertical en metros, desde la línea base al punto de cálculo considerado

-hb: distancia vertical en metros, desde el punto de cálculo al mínimo calado de diseño:

2 + 0,02·L = 2 + 0,02·266,08 = 7,32 m. (para este tipo de buques). Para puntos de carga por encima del calado en lastre, hb = 0.

-hs: distancia vertical en metros, desde la línea de flotación al calado T, hasta el punto de cálculo.

$$p_{dp} = 29{,}484 + 135 \cdot \frac{21{,}6}{43{,}2 + 75} - 1{,}2 \cdot (12{,}84 - 12{,}84) = 54{,}15\ kN/m^2$$

P0 = 25 kN/m²

$$p_1 = 10 \cdot 1{,}2 + 54{,}15 = 66{,}1\ kN/m^2$$

$$p_3 = 1{,}025 \cdot (9{,}81 + 0{,}5 \cdot 3{,}1602) \cdot 12{,}26 - 10 \cdot 0 = 143{,}13\ kN/m^2$$

$$p_4 = 1{,}025 \cdot 9{,}81 \cdot 12{,}26 - 10 \cdot 0 + 25 = 148{,}27\ kN/m^2$$

$$p_5 = 0{,}67 \cdot (1{,}025 \cdot 9{,}81 \cdot 13{,}02 + 25) - 10 \cdot 0 = 104{,}46\ kN/m^2$$

Cogemos p = p4 = 148,27 kN/m²

La separación entre longitudinales es s = 0,8 m.

$$ka = \left(1{,}1 - 0{,}25\frac{0{,}625}{0{,}925 \cdot 3}\right)^2 = 1{,}09$$

Tomamos σ = 140·f1 = 140 N/mm²

$$t_{req} = \frac{15{,}8 \cdot 1{,}09 \cdot 0{,}8 \cdot \sqrt{148{,}27}}{\sqrt{140}} + 2{,}5 = 16{,}67\ mm. \rightarrow t = 17\ mm.$$

$$t_{mín} = 5 + \frac{0{,}01 \cdot 266{,}08}{\sqrt{1}} + 2{,}5 = 10{,}16\ mm. \rightarrow t = 11\ mm.$$

**C300 Longitudinales de costado**

**C 300 Longitudinals**

**301** The section modulus requirement is given by:

$$Z = \frac{83\ l^2 s\ p\ w_k}{\sigma} \quad (cm^3),\ \text{minimum } 15\ cm^3$$

σ = allowable stress (maximum 160 $f_1$) given by:

Within 0,4 L amidships:

$$\sigma = 225 f_1 - 130 f_2 \frac{z_n - z_a}{z_n}$$

**302** The thickness of web and flange is not to be less than the larger of

$$t = 5{,}0 + \frac{k}{\sqrt{f_1}} + t_k \quad (mm)$$

$$= \frac{h}{g} + t_k$$

k = 0,01 $L_1$ in general

$$wk = 1 + 0{,}06 \cdot 1{,}5 = 1{,}09$$

$$t_{mín} = 5 + \frac{0{,}01 \cdot 266{,}08}{\sqrt{1}} + 2{,}5 = 10{,}16\ mm. \rightarrow t = 11\ mm.$$

Para el valor de la presión (p) cogeremos p = p4 = 148,27 kN/m²

Para el valor σ tomaremos el valor máximo, ya que no conocemos zn y za, σ = 160 N/mm².

$$Z = \frac{83 \cdot 2{,}775^2 \cdot 0{,}8 \cdot 148{,}27 \cdot 1{,}09}{160} = 645{,}60\ cm^3$$

Las características del perfil son las siguientes:

| | |
|---|---|
| Wx ($cm^3$) | 671 |
| A ($cm^2$) | 46,7 |
| P (kg/m) | 36,7 |
| Width (mm) | 300 |
| Thickness (mm) | 11 |
| Inercia ($cm^4$) | 4190 |

**Bulárcama**

**Pt. 3 Ch. 1 Sec. 7**

Calculamos el módulo:

The section modulus requirement is given by:

$$Z = \frac{C\, l^2\, s\, p\, w_k}{f_1}$$

Para el valor de la presión (p) cogeremos p = p4 = 148,27 kN/$m^2$ (costado)

$$Z = 1362{,}42\ cm^3$$

El espesor viene dado por la siguiente fórmula:

**302** The thickness of web and flange shall not be less than the larger of

$$t = 5.0 + \frac{k}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

$$t_{mín} = 5 + \frac{0{,}01 \cdot 266{,}08}{\sqrt{1}} + 2{,}5 = 10{,}16\ mm. \rightarrow t = 11\ mm.$$

**Pt. 3 Ch. 1 Sec. 9**

**C101 Doble casco**

**101** The thickness requirement corresponding to lateral pressure is given by:

$$t = \frac{15.8 k_a s \sqrt{p}}{\sqrt{\sigma}} + t_k \quad \text{(mm)}$$

B.101

| **Table B1 Design loads** | | | |
|---|---|---|---|
| *Structure* | | *Load type* | *p (kN/m²)* |
| Watertight bulkheads | | Sea pressure when flooded or general dry cargo minimum | $p_1 = 10\, h_b$ |
| Cargo hold bulkheads | | Dry bulk cargo | $p_2 = \rho_c (g_0 + 0.5\, a_v)\, K\, h_c$ |
| Tank bulkheads in general | | Ballast, bunker or liquid cargo | $p_3 = \rho (g_0 + 0.5\, a_v)\, h_s$ <br> $p_4 = 0.67\, (\rho\, g_0\, h_p + \Delta\, p_{dyn})$ <br> $p_5 = \rho\, g_0\, h_s + p_0$ |
| Longitudinal bulk-heads as well as transverse bulkheads at sides in wide tanks | In tanks with breadth > 0.4 B | | $p_6 = \rho g_0 [0,67(h_s + \phi b) - 0,12 \sqrt{H \phi b_t}]$ |
| | Note 1) | | $p_7 = \rho \left[3 - \frac{B}{100}\right] b_b$ |
| Transverse bulkheads and longitudinal bulkheads at ends in long tanks | In tanks with length > 0.15 L | | $p_8 = \rho g_0 [0,67(h_s + \theta l) - 0,12 \sqrt{H \theta l_t}]$ |
| | Note 2) | | $p_9 = \rho \left[4 - \frac{L}{200}\right] l_b$ |
| Longitudinal wash bulkheads | | | $p_7 = \rho \left[3 - \frac{B}{100}\right] b_b$ |
| Transverse wash bulkheads | | | $p_9 = \rho \left[4 - \frac{L}{200}\right] l_b$ |

C.102

**102** The thickness shall not be less than:

$$t = 5.0 + \frac{k\, L_1}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

k = 0.03 for longitudinal bulkheads except double skin bulkheads in way of cargo oil tanks and ballast tanks in liquid cargo tank areas
= 0.02 in peak tanks and for transverse and double skin longitudinal bulkheads in way of cargo oil tanks and ballast tanks in liquid cargo tank areas
= 0.01 for other bulkheads.

Definimos algunos parámetros:

-hp: distancia vertical en metros, desde el punto de cálculo hasta la tubería de ventilación.

-hs: distancia vertical en metros, desde el punto de cálculo a la parte superior del tanque.

-h0: distancia vertical en metros, desde la línea de flotación al calado T, hasta el punto de cálculo

p0 = 25 kN/m²

$$p_3 = 1{,}025 \cdot (9{,}81 + 0{,}5 \cdot 3{,}1602) \cdot 9{,}16 = 106{,}94\ \ kN/m^2$$

$$p_4 = 0{,}67 \cdot (1{,}025 \cdot 9{,}81 \cdot 13{,}02 + 25) - 10 \cdot 0 = 104{,}46\, kN/m^2$$

$$p_5 = 1{,}025 \cdot 9{,}81 \cdot 9{,}16 + 25 = 117{,}11\ kN/m^2$$

Se podrían calcular estos valores para el interior de la chapa que da al tanque de carga, pero no nos saldrían unos valores de la presión más alto, puesto que la densidad del gas natural licuado (0,43 t/m) es mucho menor que la del agua salada (1,025 t/m).

Tomamos el valor p = p5 = 117,11 kN/m²

La separación entre refuerzos en el doble casco es de 0,8 m.

$$ka = \left(1{,}1 - 0{,}25\frac{0{,}625}{0{,}925 \cdot 3}\right)^2 = 1{,}09$$

Tomamos σ = 140 · f1 = 140 N/mm²

$$t_{req} = \frac{15{,}8 \cdot 1{,}09 \cdot 0{,}8 \cdot \sqrt{117{,}11}}{\sqrt{140}} + 1{,}5 = 14{,}10 \rightarrow t = 15\ mm.$$

$$t_{mín} = 5 + \frac{0{,}01 \cdot 266{,}98}{\sqrt{1}} + 1{,}5 = 9{,}17 \rightarrow t = 10\ mm.$$

**C200 Longitudinales del doble casco**

**202** The web and flange thickness shall not be less than the larger of:

t = 4.5 + k + $t_k$ (mm)

k = 0.01 $L_1$ in general
= 0.015 $L_1$ in peak tanks and in cargo oil tanks and ballast tanks in cargo area

**201** The section modulus requirement for stiffeners and corrugations is given by:

$$Z = \frac{83\ l^2\ s\ p\ w_k}{\sigma} \quad (cm^3),\ \text{minimum } 15\ cm^3$$

p = $p_1 - p_9$, whichever is relevant, as given in Table B1

$\sigma$ = $225 f_1 - 130 f_2 \frac{z_n - z_a}{z_n}$, maximum 160 $f_1$

within 0.4 L amidships
= 160 $f_1$ within 0.1 L from perpendiculars.

$$t_{mín} = 4{,}5 + 0{,}01 \cdot 266{,}08 + 1{,}5 = 8{,}66 \rightarrow t = 9\ mm.$$

Para el valor de la presión (p) tomaremos el calculado para el costado, p = p5 = 117,11 kN/m²

$$wk = 1 + 0{,}06 \cdot 1{,}5 = 1{,}09$$

Para el valor σ tomaremos el valor máximo, ya que no conocemos zn y za, σ = 160 N/mm².

$$Z = \frac{83 \cdot 2{,}775^2 \cdot 0{,}8 \cdot 117{,}11 \cdot 1{,}09}{160} = 509{,}99\ cm^3$$

El perfil escogido tendrá las siguientes características:

| | |
|---|---|
| Wx ($cm^3$) | 566 |
| A ($cm^2$) | 42,6 |
| P (kg/m) | 33,5 |
| Width (mm) | 280 |
| Thickness (mm) | 11 |
| Inercia ($cm^4$) | 3330 |

**Pt. 3 Ch. 1 Sec. 7**

**D 100 Palmejares de costado**

**D 100 General**

**101** The thickness of web plates, flanges, brackets and stiffeners of girders is not to be less than:

$$t = 5{,}0 + \frac{k}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

k = 0,01 $L_1$ in general
= 0,02 $L_1$ for girder webs, flanges and brackets in cargo oil tanks and ballast tanks in cargo area
= 0,03 $L_1$ (= 6,0 maximum) for girder webs, flanges and brackets in peaks.

$$t_{mín} = 5{,}0 + \frac{0{,}02 \cdot 268{,}08}{\sqrt{1}} + 1{,}5 = 11{,}86\ mm = 12\ mm.$$

El espesor de los palmejares de costado será de 12 mm.

**Pt. 3 Ch. 1 Sec. 8**

**C100 Cubierta resistente (cubierta superior o principal)**

**C 100 Strength deck plating**

**101** The breadth of stringer plate and strakes in way of possible longitudinal bulkheads which are to be of grade B, D or E is not to be less than:

$$b = 800 + 5\,L \quad (mm),\ \text{maximum } 1800\ mm.$$

**102** The thickness requirement corresponding to lateral pressure is given by:

$$t = \frac{15,8 k_a s \sqrt{p}}{\sqrt{\sigma}} + t_k \qquad (mm)$$

**Table B1 Design loads**

| *Structure* | *Load type* | *p (kN/m²)* |
|---|---|---|
| Weather decks [1] | Sea pressure | $p_1 = a(p_{dp} - (4 + 0,2k_s)h_0)$ [2], minimum 5,0 |
| | Deck cargo | $p_2 = (g_0 + 0,5\,a_v)\,q$ |
| Cargo 'tweendecks | Deck cargo | $p_3 = \rho_c\,(g_0 + 0,5\,a_v)\,H_C$ |
| Platform deck in machinery spaces | Machinery and equipment | $p_4 = 1,6\,(g_0 + 0,5\,a_v)$ |
| Accommodation decks | Accommodation in general | $p_5 = 0,35\,(g_0 + 0,5\,a_v)$, see also Sec.4 C401 |
| Deck as tank bottom in general | Ballast, bunker or liquid cargo | $p_6 = \rho\,(g_0 + 0,5\,a_v)\,h_s$<br>$p_7 = 0,67\,(\rho\,g_0\,h_p + \Delta p_{dyn})$<br>$p_8 = \rho\,g_0\,h_s + p_0$ |
| Deck as tank top in general | | $p_7 = 0,67\,(\rho\,g_0\,h_p + \Delta p_{dyn})$<br>$p_8 = \rho\,g_0\,h_s + p_0$ |
| Deck as tank boundary in tanks with breadth > 0,4 B | | $p_9 = \rho g_0[0,67(h_s + \phi b) - 0,12\sqrt{H \phi b_t}]$ |
| Deck as tank boundary towards ends of tanks with length > 0,15 L | | $p_{10} = \rho g_0[0,67(h_s + \theta l) - 0,12\sqrt{H \theta l_t}]$ |
| Deck as tank boundary in tanks with breadth > 0,4 B [3] | | $p_{11} = \rho\left(3 - \frac{B}{100}\right) b_b$ |
| Deck as tank boundary in tanks with length > 0,1 L [4] | | $p_{12} = \rho\left(4 - \frac{L}{200}\right) l_b$ |
| Watertight decks submerged in damaged condition [5] | Sea pressure | $p_{13} = 10\,h_b$ |

1) On weather decks combination of the design pressures $p_1$ and $p_2$ may be required for deck cargo with design stowage height less than 2,3 m.
2) For ships with service restrictions $p_1$ may be reduced with the percentages given in Sec.4 B202. $C_W$ should not be reduced
3) To be used for strength members located less than 0,25 $b_b$ away from tank sides in tanks with no restrictions on their filling height. For tanks with free breadth (no longitudinal wash bulkheads) $b_b$ > 0,56 B the design pressure will be specially considered according to Sec.4 C305
4) To be used for strength members located less than 0,25 $l_b$ away from tank ends in tanks with no restrictions on their filling height. For tanks with free length (no transverse wash bulkheads or transverse web frames in narrow tanks) $l_b$ > 0,13 L the design pressure will be specially considered according to Sec.4 C305
5) The strength may be be calculated with allowable stresses for plating, stiffeners and girders increased by 60 $f_1$.

$$p_{dp} = 29{,}484 + 135 \cdot \frac{18{,}83}{43{,}2 + 75} - 1.2(12{,}84 - 12{,}84) = 51\ kN/m^2$$

$$p_1 = 0{,}8 \cdot (51 - (4 + 0{,}2 \cdot 2) \cdot 13{,}46) = -6{,}5792\ kN/m^2$$

$$p_7 = 0{,}67 \cdot (1{,}025 \cdot 9{,}81 \cdot 0{,}76 + 25) = 21{,}87\ kN/m^2$$

$$p_8 = 1{,}025 \cdot 9{,}81 \cdot 0 + 25 = 25\ kN/m^2$$

Según Pt. 3 Ch. 1 Sec. 4 B501:

$$\theta = 0,25 \cdot \frac{0,3579}{0,7777} = 0,115\ rad$$

$$p_{10} = 1,025 \cdot 9,81 \cdot \left[0,67 \cdot (0 + 0,115 \cdot 2,15) - 0,12 \cdot \sqrt{26,3 \cdot 0,115 \cdot 4,65}\right] = -3,1823\ kN/m^2$$

$$p_{12} = 1,025 \cdot \left(4 - \frac{266,08}{200}\right) \cdot 46,25 = 126,55\ kN/m^2$$

Cogemos p = p12 = 126,55 kN/m²

$$t_{requerido} = \frac{15,8 \cdot 1,02 \cdot 0,881 \cdot \sqrt{126,55}}{\sqrt{120 \cdot 1}} + 2,5 = 17,08\ mm. \rightarrow 18\ mm.$$

**104** The thickness is not to be less than:

$$t = t_0 + \frac{k\ L_1}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

$$t_{mín} = 5,5 + \frac{0,01 \cdot 266,08}{\sqrt{1}} + 2,5 = 10,66\ mm. \rightarrow 11\ mm.$$

El espesor de la cubierta superior será de 18 mm.

### C300 Longitudinales de cubierta superior

**C 300 Longitudinals**

**301** The section modulus requirement is given by:

$$Z = \frac{83\ l^2\ s\ p\ w_k}{\sigma} \quad (cm^3), \quad \text{minimum } 15\ cm^3$$

| Table C1 | |
|---|---|
| *Deck* | $\sigma$ |
| Strength deck, long superstructures and effective deckhouses above strength deck | $225\ f_1 - 130\ f_{2d}$, maximum $160\ f_1$ |
| Continuous decks below strength deck | $225 f_1 - 130 f_{2d} \frac{z_n - z_a}{z_n}$ maximum $160\ f_1$ |

Definiremos $Z_B$ como 1,2 veces $Z_0$. Por tanto: $Z_B$ =1,2·47681755 = 57218106 cm³.

$$f_{2b} = \frac{5{,}7 \cdot 8344307}{57218106} = 0{,}8312$$

$$\sigma = 225 \cdot 1 - 130 \cdot f_{2b} = 225 \cdot 1 - 130 \cdot 0{,}831 = 116{,}97\ N/mm^2$$

$$wk = 1 + 0{,}06 \cdot 1{,}5 = 1{,}09$$

Cogeremos el valor para p calculado en el apartado anterior (126,55 kN/m²).

$$Z = \frac{83 \cdot 2{,}775^2 \cdot 1 \cdot 126{,}55 \cdot 1{,}09}{116{,}97} = 753{,}73\ cm^3$$

**303** The web and flange thickness is not to be less than the larger of:

$$t = 5{,}0 + \frac{k}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

$$t_{mín} = 5 + \frac{0{,}01 \cdot 266{,}08}{\sqrt{1}} + 2{,}5 = 10{,}16\ mm. \rightarrow 11\ mm.$$

Los refuerzos longitudinales de la cubierta superior tendrán estas características.

| | |
|---|---|
| Wx (cm³) | 819 |
| A (cm²) | 54,2 |
| P (kg/m) | 42,5 |
| Width (mm) | 320 |
| Thickness (mm) | 12 |
| Inercia (cm⁴) | 5530 |

**Bao**

**Pt. 3 Ch. 1 Sec. 8**

Calculamos el módulo:

$$Z = \frac{0.63\, l^2\, s\, p\, w_k}{f_1} \quad (cm^3), \quad \text{minimum } 15\ cm^3$$

Cogemos p = p12 = 126,55 kN/m² (cubierta)

$$Z = 1857{,}03\ cm^3$$

El espesor:

$$t = 5.0 + \frac{k}{\sqrt{f_1}} + t_k \qquad \text{(mm)}$$

$$t_{mín} = 5 + \frac{0{,}01 \cdot 266{,}08}{\sqrt{1}} + 2{,}5 = 10{,}16\ mm. \rightarrow 11\ mm.$$

### C200 Cubierta de troncos

La separación entre refuerzos longitudinales es de 1 m.

**102** The thickness requirement corresponding to lateral pressure is given by:

$$t = \frac{15{,}8 k_a s \sqrt{p}}{\sqrt{\sigma}} + t_k \qquad \text{(mm)}$$

Valores de p, tabla B.1:

**Table B1 Design loads**

| *Structure* | *Load type* | *p (kN/m²)* |
|---|---|---|
| Weather decks [1)] | Sea pressure | $p_1 = a(p_{dp} - (4 + 0{,}2k_s)h_0)$ [2)], minimum 5,0 |
| | Deck cargo | $p_2 = (g_0 + 0{,}5\,a_v)\,q$ |
| Cargo 'tweendecks | Deck cargo | $p_3 = \rho_c\,(g_0 + 0{,}5\,a_v)\,H_C$ |
| Platform deck in machinery spaces | Machinery and equipment | $p_4 = 1{,}6\,(g_0 + 0{,}5\,a_v)$ |
| Accommodation decks | Accommodation in general | $p_5 = 0{,}35\,(g_0 + 0{,}5\,a_v)$, see also Sec.4 C401 |
| Deck as tank bottom in general | Ballast, bunker or liquid cargo | $p_6 = \rho\,(g_0 + 0{,}5\,a_v)\,h_s$<br>$p_7 = 0{,}67\,(\rho\,g_0\,h_p + \Delta p_{dyn})$<br>$p_8 = \rho\,g_0\,h_s + p_0$ |
| Deck as tank top in general | | $p_7 = 0{,}67\,(\rho\,g_0\,h_p + \Delta p_{dyn})$<br>$p_8 = \rho\,g_0\,h_s + p_0$ |
| Deck as tank boundary in tanks with breadth > 0,4 B | | $p_9 = \rho g_0[0{,}67(h_s + \phi b) - 0{,}12\sqrt{H\phi b_t}]$ |
| Deck as tank boundary towards ends of tanks with length > 0,15 L | | $p_{10} = \rho g_0[0{,}67(h_s + \theta l) - 0{,}12\sqrt{H\theta l_t}]$ |
| Deck as tank boundary in tanks with breadth > 0,4 B [3)] | | $p_{11} = \rho\left(3 - \frac{B}{100}\right) b_b$ |
| Deck as tank boundary in tanks with length > 0,1 L [4)] | | $p_{12} = \rho\left(4 - \frac{L}{200}\right) l_b$ |
| Watertight decks submerged in damaged condition [5)] | Sea pressure | $p_{13} = 10\,h_b$ |

1) On weather decks combination of the design pressures $p_1$ and $p_2$ may be required for deck cargo with design stowage height less than 2,3 m.

2) For ships with service restrictions $p_1$ may be reduced with the percentages given in Sec.4 B202. $C_W$ should not be reduced

3) To be used for strength members located less than 0,25 $b_b$ away from tank sides in tanks with no restrictions on their filling height. For tanks with free breadth (no longitudinal wash bulkheads) $b_b$ > 0,56 B the design pressure will be specially considered according to Sec.4 C305

4) To be used for strength members located less than 0,25 $l_b$ away from tank ends in tanks with no restrictions on their filling height. For tanks with free length (no transverse wash bulkheads or transverse web frames in narrow tanks) $l_b$ > 0,13 L the design pressure will be specially considered according to Sec.4 C305

5) The strength may be be calculated with allowable stresses for plating, stiffeners and girders increased by 60 $f_1$.

$$p_{dp} = 29{,}484 + 135 \cdot \frac{9{,}55}{43{,}2 + 75} - 1.2(12{,}84 - 12{,}84) = 40{,}39\ kN/m^2$$

$$p_1 = 0{,}8 \cdot (40{,}39 - (4 + 0{,}2 \cdot 2) \cdot 21{,}692 = -44{,}04\ kN/^2$$

$$p_7 = 0{,}67 \cdot (1{,}025 \cdot 9{,}81 \cdot 0{,}76 + 25) = 21{,}87\ kN/m^2$$

$$p_8 = 1{,}025 \cdot 9{,}81 \cdot 0 + 25 = 25\ kN/m^2$$

Tenemos que φ = 0,389

$$p_9 = 1{,}025 \cdot 9{,}81 \cdot ((0{,}67 \cdot (0 + 0{,}389 \cdot 36{,}1) - 0{,}12 \cdot \sqrt{8{,}232 \cdot 0{,}389 \cdot 19{,}836)} = 84{,}99\ kN/m^2$$

Tenemos que θ = 0,115

$$p_{10} = 1{,}025 \cdot 9{,}81 \cdot (0{,}67 \cdot (0 + 0{,}132 \cdot 11{,}07) - 0{,}12 \cdot \sqrt{8{,}232 \cdot 0{,}132 \cdot 46{,}25)} = 1{,}29\ kN/m^2$$

$$p_{11} = 1{,}025 \cdot \left(3 - \frac{43{,}2}{100}\right)$$

$$p_{12} = 1{,}025 \cdot \left(4 - \frac{266{,}08}{200}\right) \cdot 46{,}25 = 126{,}55\ kN/m^2$$

Tenemos que p = p12 = 126,55 kN/m²

$$ka = \left(1{,}1 - 0{,}25 \frac{0{,}625}{0{,}925 \cdot 3}\right)^2 = 1{,}09$$

$$t_{req} = \frac{15{,}8 \cdot 1{,}09 \cdot 1 \cdot \sqrt{126{,}55}}{\sqrt{160}} + 2{,}5 = 17{,}82 \rightarrow t = 18\ mm.$$

**202** The thickness of steel decks is not to be less than:

$$t = t_0 + \frac{k L_1}{\sqrt{f_1}} + t_k \qquad (mm)$$

$$t_{mín} = 5{,}0 + \frac{0{,}01 \cdot 266{,}08}{\sqrt{1}} + 2{,}5 = 10{,}16 \rightarrow t = 11\ mm.$$

**C300 Longitudinales de la cubierta de troncos**

**C 300 Longitudinals**

**301** The section modulus requirement is given by:

$$Z = \frac{83\ l^2 s\ p\ w_k}{\sigma} \quad (cm^3), \quad \text{minimum } 15\ cm^3$$

Tenemos que p = p12 = 126,55 kN/m²

$$\sigma = 225 \cdot 1 - 130 \cdot f_{2b} = 225 \cdot 1 - 130 \cdot 0{,}831 = 116{,}97\ N/mm^2$$

$$wk = 1 + 0{,}06 \cdot 1{,}5 = 1{,}09$$

$$Z = \frac{83 \cdot 2{,}775^2 \cdot 1 \cdot 126{,}55 \cdot 1{,}09}{116{,}97} = 753{,}73\ cm^3$$

**303** The web and flange thickness is not to be less than the larger of:

$$t = 5,0 + \frac{k}{\sqrt{f_1}} + t_k \qquad (mm)$$

$$t_{mín} = 5{,}0 + \frac{0{,}01 \cdot 266{,}08}{\sqrt{1}} + 2{,}5 = 10{,}16 \rightarrow t = 11\ mm.$$

El perfil que escogemos será el siguiente:

| | |
|---|---|
| Wx (cm³) | 819 |
| A (cm²) | 54,2 |
| P (kg/m) | 42,5 |
| Width (mm) | 320 |
| Thickness (mm) | 12 |
| Inercia (cm⁴) | 5530 |

**C100 Forro superior del tanque de carga (cubierta interior)**

La separación entre refuerzos es de 1 m.

**102** The thickness requirement corresponding to lateral pressure is given by:

$$t = \frac{15,8 k_a s \sqrt{p}}{\sqrt{\sigma}} + t_k \qquad (mm)$$

$$p_{dp} = 29{,}484 + 135 \cdot \frac{9{,}55}{43{,}2 + 75} - 1.2(12{,}84 - 12{,}84) = 40{,}39\ kN/m^2$$

$$p_6 = 1{,}025 \cdot (9{,}81 + 0{,}5 \cdot 3{,}1602) \cdot 2 = 23{,}34\ kN/m^2$$

$$p_7 = 0{,}67 \cdot (1{,}025 \cdot 9{,}81 \cdot 2{,}76 + 25) = 35{,}34\ kN/m^2$$

$$p_8 = 1{,}025 \cdot 9{,}81 \cdot 2 + 25 = 45{,}09\ kN/m^2$$

Ahora tomamos la densidad del gas (0,43 t/m³)

$$p_7 = 0{,}67 \cdot (0{,}43 \cdot 9{,}81 \cdot 2{,}76 + 25) = 24{,}55\ kN/m^2$$

$$p_8 = 0,43 \cdot 9,81 \cdot 2 + 25 = 33,43\ kN/m^2$$

φ = 0,389 rad

$$p_9 = 0,43 \cdot 9,81 \cdot \left(0,67 \cdot (0 + 0,389 \cdot 38,2) - 0,12 \cdot \sqrt{30,032 \cdot 0,389 \cdot 19,836}\right) = 34,29\ kN/m^2$$

θ = 0,132 rad

$$p_{10} = 0,43 \cdot 9,81 \cdot \left(0,67 \cdot (0 + 0,132 \cdot 11,07) - 0,12 \cdot \sqrt{30,032 \cdot 0,389 \cdot 46,25}\right) = -11,34\ kN/m^2$$

$$p_{11} = 0,43 \cdot \left(3 - \frac{43,2}{100}\right) \cdot 19,836 = 21,90\ kN/m^2$$

$$p_{12} = 0,43 \cdot \left(4 - \frac{266,08}{200}\right) \cdot 46,25 = 53,09\ kN/m^2$$

Nos quedamos con el valor de p = p12 = 53,09 kN/m²

$$ka = \left(1,1 - 0,25\frac{0,625}{0,925 \cdot 3}\right)^2 = 1,09$$

$$t_{req} = \frac{15,8 \cdot 1,02 \cdot 1 \cdot \sqrt{53,09}}{\sqrt{160 \cdot 1}} + 1,5 = 10,78 \rightarrow t = 11\ mm.$$

**202** The thickness of steel decks is not to be less than:

$$t = t_0 + \frac{k\,L_1}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

$$t_{mín} = 5 + \frac{0,01 \cdot 266,08}{\sqrt{1}} + 1,5 = 9,16 \rightarrow t = 10\ mm.$$

**C300 Longitudinales forro superior del tanque de carga (cubierta interior)**

**C 300 Longitudinals**

**301** The section modulus requirement is given by:

$$Z = \frac{83\, l^2\, s\, p\, w_k}{\sigma} \quad (\text{cm}^3),\quad \text{minimum } 15\ \text{cm}^3$$

Tomamos la presión p = p12 = 53,09

$$Z = \frac{83 \cdot 2,775^2 \cdot 1 \cdot 53,09 \cdot 1,09}{116,97} = 316,20\ cm^3$$

**303** The web and flange thickness is not to be less than the larger of:

$$t = 5,0 + \frac{k}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

$$t_{mín} = 5 + \frac{0{,}01 \cdot 266{,}08}{\sqrt{1}} + 1{,}5 = 9{,}16 \rightarrow t = 10\ mm.$$

Las características del perfil escogido son:

| | |
|---|---|
| Wx ($cm^3$) | 323 |
| A ($cm^2$) | 32,3 |
| P (kg/m) | 25,4 |
| Width (mm) | 220 |
| Thickness (mm) | 11,5 |
| Inercia ($cm^4$) | 1550 |

**D100 Vagras de la cubierta superior**

**Pt. 3 Ch. 1 Sec. 8**

**D 100 General**

**101** The thickness of web plates, flanges, brackets and stiffeners of girders is not to be less than:

$$t = 5,0 + \frac{k}{\sqrt{f_1}} + t_k \quad \text{(mm)}$$

k = 0,01 $L_1$ in general
= 0,02 $L_1$ for girder webs, flanges and brackets in cargo oil tanks and ballast tanks in cargo area
= 0,03 $L_1$ (= 6,0 maximum) for girder webs, flanges and brackets in peaks.

$$t_{mín} = 5 + \frac{0{,}02 \cdot 266{,}08}{\sqrt{1}} + 1{,}5 = 11{,}82\ mm. \rightarrow 12\ mm.$$

Las vagras de la cubierta superior tendrán un espesor de 12 mm.

**Bao**

**Pt. 3 Ch. 1 Sec. 8**

Calculamos el módulo:

$$Z = \frac{0.63\, l^2\, s\, p\, w_k}{f_1} \quad (cm^3), \quad \text{minimum } 15\ cm^3$$

Cogemos p = p12 = 126,55 kN/m² (cubierta)

$$Z = \frac{0{,}63 \cdot 2{,}775^2 \cdot 1 \cdot 126{,}55 \cdot 1{,}09}{1} = 669{,}20\ cm^3$$

El espesor:

$$t = 5.0 + \frac{k}{\sqrt{f_1}} + t_k \quad (mm)$$

$$t_{mín} = 5 + \frac{0{,}01 \cdot 266{,}08}{\sqrt{1}} + 2{,}5 = 10{,}16\ mm. \rightarrow 11\ mm.$$

Resumen de escantillonado:

| ELEMENTO | ESPESOR MÍNIMO (mm) | ESPESOR REQUERIDO (mm) | MÓDULO DNV (cm³) | REFUERZO |
|---|---|---|---|---|
| **QUILLA PLANA** | - | **23** | - | - |
| **FONDO Y PANTOQUE** | 16 | **25** | - | - |
| LONG. FONDO Y PANTOQUE | 12 | - | 2036 | 430x17 |
| **DOBLE FONDO** | 15 | **23** | | |
| LONGITUDINALES DOBLE FONDO | 12 | - | 2036 | 430x17 |
| **VAGRAS DEL FONDO** | **19** | 18 | - | - |
| **VAGRA ESTANCA DOBLE FONDO** | - | **19** | - | - |
| LONG. VAGRA ESTACANCA DF | 12 | - | 1580 | 400x14 |
| **COSTADO** | 11 | **17** | - | - |
| LONGITUDINALES COSTADO | 11 | - | 671 | 300x11 |
| **DOBLE CASCO** | 10 | **15** | - | - |
| LONGITUDINALES DOBLE CASCO | 9 | | 566 | 280x11 |
| **CUBIERTA RESISTENTE O SUPERIOR** | 11 | **18** | - | - |
| LONG. CUBIERTA SUPERIOR | 11 | - | 819 | 320x12 |
| **CUBIERTA TRONCO** | 11 | **18** | - | - |
| LONGITUDINALES CUB. TRONCO | 11 | | 819 | 320x12 |
| **FORRO SUP. TANQUE CARGA** | 10 | **11** | | |
| LONG. FORRO SUP. TANQUE CARG. | 10 | | 323 | 220x11,5 |
| **VAGRAS CUBIERTA SUPERIOR** | 12 | - | - | - |
| **PALMEJARES DE COSTADO** | 12 | - | - | - |

**Cálculo de la bulárcama de los tanques de carga (tolva inferior)**

Aunque no contribuyen a la resistencia longitudinal, vamos a calcular la bulárcama de la parte inclinada de los tanques de carga.

Pt. 3 Ch. 1 Sec. 7 C302

Calculamos el espesor mediante la siguiente expresión:

**302** The thickness of web and flange shall not be less than the larger of

$$t = 4.5 + k + t_k \text{ (mm)}$$

$$= 1.5 + \frac{h_w \sqrt{f_1}}{g} + t_k$$

$k = 0.01\ L_1$ in general
$= 0.015\ L_1$ in peaks and in cargo oil tanks and ballast tanks in cargo area

$$t = 4{,}5 + 0{,}01 \cdot 266{,}08 + 2{,}5 = 9{,}6608 \rightarrow t = 10\ mm.$$

Pt. 3 Ch. 1 Sec. 6 C601

Ahora vamos a proceder a calcular el módulo de la sección.

**601** The section modulus requirement of bottom and inner bottom frames is given by:

$$Z = \frac{0.63\, l^2 s\, p\, w_k}{f_1} \quad (cm^3)$$

$p = p_1$ to $p_{15}$ (when relevant) as given in Table B1.

Calcularemos ahora las presiones p13 y p14, que son las más desfavorables en este caso.

$$p_{13} = 0{,}67 \cdot 10 \cdot h_p + \Delta_{p_{dyn}} = 0{,}67 \cdot 10 \cdot 29{,}6524 + 25 = 223{,}67\ kN/m^2$$

$$p_{14} = \rho \cdot g \cdot h_s + p_0 = 0{,}43 \cdot 9{,}81 \cdot 26{,}8924 + 25 = 138{,}48\ kN/m^2$$

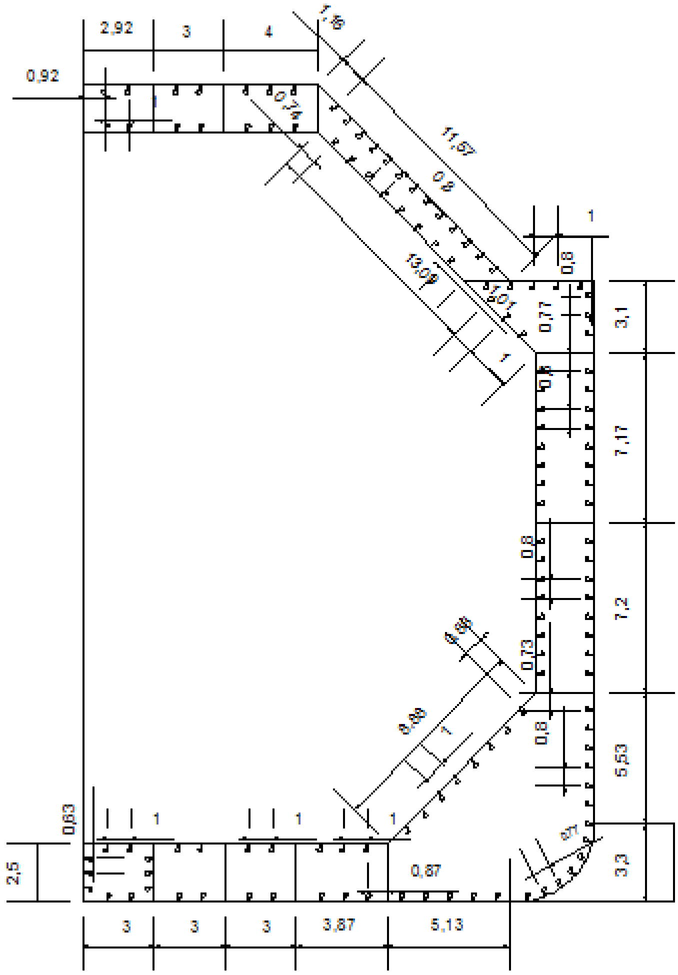
Por tanto:

$$Z = \frac{0{,}63 \cdot 8{,}88^2 \cdot 2{,}775 \cdot 223{,}67 \cdot 1{,}09}{1} = 33.609{,}62\ cm^3$$

**4-CÁLCULO DEL MÓDULO RESISTENTE DE LA CUADERNA MAESTRA**

Para realizar el cálculo del módulo de la cuaderna maestra, debemos tener en cuenta todos los elementos que contribuyen a la resistencia longitudinal.

Los escantillones y características los hemos calculado en el apartado anterior. A continuación, podemos ver un esquema de la cuaderna maestra a escala real.



El módulo e inercia mínimos los calculamos en el siguiente apartado, pero mostramos los datos finales a continuación para su comprobación una vez realizado el cálculo:

Inercia mínima (DNV)

$$I = 38.061.020.642\ cm^4$$

Cambiando las unidades tenemos:

$$I = 3.806.102{,}0642\ cm^2 \cdot m^2$$

Módulo mínimo (DNV)

$$Z_0 = 47.681.755\ cm^3 = 476.818\ cm^2 \cdot m$$

A la hora de realizar el cálculo de la altura equivalente y la posición del centro de gravedad del pantoque, utilizaremos una expresión para buques sin astilla muerta y con un ángulo de pantoque de 90º.

$$y_G = 0{,}3634 \cdot R = 1{,}254\ m.$$

Donde:

R: radio de pantoque (3,45 m.)

$$h_{ef} = 1{,}066 \cdot \left(R + \frac{e}{2}\right) = 3{,}691\ m.$$

Donde:

R: radio de pantoque (3,45 m.)

e: espesor de pantoque (0,025 m.)

La longitud de la curva de pantoque desarrollada es:

$$l_{pantoque} = \frac{\pi}{2} \cdot R = 5{,}4192\ m.$$

La inercia propia de los elementos se calcula mediante la siguiente expresión:

$$I_{propia} = \frac{A \cdot h_{eq}}{12}$$

Donde:

A: área (cm²)

heq: altura equivalente (m.)

En cuanto a la inercia propia de los refuerzos, ésta se calcula consultando el catálogo de perfiles anexado y aplicando la expresión:

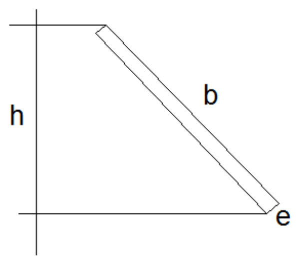
$$I_{propia} = I_x \cdot cos\alpha$$

Donde:

Ix: inercia propia del refuerzo según el catálogo de perfiles (cm⁴)

$\alpha$: ángulo que forma el refuerzo con el eje vertical (°).

La altura equivalente representa la proyección vertical de los elementos que forman la cuaderna maestra.




En el caso de las chapas, la altura equivalente se obtiene midiendo directamente la proyección vertical de la chapa sobre el plano

En el caso de los refuerzos, el cálculo se realiza a la inversa. Es decir, una vez que tenemos el valor de la inercia propia del refuerzo, despejamos el valor de la altura equivalente de la fórmula anterior.

La posición del centro de gravedad de las chapas se encuentra en el centro geométrico de la chapa más la altura que haya hasta la línea base. Para los refuerzos se consulta el catálogo en el caso de que sean paralelos a la línea de crujía.

A continuación procedemos a realizar los cálculos:

| | **b** (cm) | **h** (cm) | **Nº** | **A** (cm²) | **yG** (m) | **A·yG** (cm²·m) | **A·yG²** (cm²·m²) | **heq** (m) | **Ipropia** (cm⁴) | **Ipropia** (cm²·m²) |
|---|---|---|---|---|---|---|---|---|---|---|
| **QUILLA** | 213,5 | 2,3 | 1 | 491,050 | 0,012 | 5,647 | 0,065 | 0,023 | 216,471 | 0,022 |
| **FONDO** | 1800 | 2,5 | 1 | 4500,000 | 0,013 | 56,250 | 0,703 | 0,023 | 1983,750 | 0,198 |
| LONGITUDINALES FONDO | 430x17 | | 15 | 1545,000 | 0,292 | 451,140 | 131,733 | 0,469 | 282837,601 | 28,284 |
| **PANTOQUE** | 541,92 | 2,5 | 1 | 1354,800 | 1,254 | 1698,919 | 2130,445 | 3,691 | 15380910,049 | 1538,091 |
| LONGITUDINAL PANTOQUE 1 | 430x17 | | 1 | 103,000 | 0,038 | 3,945 | 0,151 | 0,466 | 18639,223 | 1,864 |
| LONGITUDINAL PANTOQUE 2 | 430x17 | | 1 | 103,000 | 0,246 | 25,297 | 6,213 | 0,438 | 16466,610 | 1,647 |
| LONGITUDINAL PANTOQUE 3 | 430x17 | | 1 | 103,000 | 0,616 | 63,407 | 39,033 | 0,410 | 14428,583 | 1,443 |
| LONGITUDINAL PANTOQUE 4 | 430x17 | | 1 | 103,000 | 1,131 | 116,452 | 131,660 | 0,387 | 12855,173 | 1,286 |
| LONGITUDINAL PANTOQUE 5 | 430x17 | | 1 | 103,000 | 1,769 | 182,186 | 322,251 | 0,350 | 10514,583 | 1,051 |
| LONGITUDINAL PANTOQUE 6 | 430x17 | | 1 | 103,000 | 2,490 | 256,439 | 638,456 | 0,325 | 9066,146 | 0,907 |
| **VAGRAS FONDO** | 1,9 | 250 | 3 | 1425,000 | 1,250 | 1781,250 | 2226,563 | 2,500 | 7421875,000 | 742,188 |
| **VAGRA ESTANCA FONDO** | 1,9 | 250 | 1 | 475,000 | 1,250 | 593,750 | 742,188 | 2,500 | 2473958,333 | 247,396 |
| REFUERZO VAGRA ESTANCA 1 | 400x14 | | 1 | 81,400 | 0,625 | 50,875 | 31,797 | 0,000 | 0,000 | 0,000 |
| REFUERZO VAGRA ESTANCA 2 | 400x14 | | 1 | 81,400 | 1,250 | 101,750 | 127,188 | 0,000 | 0,000 | 0,000 |
| REFUERZO VAGRA ESTANCA 3 | 400x14 | | 1 | 81,400 | 1,875 | 152,625 | 286,172 | 0,000 | 0,000 | 0,000 |
| **DOBLE FONDO** | 1286,8 | 2,3 | 1 | 2959,640 | 2,489 | 7365,064 | 18327,962 | 0,023 | 1304,708 | 0,130 |
| LONGITUDINALES DOBLE FONDO | 430x17 | | 9 | 927,000 | 2,231 | 2068,137 | 4614,014 | 0,469 | 169702,561 | 16,970 |
| **COSTADO** | 1,7 | 2300 | 1 | 3910,000 | 14,800 | 57868,000 | 856446,400 | 23,000 | 1723658333,333 | 172365,833 |
| LONGITUDINAL COSTADO 1 | 300x11 | | 1 | 46,700 | 3,300 | 154,110 | 508,563 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 2 | 300x11 | | 1 | 46,700 | 4,100 | 191,470 | 785,027 | 0,000 | 0,000 | 0,000 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| LONGITUDINAL COSTADO 3 | 300x11 | 1 | 46,700 | 4,900 | 228,830 | 1121,267 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 4 | 300x11 | 1 | 46,700 | 5,700 | 266,190 | 1517,283 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 5 | 300x11 | 1 | 46,700 | 6,500 | 303,550 | 1973,075 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 6 | 300x11 | 1 | 46,700 | 7,300 | 340,910 | 2488,643 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 7 | 300x11 | 1 | 46,700 | 8,100 | 378,270 | 3063,987 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 8 | 300x11 | 1 | 46,700 | 9,632 | 449,814 | 4332,612 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 9 | 300x11 | 1 | 46,700 | 10,432 | 487,174 | 5082,203 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 10 | 300x11 | 1 | 46,700 | 11,232 | 524,534 | 5891,570 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 11 | 300x11 | 1 | 46,700 | 12,032 | 561,894 | 6760,713 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 12 | 300x11 | 1 | 46,700 | 12,832 | 599,254 | 7689,632 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 13 | 300x11 | 1 | 46,700 | 13,632 | 636,614 | 8678,328 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 14 | 300x11 | 1 | 46,700 | 14,432 | 673,974 | 9726,799 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 15 | 300x11 | 1 | 46,700 | 15,232 | 711,334 | 10835,046 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 16 | 300x11 | 1 | 46,700 | 16,832 | 786,054 | 13230,868 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 17 | 300x11 | 1 | 46,700 | 17,632 | 823,414 | 14518,443 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 18 | 300x11 | 1 | 46,700 | 18,432 | 860,774 | 15865,794 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 19 | 300x11 | 1 | 46,700 | 19,232 | 898,134 | 17272,921 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 20 | 300x11 | 1 | 46,700 | 20,032 | 935,494 | 18739,824 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 21 | 300x11 | 1 | 46,700 | 20,832 | 972,854 | 20266,503 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 22 | 300x11 | 1 | 46,700 | 21,632 | 1010,214 | 21852,958 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 23 | 300x11 | 1 | 46,700 | 22,432 | 1047,574 | 23499,189 | 0,000 | 0,000 | 0,000 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LONGITUDINAL COSTADO 24 | 300x11 | | 1 | 46,700 | 24,000 | 1120,800 | 26899,200 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 25 | 300x11 | | 1 | 46,700 | 24,800 | 1158,160 | 28722,368 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL COSTADO 26 | 300x11 | | 1 | 46,700 | 25,600 | 1195,520 | 30605,312 | 0,000 | 0,000 | 0,000 |
| **DOBLE CASCO** | 1,5 | 1437 | 1 | 2155,200 | 16,060 | 34612,512 | 555876,943 | 14,368 | 370765205,504 | 37076,521 |
| LONGITUDINAL DOBLE CASCO 1 | 280x11 | | 1 | 42,600 | 9,632 | 410,323 | 3952,233 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 2 | 280x11 | | 1 | 42,600 | 10,432 | 444,403 | 4636,014 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 3 | 280x11 | | 1 | 42,600 | 11,232 | 478,483 | 5374,323 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 4 | 280x11 | | 1 | 42,600 | 12,032 | 512,563 | 6167,160 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 5 | 280x11 | | 1 | 42,600 | 12,832 | 546,643 | 7014,526 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 6 | 280x11 | | 1 | 42,600 | 13,632 | 580,723 | 7916,419 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 7 | 280x11 | | 1 | 42,600 | 14,432 | 614,803 | 8872,840 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 8 | 280x11 | | 1 | 42,600 | 15,232 | 648,883 | 9883,789 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 9 | 280x11 | | 1 | 42,600 | 16,832 | 717,043 | 12069,271 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 10 | 280x11 | | 1 | 42,600 | 17,632 | 751,123 | 13243,804 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 11 | 280x11 | | 1 | 42,600 | 18,432 | 785,203 | 14472,865 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 12 | 280x11 | | 1 | 42,600 | 19,232 | 819,283 | 15756,455 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 13 | 280x11 | | 1 | 42,600 | 20,032 | 853,363 | 17094,572 | 0,000 | 0,000 | 0,000 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LONGITUDINAL DOBLE CASCO 14 | 280x11 | | 1 | 42,600 | 20,832 | 887,443 | 18487,217 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 15 | 280x11 | | 1 | 42,600 | 21,632 | 921,523 | 19934,390 | 0,000 | 0,000 | 0,000 |
| LONGITUDINAL DOBLE CASCO 16 | 280x11 | | 1 | 42,600 | 22,432 | 955,603 | 21436,091 | 0,000 | 0,000 | 0,000 |
| **CUBIERTA SUPERIOR** | 555,02 | 1,8 | 1 | 999,036 | 26,282 | 26256,664 | 690077,647 | 0,018 | 269,740 | 0,027 |
| LONGITUDINALES CUBIERTA SUPERIOR | 320x12 | | 5 | 271,000 | 26,200 | 7100,065 | 186018,140 | 0,350 | 27664,583 | 2,766 |
| **CUBIERTA TRONCO** | 991,8 | 1,8 | 1 | 1785,240 | 34,523 | 61631,841 | 2127716,030 | 0,018 | 482,015 | 0,048 |
| LONGITUDINALES CUBIERTA TRONCO | 320x12 | | 7 | 379,400 | 34,331 | 13025,181 | 447167,503 | 0,350 | 38730,417 | 3,873 |
| **FORRO SUPERIOR TANQUE CARGA** | 991,8 | 1,1 | 1 | 1090,980 | 32,521 | 35479,761 | 1153837,294 | 0,011 | 110,007 | 0,011 |
| LONGITUDINALES FORRO SUPERIOR | 220x11,5 | | 7 | 226,100 | 32,663 | 7385,104 | 241219,662 | 0,240 | 10852,800 | 1,085 |
| **VAGRAS CUBIERTA SUPERIOR** | 1,2 | 200 | 3 | 720,000 | 33,532 | 24143,040 | 809564,417 | 2,000 | 2400000,000 | 240,000 |
| **PALMEJAR DE COSTADO 1** | 250 | 1,2 | 1 | 300,000 | 8,826 | 2647,800 | 23369,483 | 0,012 | 36,000 | 0,004 |
| **PALMEJAR DE COSTADO 2** | 250 | 1,2 | 1 | 300,000 | 16,030 | 4808,940 | 77086,346 | 0,012 | 36,000 | 0,004 |
| **PALMEJAR DE COSTADO 3** | 250 | 1,2 | 1 | 300,000 | 23,194 | 6958,200 | 161388,491 | 0,012 | 36,000 | 0,004 |
| **FORRO SUPERIOR TANQ CARGA INCLIN.** | 1309 | 1,1 | 1 | 1439,900 | 27,866 | 40124,253 | 1118102,445 | 9,332 | 104496211,615 | 10449,621 |
| LONG. FORRO SUP. T.C. INCLINADO 1 | 220x11,5 | | 1 | 32,300 | 23,556 | 760,872 | 17923,399 | 0,174 | 814,929 | 0,081 |
| LONG. FORRO SUP. T.C. INCLINADO 2 | 220x11,5 | | 1 | 32,300 | 23,911 | 772,337 | 18467,611 | 0,174 | 814,929 | 0,081 |
| LONG. FORRO SUP. T.C. INCLINADO 3 | 220x11,5 | | 1 | 32,300 | 24,269 | 783,887 | 19024,116 | 0,174 | 814,929 | 0,081 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LONG. FORRO SUP. T.C. INCLINADO 4 | 220x11,5 | | 1 | 32,300 | 25,107 | 810,942 | 20359,945 | 0,174 | 814,929 | 0,081 |
| LONG. FORRO SUP. T.C. INCLINADO 5 | 220x11,5 | | 1 | 32,300 | 25,463 | 822,445 | 20941,676 | 0,174 | 814,929 | 0,081 |
| LONG. FORRO SUP. T.C. INCLINADO 6 | 220x11,5 | | 1 | 32,300 | 25,813 | 833,760 | 21521,844 | 0,174 | 814,929 | 0,081 |
| LONG. FORRO SUP. T.C. INCLINADO 7 | 220x11,5 | | 1 | 32,300 | 26,174 | 845,430 | 22128,536 | 0,174 | 814,929 | 0,081 |
| LONG. FORRO SUP. T.C. INCLINADO 8 | 220x11,5 | | 1 | 32,300 | 26,532 | 856,967 | 22736,632 | 0,174 | 814,929 | 0,081 |
| LONG. FORRO SUP. T.C. INCLINADO 9 | 220x11,5 | | 1 | 32,300 | 26,887 | 868,445 | 23349,757 | 0,174 | 814,929 | 0,081 |
| LONG. FORRO SUP. T.C. INCLINADO 10 | 220x11,5 | | 1 | 32,300 | 27,243 | 879,949 | 23972,448 | 0,174 | 814,929 | 0,081 |
| LONG. FORRO SUP. T.C. INCLINADO 11 | 220x11,5 | | 1 | 32,300 | 27,602 | 891,533 | 24607,790 | 0,174 | 814,929 | 0,081 |
| **DOBLE FONDO TRAMO INCLINADO** | 888 | 2,3 | 1 | 2042,400 | 5,666 | 11572,238 | 65568,303 | 6,332 | 68240369,248 | 6824,037 |
| LONG. DOBLE FONDO TRAM. INCL. 1 | 430x17 | | 1 | 103,000 | 2,854 | 293,952 | 838,909 | 0,340 | 9922,333 | 0,992 |
| LONG. DOBLE FONDO TRAM. INCL. 2 | 430x17 | | 1 | 103,000 | 3,207 | 330,342 | 1059,472 | 0,340 | 9922,333 | 0,992 |
| LONG. DOBLE FONDO TRAM. INCL. 3 | 430x17 | | 1 | 103,000 | 3,566 | 367,339 | 1310,079 | 0,340 | 9922,333 | 0,992 |
| LONG. DOBLE FONDO TRAM. INCL. 4 | 430x17 | | 1 | 103,000 | 3,924 | 404,136 | 1585,688 | 0,340 | 9922,333 | 0,992 |
| LONG. DOBLE FONDO TRAM. INCL. 5 | 430x17 | | 1 | 103,000 | 4,281 | 440,979 | 1887,986 | 0,340 | 9922,333 | 0,992 |
| LONG. DOBLE FONDO TRAM. INCL. 6 | 430x17 | | 1 | 103,000 | 4,638 | 477,693 | 2215,446 | 0,340 | 9922,333 | 0,992 |
| LONG. DOBLE FONDO TRAM. INCL. 7 | 430x17 | | 1 | 103,000 | 4,991 | 514,104 | 2566,047 | 0,340 | 9922,333 | 0,992 |
| LONG. DOBLE FONDO TRAM. INCL. 8 | 430x17 | | 1 | 103,000 | 5,351 | 551,117 | 2948,834 | 0,340 | 9922,333 | 0,992 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **CUBIERTA TRONCO TRAMO INCLINADO** | 1157 | 1,8 | 1 | 2082,600 | 30,416 | 63344,362 | 1926682,102 | 8,232 | 117607587,552 | 11760,759 |
| LONG. CUB. TRONCO TRAMO INCL. 1 | 320x12 | | 1 | 54,200 | 26,584 | 1440,874 | 38304,784 | 0,254 | 2913,973 | 0,291 |
| LONG. CUB. TRONCO TRAMO INCL. 2 | 320x12 | | 1 | 54,200 | 26,869 | 1456,292 | 39128,882 | 0,254 | 2913,973 | 0,291 |
| LONG. CUB. TRONCO TRAMO INCL. 3 | 320x12 | | 1 | 54,200 | 27,153 | 1471,712 | 39961,899 | 0,254 | 2913,973 | 0,291 |
| LONG. CUB. TRONCO TRAMO INCL. 4 | 320x12 | | 1 | 54,200 | 27,438 | 1487,131 | 40803,690 | 0,254 | 2913,973 | 0,291 |
| LONG. CUB. TRONCO TRAMO INCL. 5 | 320x12 | | 1 | 54,200 | 27,724 | 1502,614 | 41657,711 | 0,254 | 2913,973 | 0,291 |
| LONG. CUB. TRONCO TRAMO INCL. 6 | 320x12 | | 1 | 54,200 | 28,008 | 1518,009 | 42515,719 | 0,254 | 2913,973 | 0,291 |
| LONG. CUB. TRONCO TRAMO INCL. 7 | 320x12 | | 1 | 54,200 | 28,292 | 1533,416 | 43383,086 | 0,254 | 2913,973 | 0,291 |
| LONG. CUB. TRONCO TRAMO INCL. 8 | 320x12 | | 1 | 54,200 | 28,577 | 1548,873 | 44262,155 | 0,254 | 2913,973 | 0,291 |
| LONG. CUB. TRONCO TRAMO INCL. 9 | 320x12 | | 1 | 54,200 | 28,862 | 1564,312 | 45148,946 | 0,254 | 2913,973 | 0,291 |
| LONG. CUB. TRONCO TRAMO INCL. 10 | 320x12 | | 1 | 54,200 | 29,146 | 1579,708 | 46042,005 | 0,254 | 2913,973 | 0,291 |
| LONG. CUB. TRONCO TRAMO INCL. 11 | 320x12 | | 1 | 54,200 | 29,431 | 1595,136 | 46945,724 | 0,254 | 2913,973 | 0,291 |
| LONG. CUB. TRONCO TRAMO INCL. 12 | 320x12 | | 1 | 54,200 | 29,714 | 1610,518 | 47855,489 | 0,254 | 2913,973 | 0,291 |
| LONG. CUB. TRONCO TRAMO INCL. 13 | 320x12 | | 1 | 54,200 | 29,999 | 1625,949 | 48776,911 | 0,254 | 2913,973 | 0,291 |
| | | | | **36321,246** | | **472616,197** | **11772351,109** | | | **241318,691** |

Calculamos la línea neutra:

$$Y_G = \frac{\sum A \cdot y_G}{\sum A} = \frac{472616}{36221{,}246} = 13{,}01\ m.$$

Para la determinación del momento de inercia, se tendrán en cuenta todos los momentos de inercia de cada elemento de la cuaderna, los cuales tenemos que trasladar por Steiner a la línea neutra:

$$\frac{I}{2} = I_0 + \sum A \cdot {y_G}^2 - A \cdot d^2 = 241318{,}691 + 11772351{,}109 - 13{,}01^2$$
$$= 5863933{,}909\ cm^2 \cdot m^2$$

Por tanto, I o IG respecto a la línea neutra:

$$I_G = 5863933{,}909 \cdot 2 = 11727867{,}82\ cm^2 \cdot m^2$$

Cálculo del módulo

*Módulo en cubierta*

$$W_C = \frac{I_G}{Y_G} = \frac{11727867{,}8}{13{,}01} = 901304\ m \cdot cm^2$$

*Módulo en fondo*

$$W_C = \frac{I_G}{D - Y_G} = \frac{11727867{,}8}{26{,}3 - 13{,}01} = 888475\ m \cdot cm^2$$

Como se puede observar en el siguiente cuadro, cumplimos sobradamente tanto con la inercia, como con el módulo requerido por el DNV, en fondo y en cubierta.

| | Wfondo (m·cm²) | Wcubierta (m·cm²) | Inercia (cm²·m²) |
|---|---|---|---|
| **Ofrecido** | 888485 | 901304 | 11727868 |
| **Requerido** | 476818 | 476818 | 3806103 |

## 5-MOMENTOS FLECTORES, FUERZAS CORTANTES, MÓDULO E INERCIA

### Solicitaciones en aguas tranquilas por reglamento

Según el DNV Pt. 3 Ch. 1 Sec. 5 B105:

**105** The design values of stillwater shear forces along the length of the ship are normally not to be taken less than:

$$Q_S = k_{sq} Q_{SO} \quad \text{(kN)}$$

$$Q_{SO} = 5\frac{M_{SO}}{L} \quad \text{(kN)}$$

$M_{SO}$ = design stillwater bending moments (sagging or hogging) given in 103.

**103** The design stillwater bending moments amidships (sagging and hogging) are normally not to be taken less than:

$$M_S = M_{SO} \quad \text{(kNm)}$$

$M_{SO}$ = $-0{,}065\, C_{WU}\, L^2\, B\, (C_B + 0{,}7)$ (kNm) in sagging
= $C_{WU}\, L^2\, B\, (0{,}1225 - 0{,}015\, C_B)$ (kNm) in hogging

$C_{WU}$ = $C_W$ for unrestricted service.

En arrufo:

$$M_{SO} = -0.065 C_{WU} L^2 B (C_B + 0.7)$$

En quebranto:

$$M_{SO} = C_{WU} L^2 B (0.1225 - 0.015 C_B)$$

Donde:

$k_{sq}$ = 0 at A.P. and F.P.
= 1,0 between 0,15 L and 0,3 L from A.P.
= 0,8 between 0,4 L and 0,6 L from A.P.
= 1,0 between 0,7 L and 0,85 L from A.P.

$$M_S = k_{sm} M_{SO} \quad \text{(kNm)}$$

$M_{SO}$ = as given in 103
$k_{sm}$ = 1,0 within 0,4 L amidships
= 0,15 at 0,1 L from A.P. or F.P.
= 0,0 at A.P. and F.P.

Y para hallar Cw vamos a Pt. 4 Ch. 1 Sec. 4 B 201:

**B 200 Basic parameters**

**201** The acceleration, sea pressures and hull girder loads have been related to a wave coefficient as given in Table B1.

| **Table B1 Wave coefficient $C_W$** | |
|---|---|
| *L* | $C_W$ |
| $L \leq 100$ | 0,0792 L |
| $100 < L < 300$ | $10,75 - [(300-L)/100]^{3/2}$ |
| $300 \leq L \leq 350$ | 10,75 |
| $L > 350$ | $10,75 - [(L-350)/150]^{3/2}$ |

$$Cw = 10{,}75 - \left[\frac{300 - L}{100}\right]^{3/2} = 10{,}55$$

Cwu = Cw, por tanto, tendremos:

$$M_{SO}(arrufo) = -3.099.377\ kN \cdot m$$

$$M_{SO}(quebranto) = 3.576.314\ kN \cdot m$$

$$Q_{SO}\ (arrufo) = -58.242\ kN$$

$$Q_{SO}(quebranto) = 67.204\ kN$$

**Cálculo de solicitaciones por ola**

Momentos flectores

Según el reglamento Pt. 3 Ch. 1 Sec 5 B201 y B203.

**201** The rule vertical wave bending moments amidships are given by:

$$M_W = M_{WO}\quad (kNm)$$

$M_{WO}$ = $-0{,}11\ \alpha C_W L^2 B (C_B + 0{,}7)$ (kNm) in sagging
= $0{,}19\ \alpha C_W L^2 B C_B$ (kNm) in hogging
$\alpha$ = 1,0 for seagoing conditions
= 0,5 for harbour and sheltered water conditions (enclosed fjords, lakes, rivers).

**203** The rule values of vertical wave shear forces along the length of the ship are given by:

Positive shear force, to be used when positive still water shear force:

$$Q_{WP} = 0{,}3\ \beta k_{wqp} C_W L B (C_B + 0{,}7)\quad (kN)$$

Negative shear force, to be used when negative still water shear force:

$$Q_{WN} = -0{,}3\ \beta k_{wqn} C_W L B (C_B + 0{,}7)\quad (kN)$$

Positive shear force when there is a surplus of buoyancy forward of section considered, see also Fig. 1.

Negative shear force when there is a surplus of weight forward of section considered.

$\beta$ = 1,0 for seagoing conditions
= 0,5 for harbour and sheltered water conditions (enclosed fjords, lakes, rivers)
$k_{wqp}$ = 0 at A.P. and F.P.
= $1{,}59\ C_B/(C_B + 0{,}7)$ between 0,2 L and 0,3 L from A.P.
= 0,7 between 0,4 L and 0,6 L from A.P.
= 1,0 between 0,7 L and 0,85 L from A.P.
$k_{wqn}$ = 0 at A.P. and F.P.
= 0,92 between 0,2 L and 0,3 L from A.P.
= 0,7 between 0,4 L and 0,6 L from A.P.
= $1{,}73\ C_B/(C_B + 0{,}7)$ between 0,7 L and 0,85 L from A.P.
$C_W$ = as given in 201.

$$M_{WO}(arrufo) = -5.244.930\ kN \cdot m$$

$$M_{WO}(quebranto) = 4.767.892\ kN \cdot m$$

<u>Fuerzas cortantes</u>

Según Pt. 3 Ch. 1 Sec. 5 B203:

$$Q_{WP} = 37.632\ kN$$
$$Q_{WN} = -37.632\ kN$$

**Módulo e inercia de la cuaderna maestra**

El módulo mínimo de la maestra según Pt. 3 Ch. 1 Sec. 5 C302

**302** The midship section modulus about the transverse neutral axis is not to be less than:

$$Z_O = \frac{C_{WO}}{f_1} L^2 B (C_B + 0,7) \quad (cm^3)$$

El módulo requerido e según según Pt. 3 Ch. 1 Sec. 5 C303

**303** The section modulus requirements about the transverse neutral axis based on cargo and ballast conditions are given by:

$$Z_O = \frac{|M_S + M_W|}{\sigma_l} 10^3 \quad (cm^3)$$

$\sigma_l$ = 175 $f_1$ N/mm$^2$ within 0,4 L amidship
= 125 $f_1$ N/mm$^2$ within 0,1 L from A.P. or F.P.

Between specified positions $\sigma_l$ is to be varied linearly.

La inercia mínima según Pt. 3 Ch. 1 Sec. 5 C401

**C 400 Moment of inertia**

**401** The midship section moment of inertia about the transverse neutral axis is not to be less than:

$$I = 3\, C_W L^3 B (C_B + 0,7) \quad (cm^4)$$

Por tanto, tendremos que:

$$I = 38.061.020.642\ cm^4$$

Cambiando las unidades tenemos:

$$I = 3.806.102{,}0642\ cm^2 \cdot m^2$$

Para nuestros cálculos Ms = Mso y Mw = Mwo, así que el módulo requerido será:

$$Z_0 = \frac{|Mso + Mwo|}{175 \cdot 1} \cdot 10^3 = 47.681.755\ cm^3 = 476.818\ cm^2 \cdot m$$

La ecuación la podemos ver en la imagen superior, siendo f1 igual a 1.

## 6-RESISTENCIA LONGITUDINAL

Anteriormente hemos calculado por reglamento los máximos momentos flectores y fuerzas cortantes de nuestro buque en aguas tranquilas y por olas.

En el software Maxsurf, calculamos para cada una de nuestras condiciones de carga la resistencia longitudinal en el módulo “Longitudinal Strengh”, de manera que obtenemos los momentos flectores y fuerzas cortantes de cada una de nuestras condiciones de carga. Todos los datos de las mismas se adjuntan en el repot anexado. Podemos ver que en cada una de las condiciones, cumplimos con los máximos momentos flectores y fuerzas cortantes.

Vamos a aportar un resumen de cada una de ellas y posteriormente vemos las gráficas de resistencia longitudinal.

Condición de carga 1: Salida de puerto a plena carga

| CC1 | | % | Peso (t) |
|---|---|---|---|
| Rosca | | | 36.704 |
| Carga | | 97 | 63691,917 |
| Consumos | | | |
| | Fuel Alm. (2x) | 97 | 6257,31 |
| | Fuel Sed. (2x) | 100 | 293,768 |
| | Fuel UD (2x) | 100 | 192,796 |
| | Diesel (2x) | 100 | 767,59 |
| | Aceite (2x) | 100 | 98,834 |
| | Agua dulce (2x) | 100 | 154,472 |
| | Aguas gr. | 0 | 0 |
| | Lodos | 0 | 0 |
| Lastre | | 0 | |
| Víveres | | 100 | 4,375 |
| Pesos fijos | | | 105,25 |
| TOTAL Δ | | | 108.270 |

Condición de carga 2: Salida de puerto en lastre

| CC2 | | % | Peso (t) |
|---|---|---|---|
| Rosca | | | 36.704 |
| Carga | | 0 | 0 |
| Consumos | | | |
| | Fuel Alm. (2x) | 97 | 6257,31 |
| | Fuel Sed. (2x) | 100 | 293,768 |
| | Fuel UD (2x) | 100 | 191,796 |
| | Diesel (2x) | 100 | 767,59 |
| | Aceite (2x) | 100 | 98,834 |
| | Agua dulce (2x) | 100 | 154,472 |
| | Aguas gr. | 0 | 0 |
| | Lodos | 0 | 0 |
| Lastre | | 100 | 48364,661 |
| Víveres | | 100 | 4,375 |
| Pesos fijos | | | 105,25 |
| TOTAL Δ | | | 92.942 |

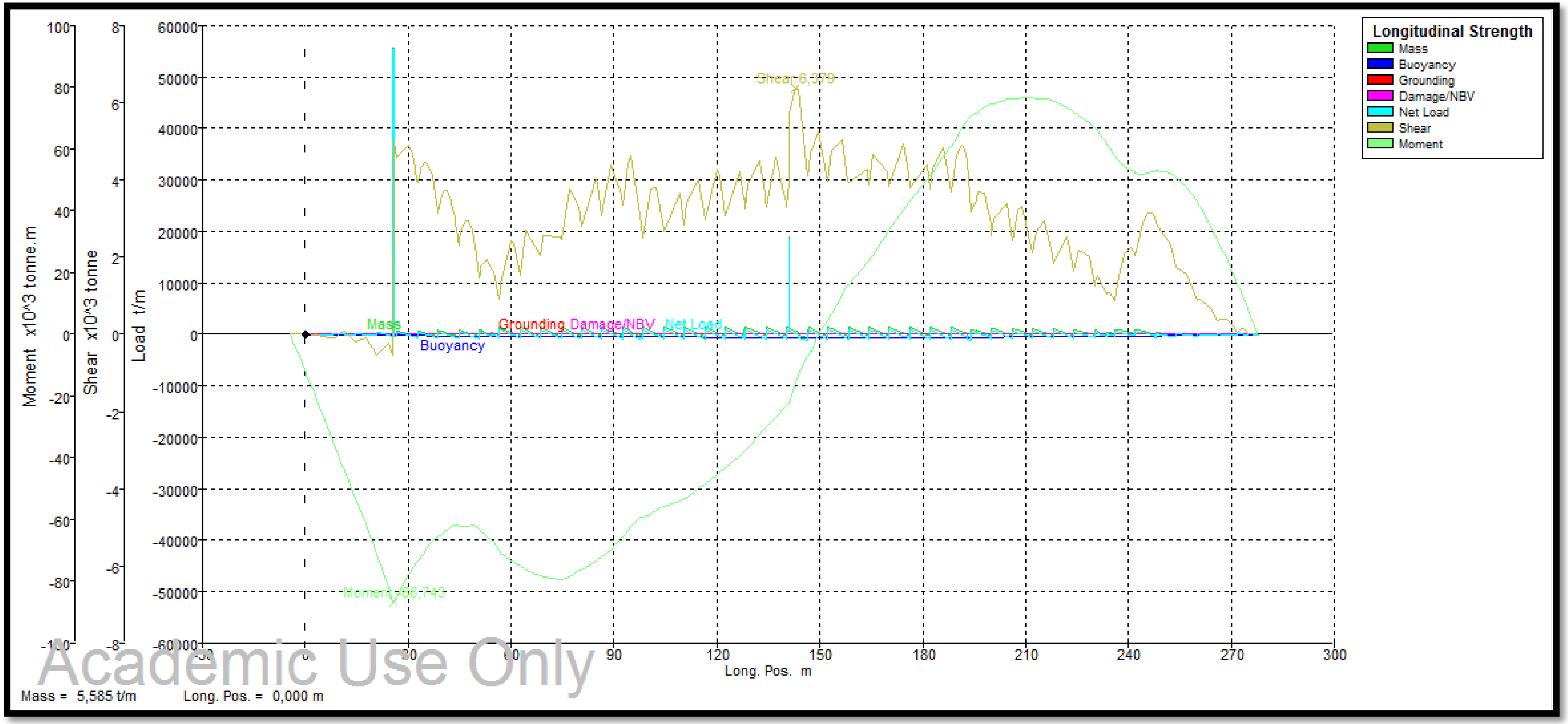
Condición de carga 3: Llegada a puerto a plena carga

| CC3 | | % | Peso (t) |
|---|---|---|---|
| Rosca | | | 36.704 |
| Carga | | 97 | 63691,923 |
| Consumos | | | |
| | Fuel Alm. (2x) | 3,52 | 227,714 |
| | Fuel Sed. (2x) | 100 | 293,768 |
| | Fuel UD (2x) | 100 | 192,796 |
| | Diesel (2x) | 10 (5+5) | 38,38 |
| | Aceite (2x) | 10 (5+5) | 4,942 |
| | Agua dulce (2x) | 10 (5+5) | 7,724 |
| | Aguas gr. | 100 | 247,326 |
| | Lodos | 100 | 110,858 |
| Lastre | | 0 | |
| Víveres | | 10 | 0,4375 |
| Pesos fijos | | | 105,25 |
| TOTAL Δ | | | 101.625 |

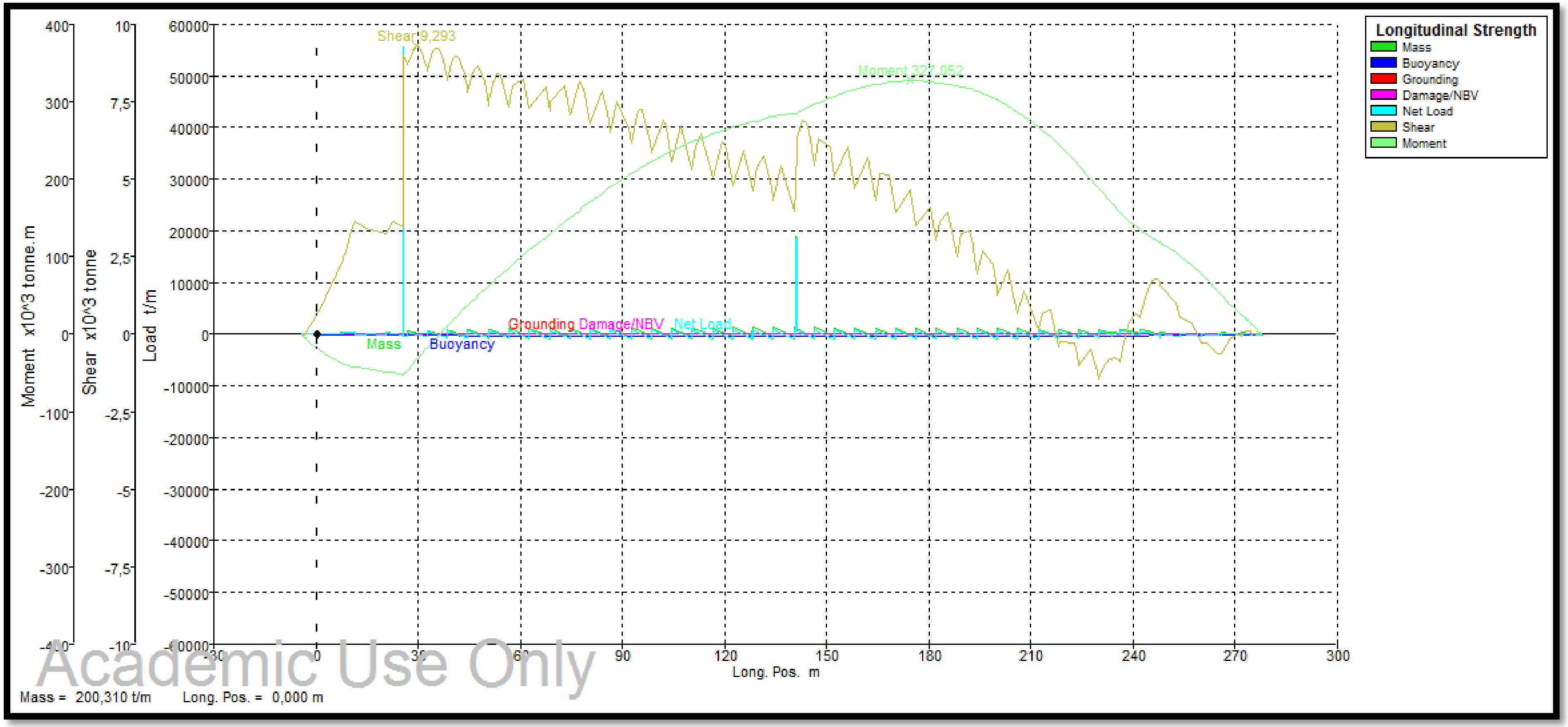
Condición de carga 4: Llegada a puerto en lastre

| CC4 | | % | Peso (t) |
|---|---|---|---|
| Rosca | | | 36.704 |
| Carga | | 0 | 0 |
| Consumos | | | |
| | Fuel Alm. (2x) | 3,52 | 227,714 |
| | Fuel Sed. (2x) | 100 | 293,768 |
| | Fuel UD (2x) | 100 | 192,796 |
| | Diesel (2x) | 10 (5+5) | 38,38 |
| | Aceite (2x) | 10 (5+5) | 4,942 |
| | Agua dulce (2x) | 10 (5+5) | 7,724 |
| | Aguas gr. | 100 | 247,326 |
| | Lodos | 100 | 110,858 |
| Lastre | | 100 | 52605,202 |
| Víveres | | 10 | 0,4375 |
| Pesos fijos | | | 105,25 |
| TOTAL Δ | | | 90.538 |

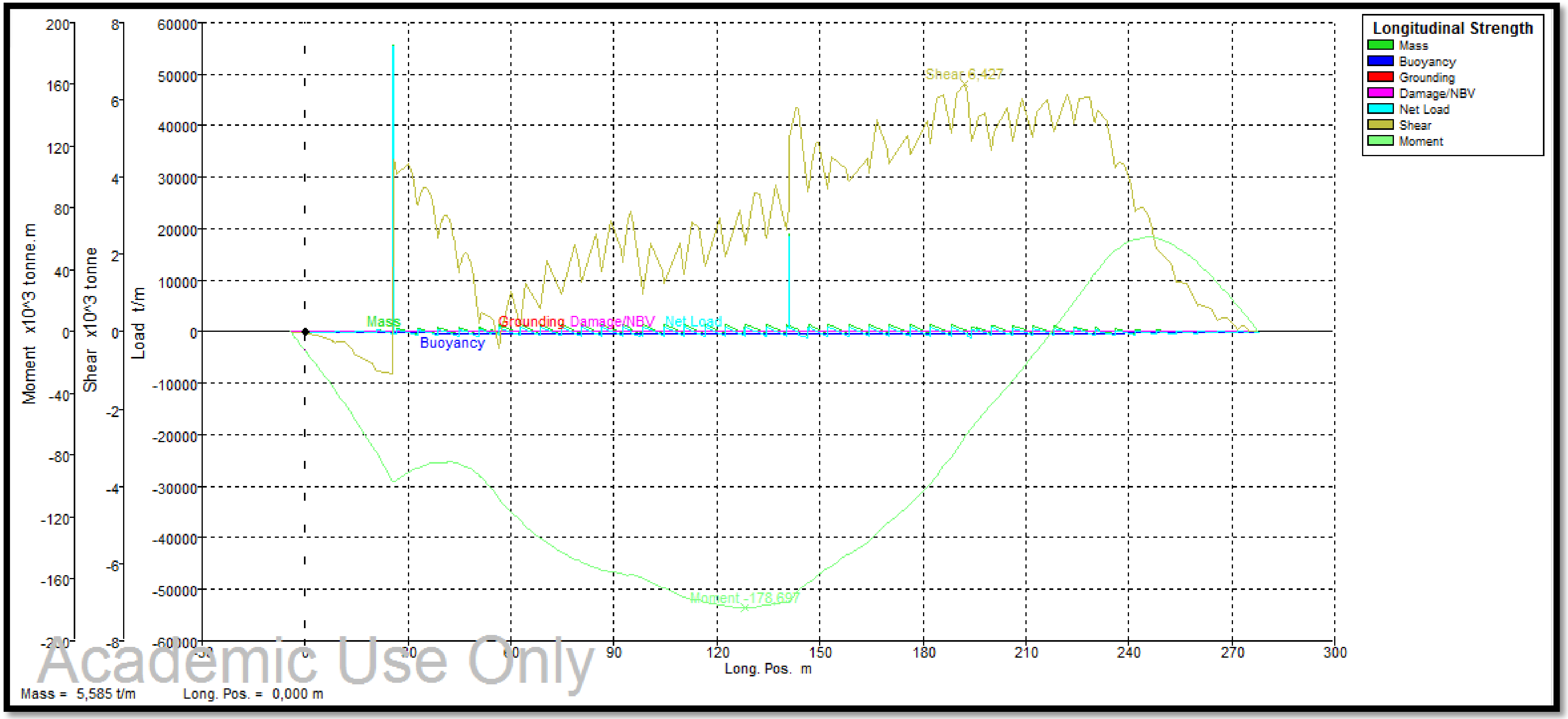
Condición de carga 1



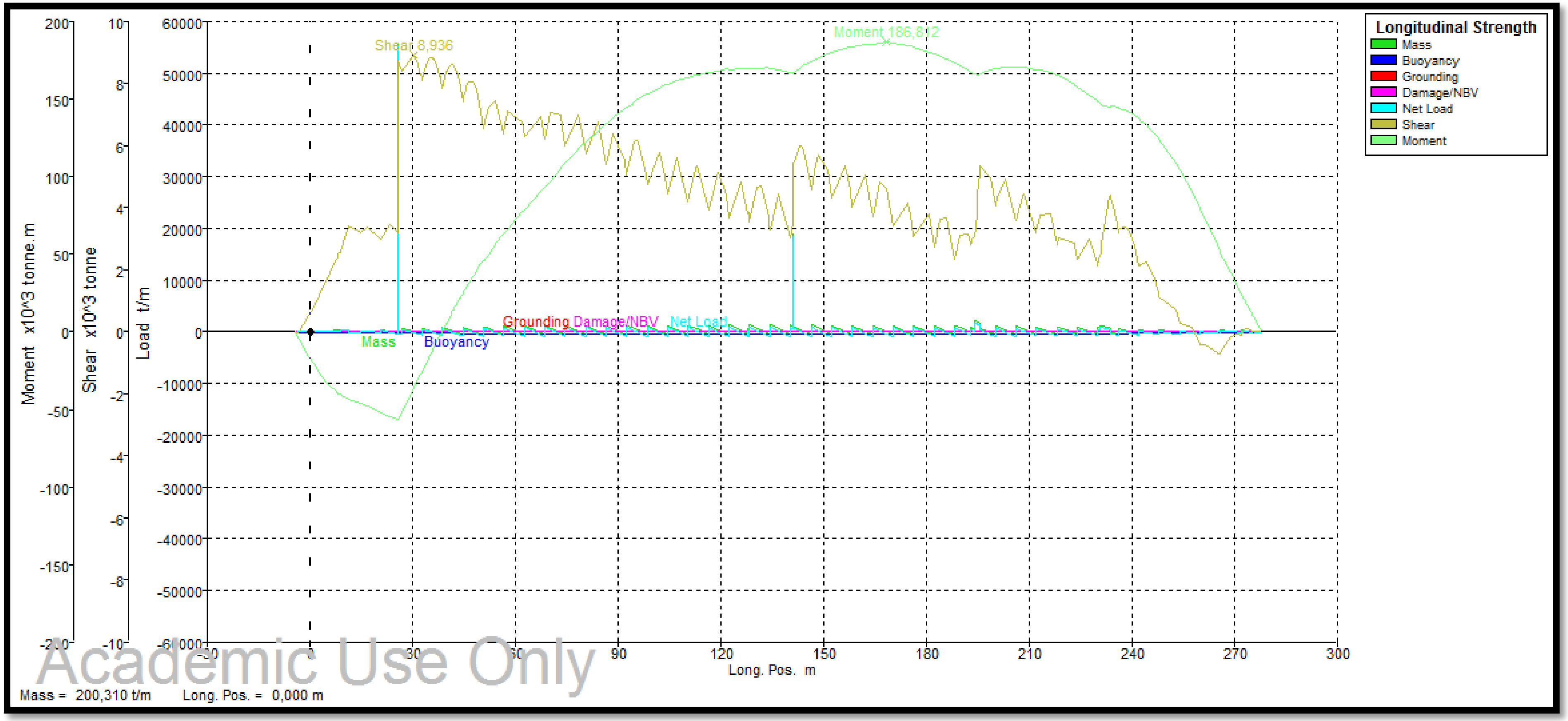
Condición de carga 2



Condición de carga 3



Condición de carga 4



## 6-BIBLIOGRAFÍA

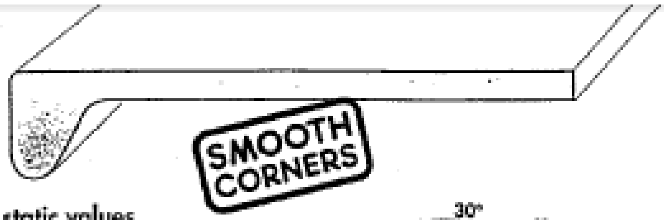
-Reglamento Sociedad de Clasificación DNV.

-Apuntes asignatura "Métodos Computacionales Aplicados al Proyecto del Buque", EPS Ferrol.

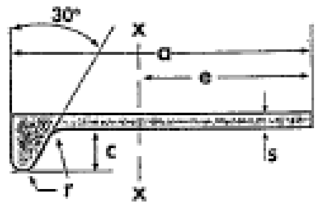
# ANEXO I

## Catálogo  de perfiles

# 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 | 15.2 | 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 |
| | 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 |

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)

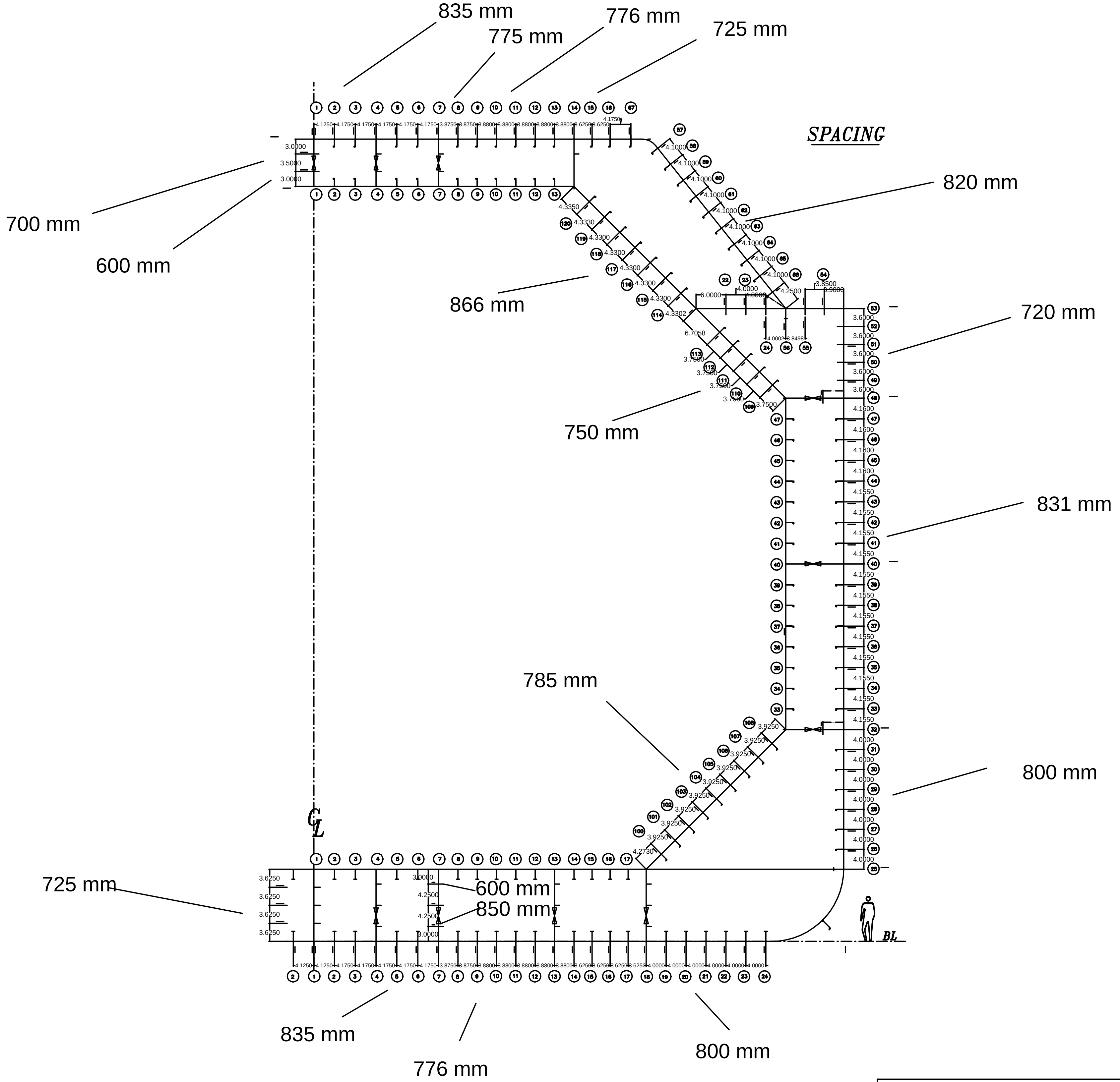
* Inclusive plate as noted

**Standard lengths**
6–18 m.
Other lengths by special agreeme

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

# ANEXO II

## Plano cuaderna maestra buque base




UNIVERSIDADE DA CORUÑA

ESCOLA POLITÉCNICA SUPERIOR

PROYECTO: 17-32 P

PLANO CUADERNA MAESTRA BUQUE BASE (CÁDIZ KNUTSEN)

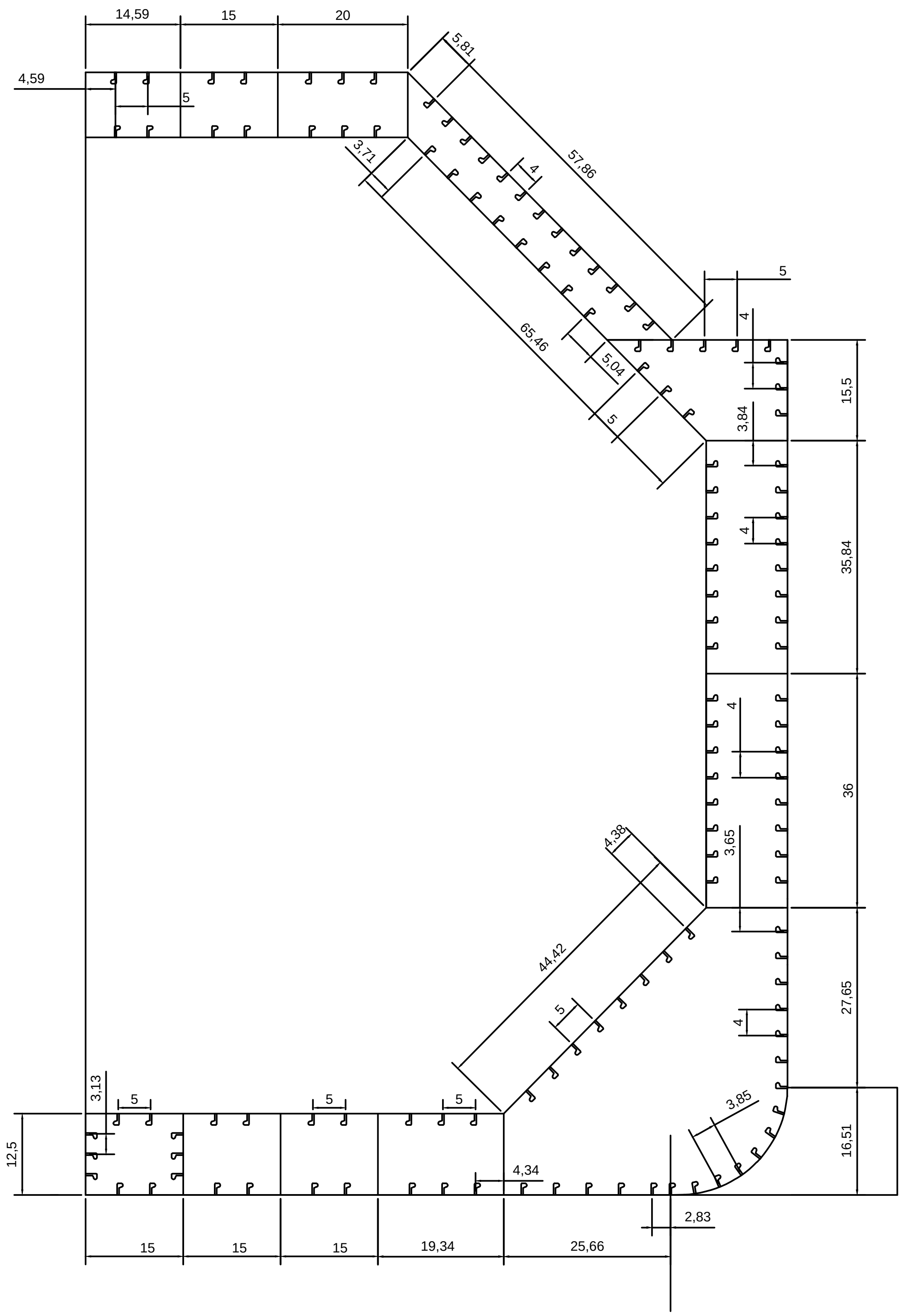
AUTOR: ISMAEL GRANDAL MOURIZ

ESCALA 1:200


PRODUCIDO POR UN PRODUCTO EDUCATIVO DE AUTODESK
PRODUCIDO POR UN PRODUCTO EDUCATIVO DE AUTODESK

# ANEXO III

## Plano cuaderna maestra buque proyecto

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PROYECTO: 17-32 P

PLANO CUADERNA MAESTRA BUQUE PROYECTO

AUTOR: ISMAEL GRANDAL MOURIZ

ESCALA 1:200

PRODUCIDO POR UN PRODUCTO EDUCATIVO DE AUTODESK
PRODUCIDO POR UN PRODUCTO EDUCATIVO DE AUTODESK
PRODUCIDO POR UN PRODUCTO EDUCATIVO DE AUTODESK

# ANEXO IV

## Reglamento DNV

# SECTION 5
# LONGITUDINAL STRENGTH

## A. General

### A 100 Introduction

**101** In this section the requirements regarding the longitudinal hull girder scantlings with respect to bending and shear are given.

**102** The wave bending moments and shear forces are given as the design values with a probability of exceedance of $10^{-8}$.

These values are applied when determining the section modulus and the shear area of the hull girder and in connection with control of buckling and ultimate strength. Reduced values will have to be used when considering combined local and longitudinal stresses in local elements, see B204.

**103** The buckling strength of longitudinal members is not covered by this section. Requirements for such control are given in Sec.13.

**104** For ships with small block coefficient, high speed and large flare the hull girder buckling strength in the forebody may have to be specially considered based on the distribution of still water and vertical wave bending moments indicated in B100 and B200 respectively. In particular this applies to ships with length L > 120 m and speed V > 17 knots.

**105** For narrow beam ships the combined effects of vertical and horizontal bending of the hull girder may have to be specially considered as indicated in C300.

**106** For ships with large deck openings (total width of hatch openings in one transverse section exceeding 65% of the ship's breadth or length of hatch opening exceeding 75% of hold length) the longitudinal strength including torsion may be required to be considered as given in Pt.5 Ch.2 Sec.6 B200. For ships with block coefficient $C_B < 0.7$ the longitudinal/local strength outside of the midship region may, subject to special consideration in each case, be taken according to Pt.5 Ch.2 Sec.6 B.

**107** In addition to the limitations given in 104 to 106, special considerations will be given to vessels with the following proportions:

$L/B \leq 5$
$B/D \geq 2.5$.

### A 200 Definitions

**201** Symbols:

$I_N$ = moment of inertia in $cm^4$ about the transverse neutral axis
$I_C$ = moment of inertia in $cm^4$ about the vertical neutral axis
$C_W$ = wave coefficient as given in Sec.4 B
$S_N$ = first moment of area in $cm^3$ of the longitudinal material above or below the horizontal neutral axis, taken about this axis
$z_n$ = vertical distance in m from the baseline or deckline to the neutral axis of the hull girder, whichever is relevant
$z_a$ = vertical distance in m from the baseline or deckline to the point in question below or above the neutral axis, respectively
$M_S$ = design stillwater bending moment in kNm as given in B100
$Q_S$ = design stillwater shear force in kN as given in B100
$M_W$ = rule wave bending moment in kNm as given in B200
$Q_W$ = rule wave shear force in kN as given in B200
$M_{WH}$ = rule wave bending moment about the vertical axis as given in B205
$M_{WT}$ = rule wave torsional moment as given in B206.

**202** Terms:

*Effective longitudinal bulkhead* is a bulkhead extending from bottom to deck and which is connected to the ship's side by transverse bulkheads both forward and aft.

*Loading manual* is a document which describes:

— the loading conditions on which the design of the ship has been based, including permissible limits of still water bending moment and shear force and shear force correction values and, where applicable, permissible

limits related to still water torsional moment [1)] and lateral loads
— the results of calculations of still water bending moments, shear forces and still water torsional moments if unsymmetrical loading conditions with respect to the ships centreline
— the allowable local loadings for the structure (hatch covers, decks, double bottom, etc.).

1) Permissible torsional still water moment limits are generally applicable for ships with large deck openings as given in 106 and class notation **CONTAINER** or **Container Carrier**.

For bulk carriers of 150 m in length and above, additional requirements as given in Pt.5 Ch.2 Sec.5 A also apply.

A *Loading computer system* is a system, which unless stated otherwise is digital, by means of which it can be easily and quickly ascertained that, at specified read-out points, the still water bending moments, shear forces, and the still water torsional moments and lateral loads, where applicable, in any load or ballast condition will not exceed the specified permissible values.

**Guidance note:**

The term “Loading computer system” covers the term “Loading instrument” as commonly used in IACS UR S1.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

An operation manual is always to be provided for the loading instrument. Single point loading instruments are not acceptable.

*Category I ships.* Ships with large deck openings where combined stresses due to vertical and horizontal hull girder bending and torsional and lateral loads have to be considered.

Ships liable to carry non-homogeneous loadings, where the cargo and or ballast may be unevenly distributed. Ships less than 120 m in length, when their design takes into account uneven distribution of cargo or ballast, belong to Category II.

Chemical tankers and gas carriers.

*Category II Ships*. Ships with arrangement giving small possibilities for variation in the distribution of cargo and ballast, and ships on regular and fixed trading pattern where the Loading Manual gives sufficient guidance, and in addition the exception given under Category I.

## B. Still Water and Wave Induced Hull Girder Bending Moments and Shear Forces

### B 100 Stillwater conditions

**101** The design stillwater bending moments, $M_S$, and stillwater shear forces, $Q_S$, shall be calculated along the ship length for design cargo and ballast loading conditions as specified in 102.

For these calculations, downward loads are assumed to be taken as positive values, and shall be integrated in the forward direction from the aft end of L. The sign conventions of $Q_S$ and $M_S$ are as shown in Fig.1.

(IACS UR S11.2.1.1 Rev.7)

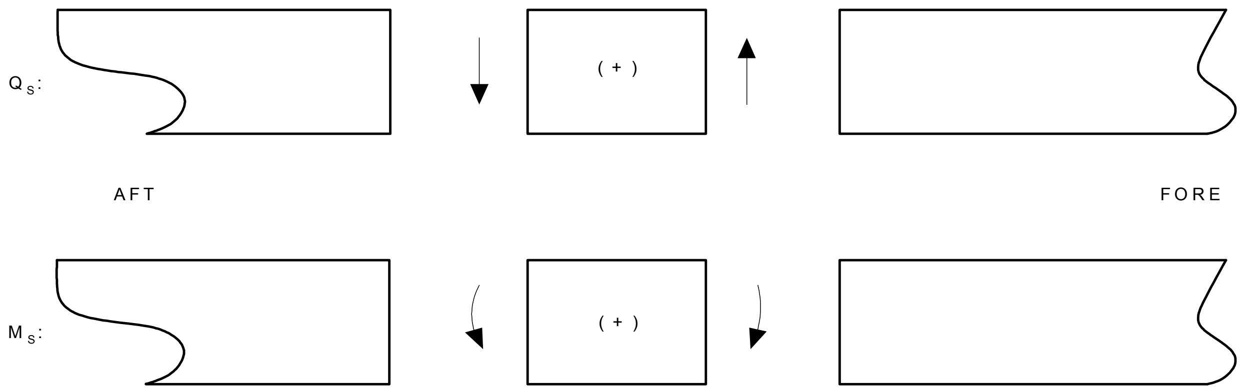



**Fig. 1**
**Sign Conventions of $Q_S$ and $M_S$**

**102** In general, the following design cargo and ballast loading conditions, based on amount of bunker, fresh water and stores at departure and arrival, shall be considered for the $M_S$ and $Q_S$ calculations. Where the amount and disposition of consumables at any intermediate stage of the voyage are considered more severe, calculations for such intermediate conditions shall be submitted in addition to those for departure and arrival conditions. Also, where any ballasting and or deballasting is intended during voyage, calculations of the intermediate condition just before and just after ballasting and or deballasting any ballast tank shall be submitted and where approved included in the loading manual for guidance.

*Cargo ships, container carriers, roll-on/roll-off and refrigerated carriers, ore carriers and bulk carriers:*

— homogenous loading conditions at maximum draught
— ballast conditions
— special loading conditions, e.g. container or light load conditions at less than the maximum draught, heavy cargo, empty holds or non-homogenous cargo conditions, deck cargo conditions, etc. where applicable
— docking condition afloat
— for vessels with **BC-A**, **BC-B**, **BC-C** or **BC-B*** notation, loading conditions as specified in Pt.5 Ch.2 Sec.5 A.

*Oil tankers:*

— homogenous loading conditions (excluding dry and clean ballast tanks) and ballast or part-loaded conditions
— any specified non-uniform distribution of loading
— mid-voyage conditions relating to tank cleaning or other operations where these differ significantly from the ballast conditions
— docking condition afloat
— for oil carriers complying with the requirements for the segregated ballast tanks as stipulated in Pt.5 Ch.3 Sec.3 B, the ballast conditions shall in addition to the segregated ballast condition include one or more relevant conditions with additional ballast in cargo tanks.

*Chemical and product tankers:*

— conditions as specified for oil tankers
— conditions for high density or segregated cargo where these are included in the approved cargo list.

*Liquefied gas carriers:*

— homogenous loading conditions for all approved cargoes
— ballast conditions
— cargo condition where one or more tanks are empty or partially filled or where more than one type of cargo having significantly different densities is carried
— harbour condition for which an increased vapour pressure has been approved
— docking condition afloat.

*Combination carriers:*

— conditions as specified for oil tankers and cargo ships.

For smaller ships the stillwater bending moments and shear forces may have to be calculated for ballast and particular non-homogeneous load conditions after special considerations.

Also short voyage or harbour conditions including loading and unloading transitory conditions shall be checked where applicable.

**Guidance note:**

It is advised that the ballast conditions determining the scantlings are based on the filling of ballast in as few cargo tanks as practicable, and it is important that the conditions will allow cleaning of all cargo tanks with the least possible shifting.

---e-n-d---of---G-u-i-d-a-n-c-e---n-o-t-e---

(IACS UR S11.2.1.2 Rev.7)

**103** Ballast loading conditions involving partially filled peak and or other ballast tanks at departure, arrival or during intermediate conditions are not permitted to be used as design conditions unless:

— design stress limits are satisfied for all filling levels between empty and full and
— for bulk carriers, Pt.5 Ch.2 Sec.8 C, as applicable, is complied with for all filling levels between empty and full.

To demonstrate compliance with all filling levels between empty and full, it will be acceptable if, in each condition at departure, arrival and where required by 102 any intermediate condition, the tanks intended to be partially filled are assumed to be:

— empty
— full
— partially filled at intended level.

Where multiple tanks are intended to be partially filled, all combinations of empty, full or partially filled at intended level for those tanks shall be investigated.

However, for conventional Ore Carriers with large wing water ballast tanks in cargo area, where empty or full ballast water filling levels of one or maximum two pairs of these tanks lead to the ship's trim exceeding one of the following conditions, it is sufficient to demonstrate compliance with maximum, minimum and intended partial filling levels of these one or maximum two pairs of ballast tanks such that the ship's condition does not exceed any of these trim limits. Filling levels of all other wing ballast tanks shall be considered between empty and full. The trim conditions mentioned above are:

— trim by stern of 3% of the ship's length, or
— trim by bow of 1.5% of ship's length, or
— any trim that cannot maintain propeller immersion (I/D) not less than 25%.

where:

I = the distance from propeller centreline to the waterline
D = propeller diameter.

See Fig.2.

The maximum and minimum filling levels of the above mentioned pairs of side ballast tanks shall be indicated in the loading manual.

(IACS UR S11.2.1.3 Rev.7)

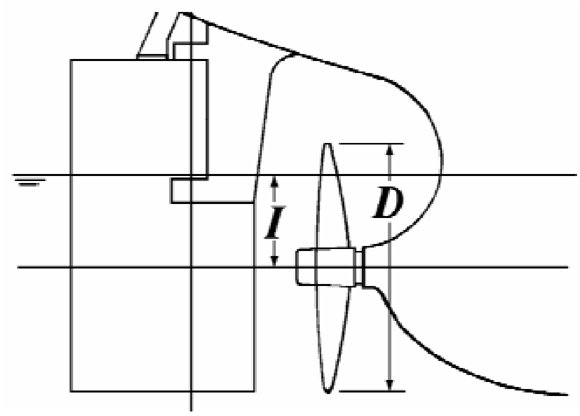



**Fig. 2**

**104** In cargo loading conditions, the requirements given in 103 applies to peak tanks only.

(IACS UR S11.2.1.4 Rev.7)

**105** Requirements given in 103 and 104 are not applicable to ballast water exchange using the sequential method. However, bending moment and shear force calculations for each de-ballasting or ballasting stage in the ballast water exchange sequence are to be included in the loading manual or ballast water management plan of any vessel that intends to employ the sequential ballast water exchange method.

(IACS UR S11.2.1.5 Rev.7)

**106** The design stillwater bending moments amidships (sagging and hogging) are normally not to be taken less than:

$$M_S = M_{SO} \quad \text{(kNm)}$$

$M_{SO}$ = $-0.065\, C_{WU}\, L^2\, B\, (C_B + 0.7)$ (kNm) in sagging
= $C_{WU}\, L^2\, B\, (0.1225 - 0.015\, C_B)$ (kNm) in hogging
$C_{WU}$ = $C_W$ for unrestricted service.

Larger values of $M_{SO}$ based on cargo and ballast conditions shall be applied when relevant, see 102.

For ships with arrangement giving small possibilities for variation of the distribution of cargo and ballast, $M_{SO}$ may be dispensed with as design basis.

**107** When required in connection with stress analysis or buckling control, the stillwater bending moments at arbitrary positions along the length of the ship are normally not to be taken less than:

$$M_S = k_{sm}\, M_{SO} \quad \text{(kNm)}$$

$M_{SO}$ = as given in 106
$k_{sm}$ = 1.0 within 0.4 L amidships
= 0.15 at 0.1 L from A.P. or F.P.

= 0.0 at A.P. and F.P.

Between specified positions $k_{sm}$ shall be varied linearly.

Values of $k_{sm}$ may also be obtained from Fig.3.

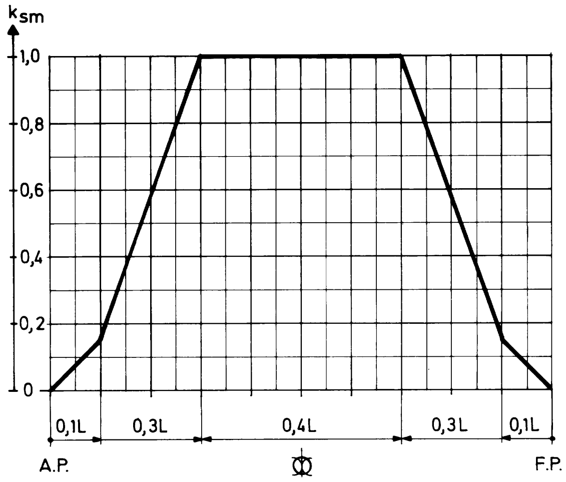



**Fig. 3**
**Stillwater bending moment**

The extent of the constant design bending moments amidships may be adjusted after special consideration.

**108** The design values of stillwater shear forces along the length of the ship are normally not to be taken less than:

$$Q_S = k_{sq}\, Q_{SO} \quad \text{(kN)}$$

$$Q_{SO} = 5\frac{M_{SO}}{L} \quad \text{(kN)}$$

$M_{SO}$ = design stillwater bending moments (sagging or hogging) given in 106.

Larger values of $Q_S$ based on load conditions ($Q_S = Q_{SL}$) shall be applied when relevant, see 102. For ships with arrangement giving small possibilities for variation in the distribution of cargo and ballast, $Q_{SO}$ may be dispensed with as design basis

$k_{sq}$ = 0 at A.P. and F.P.
= 1.0 between 0.15 L and 0.3 L from A.P.
= 0.8 between 0.4 L and 0.6 L from A.P.
= 1.0 between 0.7 L and 0.85 L from A.P.

Between specified positions $k_{sq}$ shall be varied linearly.

Sign convention to be applied:

— when sagging condition positive in forebody, negative in afterbody
— when hogging condition negative in forebody, positive in afterbody.

### B 200 Wave load conditions

**201** The rule vertical wave bending moments amidships are given by:

$$M_W = M_{WO} \quad \text{(kNm)}$$

$M_{WO}$ = $-0.11\,\alpha C_W L^2 B (C_B + 0.7)$ (kNm) in sagging
= $0.19\,\alpha C_W L^2 B C_B$ (kNm) in hogging

$\alpha$ = 1.0 for seagoing conditions
= 0.5 for harbour and sheltered water conditions (enclosed fjords, lakes, rivers).

$C_B$ is not be taken less than 0.6.

**202** When required in connection with stress analysis or buckling control, the wave bending moments at arbitrary positions along the length of the ship are normally not to be taken less than:

$$M_W = k_{wm} M_{WO} \quad \text{(kNm)}$$

$M_{WO}$ = as given in 201

$k_{wm}$ = 1.0 between 0.40 L and 0.65 L from A.P.
= 0.0 at A.P. and F.P.

For ships with high speed and or large flare in the forebody the adjustments to $k_{wm}$ as given in Table B1, limited to the control for buckling as given in Sec.13, apply.

**Table B1 Adjustments to $k_{wm}$**

| *Load condition* | *Sagging and hogging* | | *Sagging only* | |
|---|---|---|---|---|
| $C_{AV}$ | ≤ 0.28 | ≥ 0.32 [1)] | | |
| $C_{AF}$ | | | ≤ 0.40 | ≥ 0.50 |
| $k_{wm}$ | No adjust ment | 1.2 between 0.48 L and 0.65 L from A.P. 0.0 at F.P. and A.P. | No adjust ment | 1.2 between 0.48 L and 0.65 L from A.P. 0.0 at F.P. and A.P. |
| 1) Adjustment for $C_{AV}$ not to be applied when $C_{AF} \geq 0.50$. | | | | |

$$C_{AV} = \frac{c_v V}{\sqrt{L}}$$

$$C_{AF} = \frac{c_v V}{\sqrt{L}} + \frac{A_{DK} - A_{WP}}{L z_f}$$

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

$A_{DK}$ = projected area in the horizontal plane of upper deck (including any forecastle deck) forward of 0.2 L from F.P.

$A_{WP}$ = area of waterplane forward of 0.2 L from F.P. at draught T

$z_f$ = vertical distance from summer load waterline to deckline measured at F.P.

Between specified $C_A$-values and positions $k_{wm}$ shall be varied linearly. Values of $k_{wm}$ may also be obtained from Fig.4.

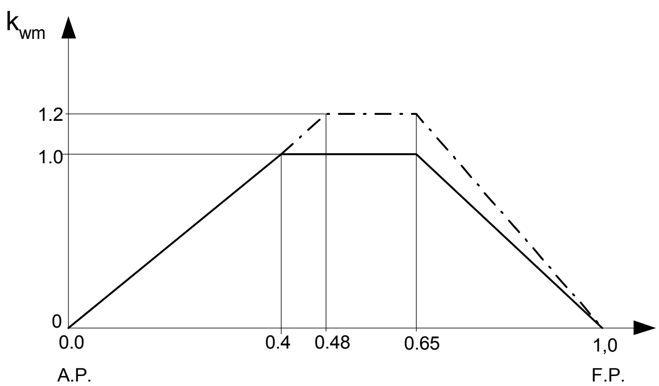



**Fig. 4**
**Wave bending moment distribution**

**203** The rule values of vertical wave shear forces along the length of the ship are given by:

Positive shear force, to be used when positive still water shear force:

$$Q_{WP} = 0.3\, \beta\, k_{wqp}\, C_W\, L\, B\, (C_B + 0.7) \quad \text{(kN)}$$

Negative shear force, to be used when negative still water shear force:

$$Q_{WN} = -\,0.3\, \beta\, k_{wqn}\, C_W\, L\, B\, (C_B + 0.7) \quad \text{(kN)}$$

Positive shear force when there is a surplus of buoyancy forward of section considered, see also Fig.1.

Negative shear force when there is a surplus of weight forward of section considered.

$\beta$ = 1.0 for seagoing conditions
= 0.5 for harbour and sheltered water conditions (enclosed fjords, lakes, rivers)

$k_{wqp}$ = 0 at A.P. and F.P.

= 1.59 $C_B/(C_B + 0.7)$ between 0.2 L and 0.3 L from A.P.
= 0.7 between 0.4 L and 0.6 L from A.P.
= 1.0 between 0.7 L and 0.85 L from A.P.

$k_{wqn}$ = 0 at A.P. and F.P.
= 0.92 between 0.2 L and 0.3 L from A.P.
= 0.7 between 0.4 L and 0.6 L from A.P.
= 1.73 $C_B/(C_B + 0.7)$ between 0.7 L and 0.85 L from A.P.

$C_W$ = as given in 201.

For ships with high speed and or large flare in the forebody, the adjustments given in Table B2 apply.

| Table B2 Adjustments to $k_{wq}$ | | | | |
|---|---|---|---|---|
| *Load condition* | *Sagging and hogging* | | *Sagging only* | |
| $C_{AV}$ | ≤ 0.28 | ≥ 0.32 1) | | |
| $C_{AF}$ | | | ≤ 0.40 | ≥ 0.50 |
| Multiply $k_{wq}$ by | 1.0 | 1.0 aft of 0.6 L from A.P.<br>1.2 between 0.7 L and 0.85 L from A.P. | 1.0 | 1.0 aft of 0.6 L from A.P.<br>1.2 between 0.7 L and 0.85 L from A.P. |
| 1) Adjustment for $C_{AV}$ not to be applied when $C_{AF} \geq 0.50$. | | | | |

$C_{AV}$ = as defined in 202
$C_{AF}$ = as defined in 202.

Between specified positions $k_{wq}$ shall be varied linearly. Values of $k_{wq}$ may also be obtained from Fig.5.

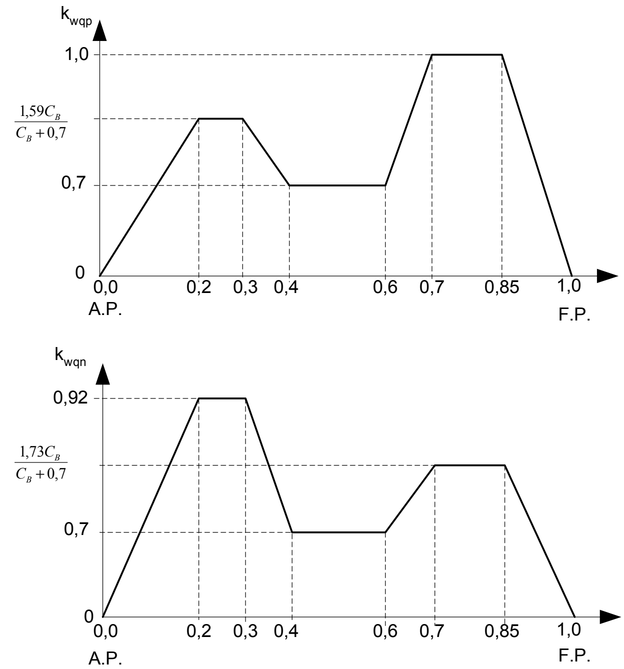



**Fig. 5**
**Wave shear force distribution**

**204** When hull girder stresses due to wave loads are combined with local stresses in girder systems, stiffeners and plating in accordance with Sec.12, the wave bending moments and shear forces may be reduced as follows:

$$M_{WR} = 0.59\ M_W$$

$$Q_{WR} = 0.59\ Q_W$$

**205** The rule horizontal wave bending moments along the length of the ship are given by:

$$M_{WH} = 0.22\ L^{9/4}\ (T + 0.3\ B)\ C_B\ (1 - \cos\ (360\ x/L))\ (\text{kNm})$$

x = distance in m from A.P. to section considered.

**206** The rule wave torsional moments along the length of the ship due to the horizontal wave- and inertia forces and the rotational wave- and inertia moment loads are given by:

$M_{WT} = K_{T1}\ L^{5/4}\ (T + 0.3\ B)\ C_B\ z_e$

$$\pm K_{T2} L^{4/3} B^2 C_{SWP} \quad (kNm)$$

$K_{T1}$ = 1.40 sin (360 x/L)
$K_{T2}$ = 0.13 (1 – cos (360 x/L))
$C_{SWP}$ = $A_{WP}/(LB)$
$A_{WP}$ = water plane area of vessel in $m^2$ at draught T
$z_e$ = distance in m from the shear centre of the midship section to a level 0.7 T above the base line
x = distance in m from A.P. to section considered.

## C. Bending Strength and Stiffness

### C 100 Midship section particulars

**101** When calculating the moment of inertia and section modulus, the effective sectional area of continuous longitudinal strength members is in general the net area after deduction for openings as given in E.

The effective sectional area of strength members between hatch openings in ships with twin or triple hatchways shall be taken as the net area multiplied by a factor 0.6 unless a higher factor is justified by direct calculations.

Superstructures which do not form a strength deck shall not be included in the net section. This applies also to deckhouses, bulwarks and non-continuous hatch side coamings.

For definition of strength deck, see Sec.1 B205.

**102** The rule section modulus generally refers to the baseline and the deckline.

**103** Continuous trunks, longitudinal hatch coamings and above deck longitudinal girders shall be included in the longitudinal sectional area provided they are effectively supported by longitudinal bulkheads or deep girders. The deck modulus is then to be calculated by dividing the moment of inertia by the following distance, provided this is greater than the distance to the deck line at side:

$$z = (z_n + z_a)\left[0.9 + 0.2\frac{y_a}{B}\right], \quad \text{minimum } z_n$$

$y_a$ = distance in m from the centre line of the ship to the side of the strength member.

$y_a$ and $z_a$ shall be measured to the point giving the largest value of z.

**104** The main strength members included in the hull section modulus calculation shall extend continuously through the cargo region and sufficiently far towards the ends of the ship.

**105** Longitudinal bulkheads shall terminate at an effective transverse bulkhead, and large transition brackets shall be fitted in line with the longitudinal bulkheads.

### C 200 Extent of high strength steel (HS-steel)

**201** The vertical extent of HS-steel used in deck or bottom shall not be less than:

$$z_{hs} = z_n \frac{f_2 - f_3}{f_2}$$

$f_2$ = stress factor, for the bottom given in Sec.6 and for the deck in Sec.8
$f_3$ = material factor (general symbol $f_1$) for the members located more than $z_{hs}$ from deck or bottom, see Fig.6.

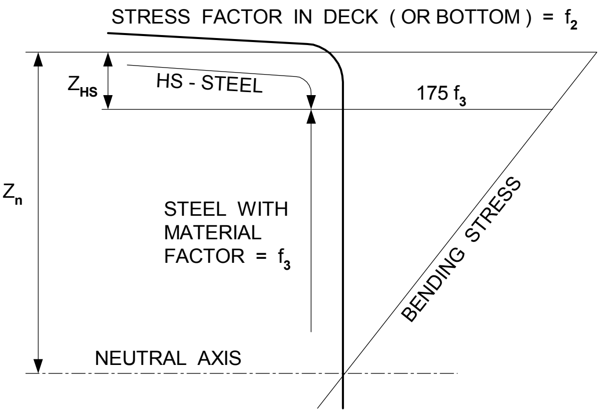



**Fig. 6**
**Vertical extent of HS-steel**

For narrow beam ships the vertical extent of HS-steel may have to be increased after special consideration.

**202** The longitudinal extent of HS-steel used in deck or bottom shall not be less than $x_{hs}$ as indicated in Fig.7.

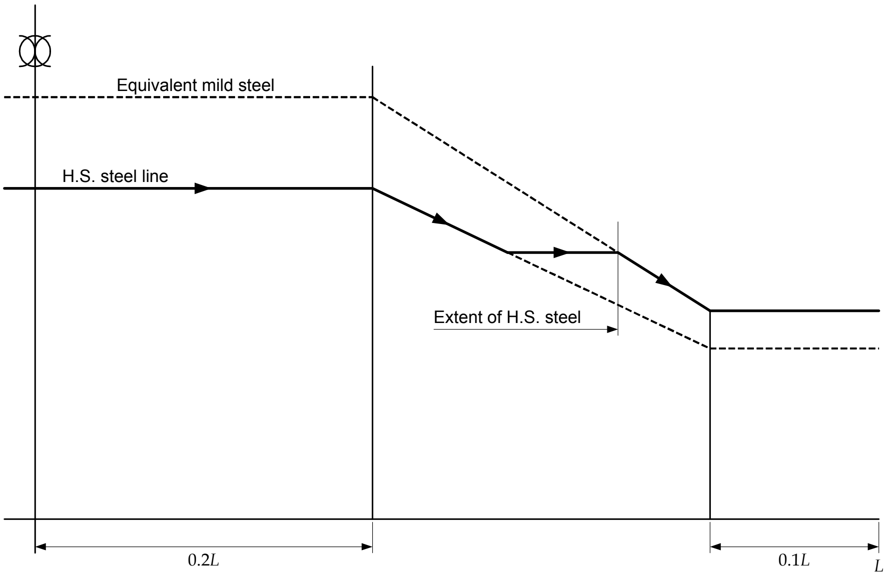



**Fig. 7**
**Longitudinal extent of HS-steel**

$x_{hs}$ (minimum) implies that the midship scantlings shall be maintained outside 0.4 L amidships to a point where the scantlings equal those of an identical ship built of normal strength steel over the full length. $x_{hs}$ (general) implies that the scantlings outside 0.4 L may be gradually reduced as if HS-steel was used over the full length. Where material strength group changes, however, continuity in scantlings shall be maintained.

## C 300 Section modulus

**301** The requirements given in 302 and 303 will normally be satisfied when calculated for the midship section only, provided the following rules for tapering are complied with:

a) Scantlings of all continuous longitudinal strength members shall be maintained within 0.4 L amidships.
   In special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0.4 L amidship part, bearing in mind the desire not to inhibit the vessel's loading flexibility.
b) Scantlings outside 0.4 L amidships are gradually reduced to the local requirements at the ends, and the same material strength group is applied over the full length of the ship.

The section modulus at other positions along the length of the ship may have to be specially considered for ships with small block coefficient, high speed and large flare in the forebody or when considered necessary due to structural arrangement, see A106.

In particular this applies to ships of length L > 120 m and speed V > 17 knots.

**302** As a minimum, hull girder bending strength checks are to be carried out at the following locations:

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

Buckling strength of members contributing to the longitudinal strength and subjected to compressive and shear stresses is to be checked, in particular in regions where changes in the framing system or significant changes in the hull cross-section occur. The buckling evaluation criteria used for this check is determined by each Classification Society.

Continuity of structure is be maintained throughout the length of the ship. Where significant changes in structural arrangement occur adequate transitional structure is to be provided.

For ships with large deck openings such as containerships, sections at or near to the aft and forward quarter length positions are to be checked. For such ships with cargo holds aft of the superstructure, deckhouse or engine room, strength checks of sections in way of the aft end of the aft-most holds, and the aft end of the deckhouse or engine room are to be performed.

**303** The midship section modulus about the transverse neutral axis shall not be less than:

$$Z_O = \frac{C_{WO}}{f_1} L^2 B (C_B + 0.7) \quad (\text{cm}^3)$$

$C_{WO}$ = $10.75 - [ (300 - L)/100 ]^{3/2}$ for L < 300
= 10.75 for $300 \le L \le 350$
= $10.75 - [ (L - 350)/150 ]^{3/2}$ for L > 350

Values of $C_{WO}$ are also given in Table C1.

$C_B$ is in this case not to be taken less than 0.60.

**Table C1 Values for $C_{WO}$**

| L | $C_{WO}$ | L | $C_{WO}$ | L | $C_{WO}$ |
|---|---|---|---|---|---|
| | | 160 | 9.09 | 260 | 10.50 |
| | | 170 | 9.27 | 280 | 10.66 |
| | | 180 | 9.44 | 300 | 10.75 |
| | | 190 | 9.60 | 350 | 10.75 |
| 100 | 7.92 | 200 | 9.75 | 370 | 10.70 |
| 110 | 8.14 | 210 | 9.90 | 390 | 10.61 |
| 120 | 8.34 | 220 | 10.03 | 410 | 10.50 |
| 130 | 8.53 | 230 | 10.16 | 440 | 10.29 |
| 140 | 8.73 | 240 | 10.29 | 470 | 10.03 |
| 150 | 8.91 | 250 | 10.40 | 500 | 9.75 |

For ships with restricted service, $C_{WO}$ may be reduced as follows:

— service area notation **R0**: No reduction
— service area notation **R1**: 5%
— service area notation **R2**: 10%
— service area notation **R3**: 15%
— service area notation **R4**: 20%
— service area notation **RE**: 25%.

**304** The section modulus requirements about the transverse neutral axis based on cargo and ballast conditions are given by:

$$Z_O = \frac{|M_S + M_W|}{\sigma_l} 10^3 \quad (\text{cm}^3)$$

$\sigma_l$ = 175 $f_1$ N/mm$^2$ within 0.4 L amidship
= 125 $f_1$ N/mm$^2$ within 0.1 L from A.P. or F.P.

Between specified positions $\sigma_l$ shall be varied linearly.

# ANEXO V

## Report resistencia longitudinal

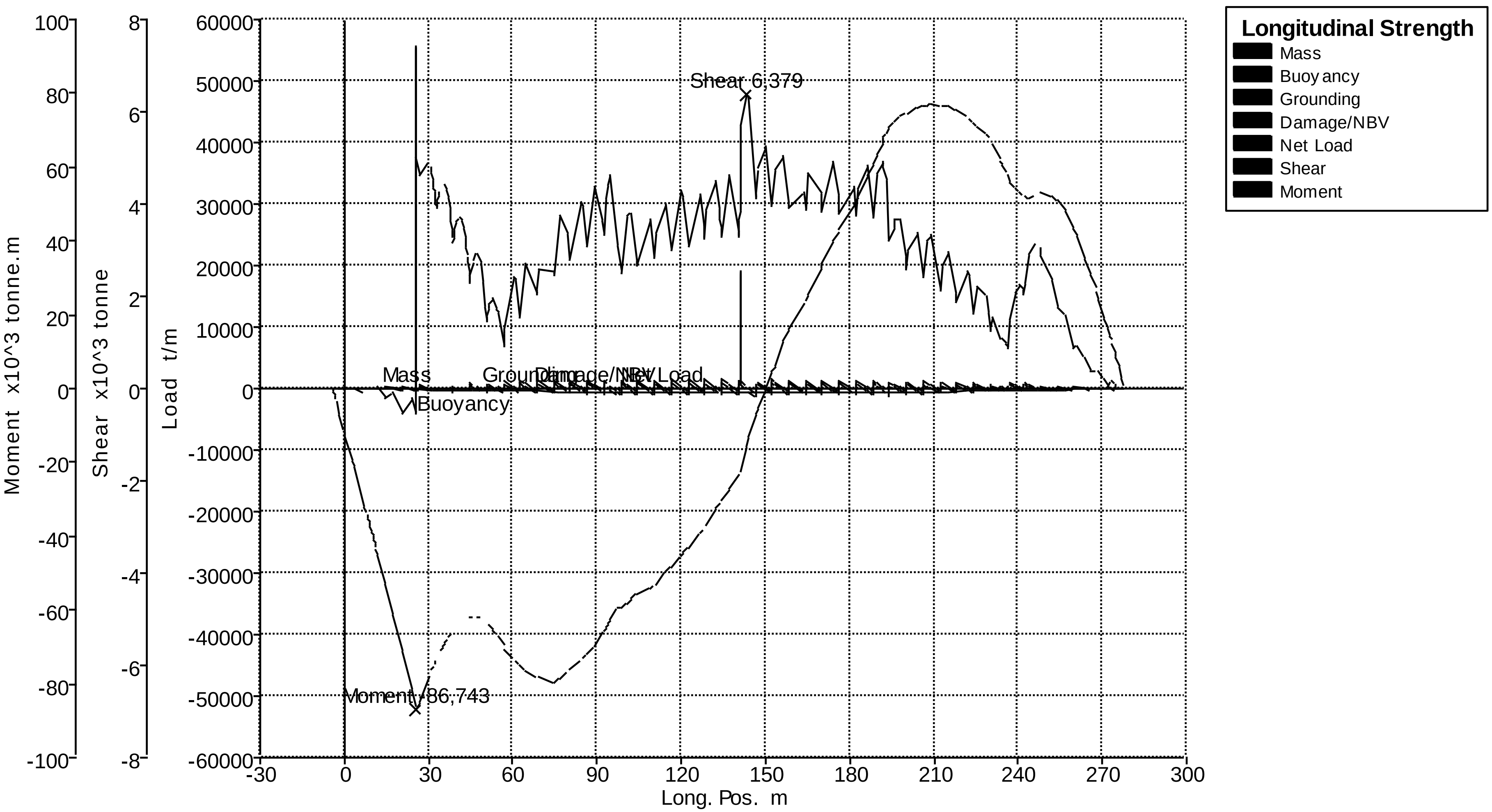
## Longitudinal Strength Calculation - Tanques final - copia (2)

Stability 20.00.04.9, build: 9
Model file: F:\TFM\CONTENIDO\TFG\CUADERNO 4\MÁSTER\Tanques final - copia (2) (Medium precision, 65 sections, Trimming off, Skin thickness not applied).
Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0,01000(0,100); Trim%(LCG-TCG): 0,01000(0,100); Heel%(LCG-TCG): 0,01000(0,100)

**Loadcase - C1 Salida puerto a plena carga**
**Damage Case - Intact**
Free to Trim
Specific gravity = 1,025; (Density = 1,025 tonne/m^3)
Fluid analysis method: Simulate fluid movement

| Item Name | Quantity | Unit Mass tonne | Total Mass tonne | Unit Volume m^3 | Total Volume m^3 | Long. Arm m | Aft. Limit m | Fwd. Limit m | Trans. Arm m | Vert. Arm m |
|---|---|---|---|---|---|---|---|---|---|---|
| rosca | 1 | 36703,970 | 36703,970 | | | 114,365 | | | 0,000 | 13,409 |
| Total rosca | | | 36703,970 | | | 114,365 | | | 0,000 | 13,409 |
| | | | | | | | | | | |
| Tanque 4 | 97% | 16408,559 | 15916,304 | 38159,440 | 37014,661 | 74,511 | | | 0,000 | 16,595 |
| Tanque 3 | 97% | 18646,092 | 18086,710 | 43363,003 | 42062,115 | 120,768 | | | 0,000 | 16,595 |
| Tanque 2 | 97% | 18646,092 | 18086,710 | 43363,003 | 42062,117 | 169,793 | | | 0,000 | 16,595 |
| Tanque 1 | 97% | 11961,030 | 11602,200 | 27816,349 | 26981,859 | 212,078 | | | 0,000 | 16,540 |
| Total carga | 97% | 65661,773 | 63691,924 | 152701,796 | 148120,751 | 139,763 | | | 0,000 | 16,585 |
| | | | | | | | | | | |
| Pique PP BR | 0% | 1728,991 | 0,000 | 1686,821 | 0,000 | 10,794 | | | -1,532 | 8,029 |
| Pique PP ER | 0% | 1728,991 | 0,000 | 1686,821 | 0,000 | 10,794 | | | 1,532 | 8,029 |
| Cofferdam 5 | 0% | 2627,904 | 0,000 | 2563,809 | 0,000 | 54,119 | | | 0,000 | 3,032 |
| Cofferdam 4 | 0% | 2666,826 | 0,000 | 2601,782 | 0,000 | 97,594 | | | 0,000 | 3,032 |
| Cofferdam 3 | 0% | 2666,819 | 0,000 | 2601,774 | 0,000 | 146,619 | | | 0,000 | 3,032 |
| Cofferdam 2 | 0% | 2666,833 | 0,000 | 2601,789 | 0,000 | 195,644 | | | 0,000 | 3,032 |
| Cofferdam 1 | 0% | 1573,708 | 0,000 | 1535,325 | 0,000 | 233,569 | | | 0,000 | 3,032 |
| Pique PR BR | 0% | 581,031 | 0,000 | 566,859 | 0,000 | 275,869 | | | -0,070 | 2,500 |
| Pique PR ER | 0% | 581,031 | 0,000 | 566,859 | 0,000 | 275,869 | | | 0,070 | 2,500 |
| Lastre 4 BR | 0% | 5014,252 | 0,000 | 4891,953 | 0,000 | 94,588 | | | -0,048 | 0,000 |
| Lastre 4 ER | 0% | 5014,252 | 0,000 | 4891,953 | 0,000 | 94,588 | | | 0,048 | 0,000 |
| Lastre 3 BR | 0% | 6457,632 | 0,000 | 6300,129 | 0,000 | 143,582 | | | -4,067 | 0,029 |
| Lastre 3 ER | 0% | 6457,632 | 0,000 | 6300,129 | 0,000 | 143,582 | | | 4,067 | 0,029 |
| Lastre 2 BR | 0% | 6146,861 | 0,000 | 5996,938 | 0,000 | 192,607 | | | -0,203 | 0,046 |
| Lastre 2 ER | 0% | 6146,861 | 0,000 | 5996,938 | 0,000 | 192,607 | | | 0,203 | 0,046 |
| Lastre 1 BR | 0% | 4253,564 | 0,000 | 4149,819 | 0,000 | 233,354 | | | -0,004 | 0,046 |
| Lastre 1 ER | 0% | 4253,564 | 0,000 | 4149,819 | 0,000 | 233,354 | | | 0,004 | 0,046 |
| Total lastre | 0% | 60566,752 | 0,000 | 59089,514 | 0,000 | 0,000 | | | 0,000 | 0,000 |
| | | | | | | | | | | |
| Agua dulce BR | 100% | 77,236 | 77,236 | 77,236 | 77,236 | 9,610 | | | -1,750 | 21,550 |
| Agua dulce ER | 100% | 77,236 | 77,236 | 77,236 | 77,236 | 9,610 | | | 1,750 | 21,550 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Aceite BR | 100% | 49,417 | 49,417 | 54,908 | 54,908 | 32,095 | | | -17,140 | 20,200 |
| Aceite ER | 100% | 49,417 | 49,417 | 54,908 | 54,908 | 32,095 | | | 17,140 | 20,200 |
| FO UD BR | 100% | 96,398 | 96,398 | 99,380 | 99,380 | 36,305 | | | -16,700 | 20,610 |
| FO UD ER | 100% | 96,398 | 96,398 | 99,380 | 99,380 | 36,305 | | | 16,700 | 20,610 |
| FO Sed. BR | 100% | 146,884 | 146,884 | 151,427 | 151,427 | 41,235 | | | -16,300 | 20,960 |
| FO Sed. ER | 100% | 146,884 | 146,884 | 151,427 | 151,427 | 41,235 | | | 16,300 | 20,960 |
| Diesel BR | 100% | 383,795 | 383,795 | 426,439 | 426,439 | 47,608 | | | -15,200 | 22,055 |
| Diesel ER | 100% | 383,795 | 383,795 | 426,439 | 426,439 | 47,608 | | | 15,200 | 22,055 |
| Aguas grises | 0% | 247,326 | 0,000 | 164,884 | 0,000 | 51,307 | | | 0,000 | 0,041 |
| Lodos | 0% | 110,858 | 0,000 | 73,905 | 0,000 | 41,955 | | | 0,000 | 0,510 |
| FO Almacén BR | 97% | 3225,417 | 3128,655 | 3325,172 | 3225,417 | 240,193 | | | -6,204 | 13,373 |
| FO Almacén ER | 97% | 3225,417 | 3128,655 | 3325,172 | 3225,417 | 240,193 | | | 6,204 | 13,373 |
| Viveres | 1 | 4,375 | 4,375 | | | 57,000 | 57,000 | 57,000 | 0,000 | 39,200 |
| Total consumos | | | 7769,147 | | | 201,247 | | | 0,000 | 14,961 |
| | | | | | | | | | | |
| Tripulacion | 1 | 5,250 | 5,250 | | | 57,000 | 57,000 | 57,000 | 0,000 | 39,200 |
| Perterechos | 1 | 100,000 | 100,000 | | | 128,000 | 128,000 | 128,000 | 0,000 | 28,000 |
| Total pesos fijos | | | 105,250 | | | 124,458 | | | 0,000 | 28,559 |
| | | | | | | | | | | |
| Total Loadcase | | | 108270,291 | 220299,223 | 156190,365 | 135,550 | | | 0,000 | 15,403 |



Longitudinal Strength
Mass
Buoyancy
Grounding
Damage/NBV
Net Load
Shear
Moment
Shear 6,379
Moment -86,743
Buoyancy
Moment x10^3 tonne.m
Shear x10^3 tonne
Load t/m
Long. Pos. m

| Name | Long. Pos. m | Mass t/m | Buoyancy t/m | Grounding t/m | Damage/NBV t/m | Net Load t/m | Shear x10^3 tonne | Moment x10^3 tonne.m |
|---|---|---|---|---|---|---|---|---|
| -1/4 | -5,304 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| 0 | -1,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | -6,581 |
| 1/2 | 4,810 | 4,838 | -17,100 | 0,000 | 0,000 | -12,262 | -0,036 | -25,345 |
| 1 | 11,552 | 20,277 | -49,553 | 0,000 | 0,000 | -29,277 | 0,071 | -44,222 |
| 1 1/2 | 18,295 | -2,708 | -89,189 | 0,000 | 0,000 | -91,897 | -0,195 | -63,702 |
| 2 | 25,037 | -95,672 | -139,928 | 0,000 | 0,000 | -235,600 | -0,421 | -84,816 |
| 2 1/2 | 31,780 | -215,333 | -226,826 | 0,000 | 0,000 | -442,159 | 4,408 | -74,797 |
| 3 | 38,522 | -397,550 | -289,059 | 0,000 | 0,000 | -686,609 | 3,260 | -65,495 |
| 4 | 52,007 | 518,635 | -379,682 | 0,000 | 0,000 | 138,954 | 1,867 | -64,559 |
| 5 | 65,492 | 549,222 | -438,343 | 0,000 | 0,000 | 110,879 | 2,516 | -76,785 |
| 6 | 78,977 | 134,216 | -476,327 | 0,000 | 0,000 | -342,111 | 3,435 | -77,033 |
| 7 | 92,462 | -295,524 | -490,322 | 0,000 | 0,000 | -785,846 | 3,364 | -65,438 |
| 8 | 105,947 | 964,456 | -504,252 | 0,000 | 0,000 | 460,204 | 2,997 | -55,223 |
| 9 | 119,432 | 528,198 | -519,161 | 0,000 | 0,000 | 9,037 | 4,052 | -45,883 |
| 10 | 132,917 | 81,006 | -534,849 | 0,000 | 0,000 | -453,843 | 4,194 | -31,679 |
| 11 | 146,402 | 998,225 | -539,415 | 0,000 | 0,000 | 458,810 | 4,151 | -6,886 |
| 12 | 159,887 | 933,534 | -542,024 | 0,000 | 0,000 | 391,510 | 4,027 | 18,254 |
| 13 | 173,372 | 490,398 | -540,974 | 0,000 | 0,000 | -50,577 | 4,697 | 38,742 |
| 14 | 186,857 | 65,166 | -535,815 | 0,000 | 0,000 | -470,650 | 4,432 | 59,049 |
| 15 | 200,342 | 1209,183 | -522,602 | 0,000 | 0,000 | 686,581 | 2,713 | 74,657 |
| 16 | 213,827 | 717,187 | -488,082 | 0,000 | 0,000 | 229,105 | 2,753 | 76,382 |
| 17 | 227,312 | 311,726 | -424,254 | 0,000 | 0,000 | -112,528 | 2,093 | 69,513 |
| 17 1/2 | 234,055 | 427,464 | -378,689 | 0,000 | 0,000 | 48,775 | 1,084 | 61,086 |
| 18 | 240,797 | 257,363 | -326,293 | 0,000 | 0,000 | -68,930 | 2,225 | 53,040 |
| 18 1/2 | 247,540 | 110,086 | -273,603 | 0,000 | 0,000 | -163,517 | 3,069 | 52,826 |
| 19 | 254,282 | 219,874 | -204,425 | 0,000 | 0,000 | 15,449 | 1,725 | 50,708 |
| 19 1/2 | 261,025 | 116,070 | -132,722 | 0,000 | 0,000 | -16,652 | 0,891 | 41,121 |
| 20 | 267,767 | 64,448 | -67,878 | 0,000 | 0,000 | -3,430 | 0,391 | 26,493 |
| 20 1/4 | 271,138 | -69,155 | -63,116 | 0,000 | 0,000 | -132,271 | 0,157 | 18,162 |
| 20 1/2 | 274,510 | -126,373 | -24,756 | 0,000 | 0,000 | -151,129 | 0,072 | 9,238 |
| st 1 | -11,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 2 | -9,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 3 | -7,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 4 | -5,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 5 | -3,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | -1,041 |
| st 6 | -1,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | -6,581 |
| st 7 | 0,067 | 5,344 | -1,812 | 0,000 | 0,000 | 3,531 | 0,000 | -12,122 |
| st 8 | 2,067 | -1,851 | -7,240 | 0,000 | 0,000 | -9,091 | -0,009 | -17,672 |
| st 9 | 4,067 | 7,025 | -13,965 | 0,000 | 0,000 | -6,940 | -0,025 | -23,255 |
| st 10 | 6,067 | 1,135 | -22,410 | 0,000 | 0,000 | -21,275 | -0,056 | -28,883 |
| st 11 | 8,067 | 39,380 | -31,657 | 0,000 | 0,000 | 7,723 | -0,093 | -34,548 |
| st 12 | 10,067 | 106,583 | -41,927 | 0,000 | 0,000 | 64,656 | 0,021 | -40,191 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| st 13 | 12,067 | 5,651 | -52,305 | 0,000 | 0,000 | -46,653 | 0,045 | -45,635 |
| st 14 | 14,067 | -51,146 | -63,924 | 0,000 | 0,000 | -115,070 | -0,135 | -51,313 |
| st 15 | 16,067 | 120,922 | -75,544 | 0,000 | 0,000 | 45,378 | -0,143 | -57,084 |
| st 16 | 18,067 | 9,919 | -87,662 | 0,000 | 0,000 | -77,743 | -0,163 | -63,000 |
| st 17 | 20,067 | -101,085 | -101,088 | 0,000 | 0,000 | -202,173 | -0,450 | -69,170 |
| st 18 | 22,067 | 254,440 | -114,515 | 0,000 | 0,000 | 139,924 | -0,423 | -75,436 |
| st 19 | 24,067 | 18,674 | -127,942 | 0,000 | 0,000 | -109,268 | -0,237 | -81,751 |
| st 20 | 26,067 | -217,092 | -153,203 | 0,000 | 0,000 | -370,295 | 4,863 | -86,059 |
| st 21 | 27,067 | 481,048 | -166,091 | 0,000 | 0,000 | 314,957 | 4,639 | -84,043 |

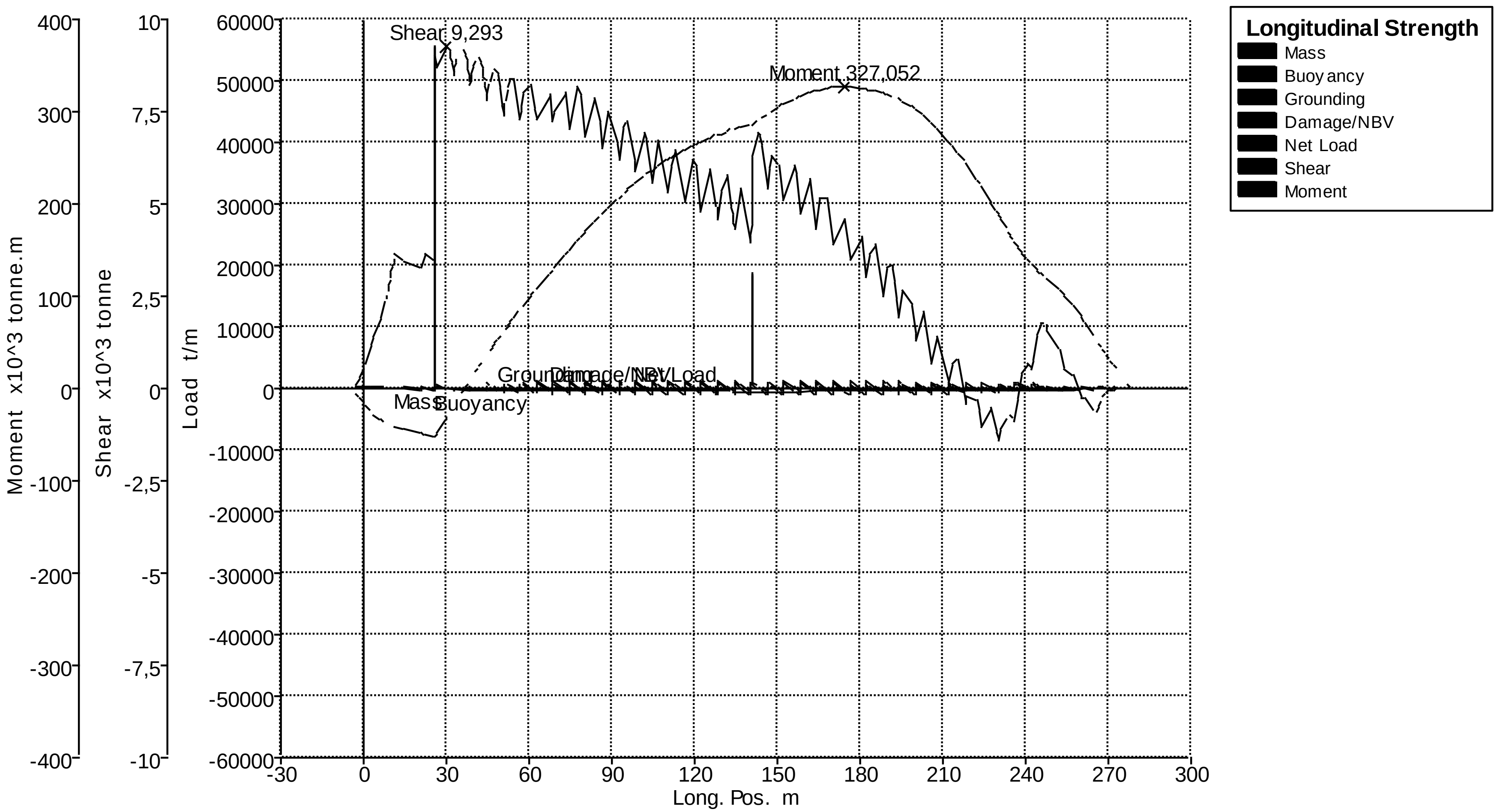
## Longitudinal Strength Calculation - Tanques final - copia (2)

Stability 20.00.04.9, build: 9
Model file: F:\TFM\CONTENIDO\TFG\CUADERNO 4\MÁSTER\Tanques final - copia (2) (Medium precision, 65 sections, Trimming off, Skin thickness not applied).
Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0,01000(0,100); Trim%(LCG-TCG): 0,01000(0,100); Heel%(LCG-TCG): 0,01000(0,100)

**Loadcase - C2 Salida de puerto en lastre**
**Damage Case - Intact**
Free to Trim
Specific gravity = 1,025; (Density = 1,025 tonne/m^3)
Fluid analysis method: Simulate fluid movement

| **Item Name** | **Quantity** | **Unit Mass tonne** | **Total Mass tonne** | **Unit Volume m^3** | **Total Volume m^3** | **Long. Arm m** | **Aft. Limit m** | **Fwd. Limit m** | **Trans. Arm m** | **Vert. Arm m** |
|---|---|---|---|---|---|---|---|---|---|---|
| rosca | 1 | 36703,970 | 36703,970 | | | 114,365 | | | 0,000 | 13,409 |
| Total rosca | | | 36703,970 | | | 114,365 | | | 0,000 | 13,409 |
| | | | | | | | | | | |
| Tanque 4 | 0% | 16408,559 | 0,000 | 38159,440 | 0,000 | 54,366 | | | 0,000 | 3,032 |
| Tanque 3 | 0% | 18646,092 | 0,000 | 43363,003 | 0,000 | 97,873 | | | 0,000 | 3,032 |
| Tanque 2 | 0% | 18646,092 | 0,000 | 43363,003 | 0,000 | 146,898 | | | 0,000 | 3,032 |
| Tanque 1 | 0% | 11961,030 | 0,000 | 27816,349 | 0,000 | 195,860 | | | 0,000 | 3,032 |
| Total carga | 0% | 65661,773 | 0,000 | 152701,796 | 0,000 | 0,000 | | | 0,000 | 0,000 |
| | | | | | | | | | | |
| Pique PP BR | 100% | 1728,991 | 1728,991 | 1686,821 | 1686,821 | 4,740 | | | -7,841 | 14,783 |
| Pique PP ER | 100% | 1728,991 | 1728,991 | 1686,821 | 1686,821 | 4,740 | | | 7,841 | 14,783 |
| Cofferdam 5 | 0% | 2627,904 | 0,000 | 2563,809 | 0,000 | 51,416 | | | 0,000 | 3,032 |
| Cofferdam 4 | 0% | 2666,826 | 0,000 | 2601,782 | 0,000 | 94,851 | | | 0,000 | 3,032 |
| Cofferdam 3 | 0% | 2666,819 | 0,000 | 2601,774 | 0,000 | 143,876 | | | 0,000 | 3,032 |
| Cofferdam 2 | 0% | 2666,833 | 0,000 | 2601,789 | 0,000 | 192,901 | | | 0,000 | 3,032 |
| Cofferdam 1 | 0% | 1573,708 | 0,000 | 1535,325 | 0,000 | 230,826 | | | 0,000 | 3,032 |
| Pique PR BR | 100% | 581,031 | 581,031 | 566,859 | 566,859 | 268,686 | | | -1,906 | 16,155 |
| Pique PR ER | 100% | 581,031 | 581,031 | 566,859 | 566,859 | 268,686 | | | 1,906 | 16,155 |
| Lastre 4 BR | 100% | 5014,252 | 5014,252 | 4891,953 | 4891,953 | 73,863 | | | -15,611 | 9,342 |
| Lastre 4 ER | 100% | 5014,252 | 5014,252 | 4891,953 | 4891,953 | 73,863 | | | 15,611 | 9,342 |
| Lastre 3 BR | 100% | 6457,632 | 6457,632 | 6300,129 | 6300,129 | 119,611 | | | -15,946 | 8,500 |
| Lastre 3 ER | 100% | 6457,632 | 6457,632 | 6300,129 | 6300,129 | 119,611 | | | 15,946 | 8,500 |
| Lastre 2 BR | 100% | 6146,861 | 6146,861 | 5996,938 | 5996,938 | 167,618 | | | -15,733 | 8,698 |
| Lastre 2 ER | 100% | 6146,861 | 6146,861 | 5996,938 | 5996,938 | 167,618 | | | 15,733 | 8,698 |
| Lastre 1 BR | 100% | 4253,564 | 4253,564 | 4149,819 | 4149,819 | 213,247 | | | -13,942 | 11,812 |
| Lastre 1 ER | 100% | 4253,564 | 4253,564 | 4149,819 | 4149,819 | 213,247 | | | 13,942 | 11,812 |
| Total lastre | 79,85% | 60566,752 | 48364,661 | 59089,514 | 47185,035 | 134,167 | | | 0,000 | 9,941 |
| | | | | | | | | | | |
| Agua dulce BR | 100% | 77,236 | 77,236 | 77,236 | 77,236 | 9,610 | | | -1,750 | 21,550 |
| Agua dulce ER | 100% | 77,236 | 77,236 | 77,236 | 77,236 | 9,610 | | | 1,750 | 21,550 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Aceite BR | 100% | 49,417 | 49,417 | 54,908 | 54,908 | 32,095 | | | -17,140 | 20,200 |
| Aceite ER | 100% | 49,417 | 49,417 | 54,908 | 54,908 | 32,095 | | | 17,140 | 20,200 |
| FO UD BR | 100% | 96,398 | 96,398 | 99,380 | 99,380 | 36,305 | | | -16,700 | 20,610 |
| FO UD ER | 100% | 96,398 | 96,398 | 99,380 | 99,380 | 36,305 | | | 16,700 | 20,610 |
| FO Sed. BR | 100% | 146,884 | 146,884 | 151,427 | 151,427 | 41,235 | | | -16,300 | 20,960 |
| FO Sed. ER | 100% | 146,884 | 146,884 | 151,427 | 151,427 | 41,235 | | | 16,300 | 20,960 |
| Diesel BR | 100% | 383,795 | 383,795 | 426,439 | 426,439 | 47,608 | | | -15,200 | 22,055 |
| Diesel ER | 100% | 383,795 | 383,795 | 426,439 | 426,439 | 47,608 | | | 15,200 | 22,055 |
| Aguas grises | 0% | 247,326 | 0,000 | 164,884 | 0,000 | 51,307 | | | 0,000 | 0,041 |
| Lodos | 0% | 110,858 | 0,000 | 73,905 | 0,000 | 41,955 | | | 0,000 | 0,510 |
| FO Almacén BR | 97% | 3225,417 | 3128,655 | 3325,172 | 3225,417 | 240,182 | | | -6,205 | 13,372 |
| FO Almacén ER | 97% | 3225,417 | 3128,655 | 3325,172 | 3225,417 | 240,182 | | | 6,205 | 13,372 |
| Viveres | 1 | 4,375 | 4,375 | | | 57,000 | 57,000 | 57,000 | 0,000 | 39,200 |
| Total consumos | | | 7769,146 | | | 201,239 | | | 0,000 | 14,961 |
| | | | | | | | | | | |
| Tripulacion | 1 | 5,250 | 5,250 | | | 57,000 | 57,000 | 57,000 | 0,000 | 39,200 |
| Perterechos | 1 | 100,000 | 100,000 | | | 128,000 | 128,000 | 128,000 | 0,000 | 28,000 |
| Total pesos fijos | | | 105,250 | | | 124,458 | | | 0,000 | 28,559 |
| | | | | | | | | | | |
| Total Loadcase | | | 92943,027 | 220299,223 | 55254,649 | 131,943 | | | 0,000 | 11,751 |



Longitudinal Strength
Mass
Buoyancy
Grounding
Damage/NBV
Net Load
Shear
Moment
Shear 9,293
Moment 327,052
Grounding
Damage/NBV
Net Load
Mass
Buoyancy
Moment x10^3 tonne.m
Shear x10^3 tonne
Load t/m
Long. Pos. m
400
300
200
100
0
-100
-200
-300
-400
10
7,5
5
2,5
0
-2,5
-5
-7,5
-10
60000
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-30
0
30
60
90
120
150
180
210
240
270
300

| **Name** | **Long. Pos. m** | **Mass t/m** | **Buoyancy t/m** | **Grounding t/m** | **Damage/NBV t/m** | **Net Load t/m** | **Shear x10^3 tonne** | **Moment x10^3 tonne.m** |
|---|---|---|---|---|---|---|---|---|
| -1/4 | -5,304 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| 0 | -1,933 | 178,035 | 0,000 | 0,000 | 0,000 | 178,035 | 0,250 | -9,642 |
| 1/2 | 4,810 | 246,991 | -10,706 | 0,000 | 0,000 | 236,284 | 1,655 | -31,250 |
| 1 | 11,552 | 20,277 | -32,315 | 0,000 | 0,000 | -12,038 | 3,616 | -42,009 |
| 1 1/2 | 18,295 | -2,708 | -57,513 | 0,000 | 0,000 | -60,222 | 3,325 | -46,817 |
| 2 | 25,037 | -95,672 | -88,678 | 0,000 | 0,000 | -184,350 | 3,506 | -51,436 |
| 2 1/2 | 31,780 | -215,333 | -138,485 | 0,000 | 0,000 | -353,818 | 8,894 | -22,027 |
| 3 | 38,522 | -397,550 | -213,115 | 0,000 | 0,000 | -610,665 | 8,302 | 10,210 |
| 4 | 52,007 | 711,599 | -313,100 | 0,000 | 0,000 | 398,499 | 8,097 | 67,464 |
| 5 | 65,492 | 388,196 | -375,625 | 0,000 | 0,000 | 12,571 | 7,689 | 118,520 |
| 6 | 78,977 | -19,341 | -420,587 | 0,000 | 0,000 | -439,928 | 7,773 | 166,305 |
| 7 | 92,462 | -439,712 | -441,500 | 0,000 | 0,000 | -881,211 | 6,198 | 207,102 |
| 8 | 105,947 | 833,114 | -447,820 | 0,000 | 0,000 | 385,294 | 6,226 | 239,274 |
| 9 | 119,432 | 404,497 | -456,362 | 0,000 | 0,000 | -51,865 | 6,206 | 262,639 |
| 10 | 132,917 | -43,200 | -466,956 | 0,000 | 0,000 | -510,157 | 5,207 | 279,740 |
| 11 | 146,402 | 1265,293 | -469,143 | 0,000 | 0,000 | 796,150 | 5,484 | 296,993 |
| 12 | 159,887 | 803,546 | -468,767 | 0,000 | 0,000 | 334,779 | 5,134 | 317,742 |
| 13 | 173,372 | 349,053 | -465,212 | 0,000 | 0,000 | -116,159 | 4,460 | 326,790 |
| 14 | 186,857 | -96,844 | -456,533 | 0,000 | 0,000 | -553,378 | 3,257 | 321,689 |
| 15 | 200,342 | 1028,930 | -442,111 | 0,000 | 0,000 | 586,819 | 1,349 | 301,859 |
| 16 | 213,827 | 608,962 | -420,719 | 0,000 | 0,000 | 188,243 | 0,696 | 260,890 |
| 17 | 227,312 | 248,966 | -364,214 | 0,000 | 0,000 | -115,248 | -0,559 | 202,191 |
| 17 1/2 | 234,055 | 429,446 | -331,400 | 0,000 | 0,000 | 98,046 | -0,780 | 167,835 |
| 18 | 240,797 | 257,249 | -287,859 | 0,000 | 0,000 | -30,610 | 0,645 | 138,973 |
| 18 1/2 | 247,540 | 108,247 | -240,315 | 0,000 | 0,000 | -132,068 | 1,729 | 119,681 |
| 19 | 254,282 | 219,874 | -191,869 | 0,000 | 0,000 | 28,005 | 0,526 | 99,698 |
| 19 1/2 | 261,025 | 116,070 | -134,233 | 0,000 | 0,000 | -18,162 | -0,265 | 72,990 |
| 20 | 267,767 | 224,964 | -66,760 | 0,000 | 0,000 | 158,204 | -0,274 | 41,963 |
| 20 1/4 | 271,138 | 23,694 | -55,381 | 0,000 | 0,000 | -31,686 | -0,038 | 27,648 |
| 20 1/2 | 274,510 | -98,487 | -26,853 | 0,000 | 0,000 | -125,339 | 0,069 | 13,826 |
| st 1 | -11,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 2 | -9,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 3 | -7,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 4 | -5,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 5 | -3,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | -1,556 |
| st 6 | -1,933 | 178,035 | 0,000 | 0,000 | 0,000 | 178,035 | 0,250 | -9,642 |
| st 7 | 0,067 | 200,680 | -0,580 | 0,000 | 0,000 | 200,101 | 0,623 | -17,077 |
| st 8 | 2,067 | 213,012 | -4,254 | 0,000 | 0,000 | 208,757 | 1,035 | -23,579 |
| st 9 | 4,067 | 241,758 | -8,519 | 0,000 | 0,000 | 233,239 | 1,480 | -29,417 |
| st 10 | 6,067 | 255,847 | -14,412 | 0,000 | 0,000 | 241,435 | 1,953 | -34,322 |
| st 11 | 8,067 | 313,864 | -20,305 | 0,000 | 0,000 | 293,558 | 2,453 | -38,222 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| st 12 | 10,067 | 400,819 | -27,085 | 0,000 | 0,000 | 373,734 | 3,163 | -40,929 |
| st 13 | 12,067 | 5,651 | -34,128 | 0,000 | 0,000 | -28,477 | 3,585 | -42,326 |
| st 14 | 14,067 | -51,146 | -41,171 | 0,000 | 0,000 | -92,316 | 3,466 | -43,555 |
| st 15 | 16,067 | 120,922 | -48,760 | 0,000 | 0,000 | 72,162 | 3,387 | -45,032 |
| st 16 | 18,067 | 9,919 | -56,619 | 0,000 | 0,000 | -46,701 | 3,332 | -46,635 |
| st 17 | 20,067 | -101,085 | -64,479 | 0,000 | 0,000 | -165,563 | 3,276 | -48,238 |
| st 18 | 22,067 | 254,440 | -72,338 | 0,000 | 0,000 | 182,101 | 3,585 | -49,688 |
| st 19 | 24,067 | 18,674 | -83,186 | 0,000 | 0,000 | -64,512 | 3,559 | -50,875 |
| st 20 | 26,067 | -217,092 | -94,509 | 0,000 | 0,000 | -311,600 | 8,912 | -49,978 |
| st 21 | 27,067 | 481,048 | -100,170 | 0,000 | 0,000 | 380,878 | 8,767 | -45,213 |

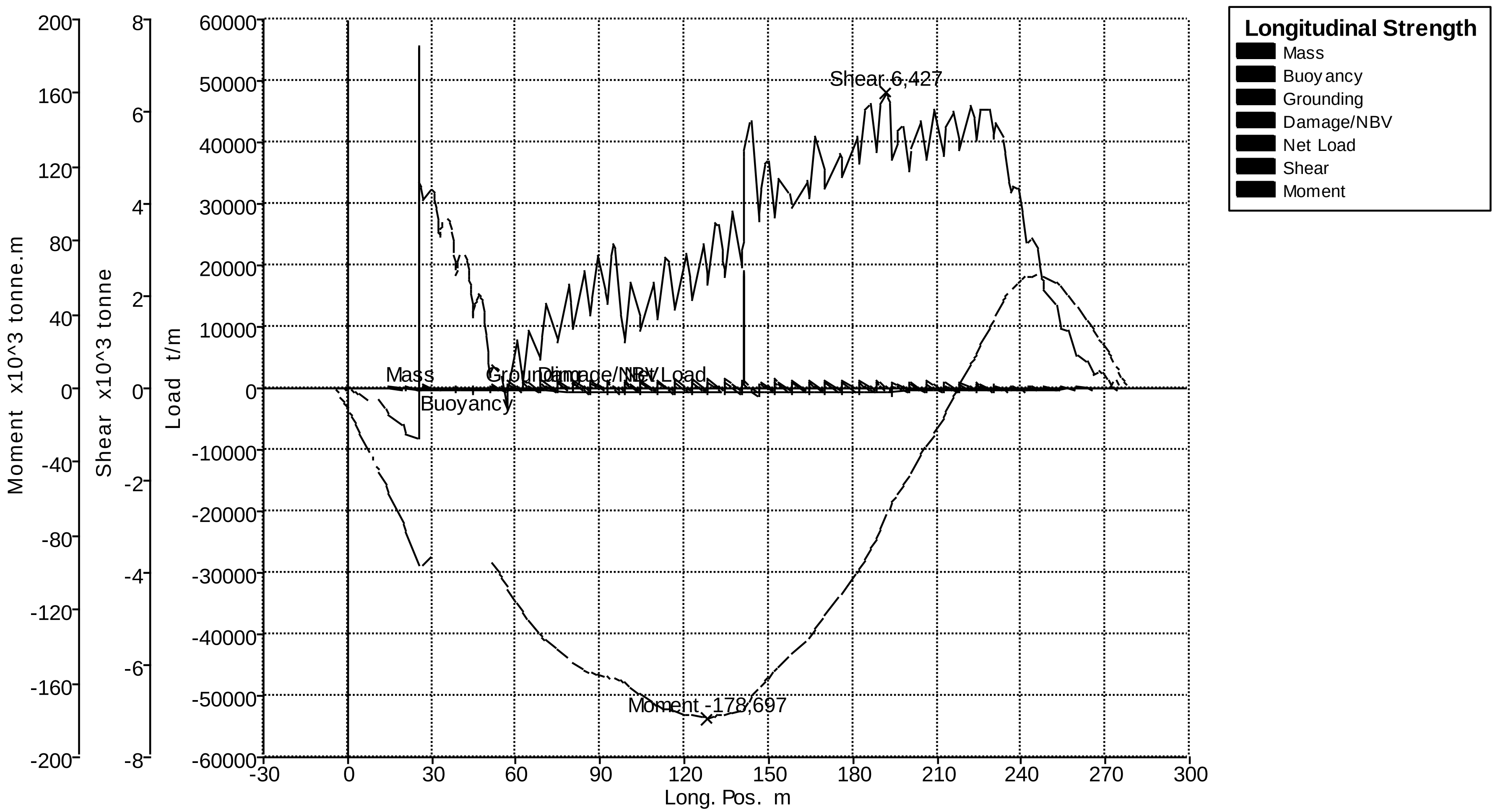
## Longitudinal Strength Calculation - Tanques final - copia (2)

Stability 20.00.04.9, build: 9
Model file: F:\TFM\CONTENIDO\TFG\CUADERNO 4\MÁSTER\Tanques final - copia (2) (Medium precision, 65 sections, Trimming off, Skin thickness not applied).
Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0,01000(0,100); Trim%(LCG-TCG): 0,01000(0,100); Heel%(LCG-TCG): 0,01000(0,100)

**Loadcase - C3 Llegada a puerto a plena carga**
**Damage Case - Intact**
Free to Trim
Specific gravity = 1,025; (Density = 1,025 tonne/m^3)
Fluid analysis method: Simulate fluid movement

| Item Name | Quantity | Unit Mass tonne | Total Mass tonne | Unit Volume m^3 | Total Volume m^3 | Long. Arm m | Aft. Limit m | Fwd. Limit m | Trans. Arm m | Vert. Arm m |
|---|---|---|---|---|---|---|---|---|---|---|
| rosca | 1 | 36703,970 | 36703,970 | | | 114,365 | | | 0,000 | 13,409 |
| Total rosca | | | 36703,970 | | | 114,365 | | | 0,000 | 13,409 |
| | | | | | | | | | | |
| Tanque 4 | 97% | 16408,559 | 15916,304 | 38159,440 | 37014,659 | 74,466 | | | 0,000 | 16,594 |
| Tanque 3 | 97% | 18646,092 | 18086,710 | 43363,003 | 42062,117 | 120,710 | | | 0,000 | 16,595 |
| Tanque 2 | 97% | 18646,092 | 18086,709 | 43363,003 | 42062,113 | 169,735 | | | 0,000 | 16,595 |
| Tanque 1 | 97% | 11961,030 | 11602,199 | 27816,349 | 26981,857 | 212,047 | | | 0,000 | 16,540 |
| Total carga | 97% | 65661,773 | 63691,922 | 152701,796 | 148120,746 | 139,714 | | | 0,000 | 16,585 |
| | | | | | | | | | | |
| Pique PP BR | 0% | 1728,991 | 0,000 | 1686,821 | 0,000 | 10,794 | | | -1,532 | 8,029 |
| Pique PP ER | 0% | 1728,991 | 0,000 | 1686,821 | 0,000 | 10,794 | | | 1,532 | 8,029 |
| Cofferdam 5 | 0% | 2627,904 | 0,000 | 2563,809 | 0,000 | 51,416 | | | 0,000 | 3,032 |
| Cofferdam 4 | 0% | 2666,826 | 0,000 | 2601,782 | 0,000 | 94,851 | | | 0,000 | 3,032 |
| Cofferdam 3 | 0% | 2666,819 | 0,000 | 2601,774 | 0,000 | 143,876 | | | 0,000 | 3,032 |
| Cofferdam 2 | 0% | 2666,833 | 0,000 | 2601,789 | 0,000 | 192,901 | | | 0,000 | 3,032 |
| Cofferdam 1 | 0% | 1573,708 | 0,000 | 1535,325 | 0,000 | 230,826 | | | 0,000 | 3,032 |
| Pique PR BR | 0% | 581,031 | 0,000 | 566,859 | 0,000 | 265,062 | | | -1,106 | 2,500 |
| Pique PR ER | 0% | 581,031 | 0,000 | 566,859 | 0,000 | 265,062 | | | 1,106 | 2,500 |
| Lastre 4 BR | 0% | 5014,252 | 0,000 | 4891,953 | 0,000 | 52,578 | | | -0,001 | 0,000 |
| Lastre 4 ER | 0% | 5014,252 | 0,000 | 4891,953 | 0,000 | 52,578 | | | 0,001 | 0,000 |
| Lastre 3 BR | 0% | 6457,632 | 0,000 | 6300,129 | 0,000 | 95,113 | | | -0,048 | 0,029 |
| Lastre 3 ER | 0% | 6457,632 | 0,000 | 6300,129 | 0,000 | 95,113 | | | 0,048 | 0,029 |
| Lastre 2 BR | 0% | 6146,861 | 0,000 | 5996,938 | 0,000 | 144,138 | | | -4,067 | 0,046 |
| Lastre 2 ER | 0% | 6146,861 | 0,000 | 5996,938 | 0,000 | 144,138 | | | 4,067 | 0,046 |
| Lastre 1 BR | 0% | 4253,564 | 0,000 | 4149,819 | 0,000 | 193,116 | | | -0,203 | 0,046 |
| Lastre 1 ER | 0% | 4253,564 | 0,000 | 4149,819 | 0,000 | 193,116 | | | 0,203 | 0,046 |
| Total lastre | 0% | 60566,752 | 0,000 | 59089,514 | 0,000 | 0,000 | | | 0,000 | 0,000 |
| | | | | | | | | | | |
| Agua dulce BR | 5% | 77,236 | 3,862 | 77,236 | 3,862 | 9,592 | | | -1,750 | 18,463 |
| Agua dulce ER | 5% | 77,236 | 3,862 | 77,236 | 3,862 | 9,592 | | | 1,750 | 18,463 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Aceite BR | 5% | 49,417 | 2,471 | 54,908 | 2,745 | 32,059 | | | -17,140 | 18,395 |
| Aceite ER | 5% | 49,417 | 2,471 | 54,908 | 2,745 | 32,059 | | | 17,140 | 18,395 |
| FO UD BR | 100% | 96,398 | 96,398 | 99,380 | 99,380 | 36,305 | | | -16,700 | 20,610 |
| FO UD ER | 100% | 96,398 | 96,398 | 99,380 | 99,380 | 36,305 | | | 16,700 | 20,610 |
| FO Sed. BR | 100% | 146,884 | 146,884 | 151,427 | 151,427 | 41,235 | | | -16,300 | 20,960 |
| FO Sed. ER | 100% | 146,884 | 146,884 | 151,427 | 151,427 | 41,235 | | | 16,300 | 20,960 |
| Diesel BR | 5% | 383,795 | 19,190 | 426,439 | 21,322 | 47,536 | | | -15,200 | 18,488 |
| Diesel ER | 5% | 383,795 | 19,190 | 426,439 | 21,322 | 47,536 | | | 15,200 | 18,488 |
| Aguas grises | 100% | 247,326 | 247,326 | 164,884 | 164,884 | 46,898 | | | 0,000 | 1,435 |
| Lodos | 100% | 110,858 | 110,858 | 73,905 | 73,905 | 38,565 | | | 0,000 | 1,804 |
| FO Almacén BR | 3,52% | 3225,417 | 113,534 | 3325,172 | 117,046 | 240,056 | | | -4,118 | 3,038 |
| FO Almacén ER | 3,52% | 3225,417 | 113,534 | 3325,172 | 117,046 | 240,056 | | | 4,118 | 3,038 |
| Viveres | 1 | 0,438 | 0,438 | | | 57,000 | 57,000 | 57,000 | 0,000 | 39,200 |
| Total consumos | | | 1123,300 | | | 81,526 | | | 0,000 | 10,982 |
| | | | | | | | | | | |
| Tripulacion | 1 | 5,250 | 5,250 | | | 57,000 | 57,000 | 57,000 | 0,000 | 39,200 |
| Perterechos | 1 | 100,000 | 100,000 | | | 128,000 | 128,000 | 128,000 | 0,000 | 28,000 |
| Total pesos fijos | | | 105,250 | | | 124,458 | | | 0,000 | 28,559 |
| | | | | | | | | | | |
| Total Loadcase | | | 101624,442 | 220299,223 | 149151,098 | 129,900 | | | 0,000 | 15,388 |



Longitudinal Strength
Mass
Buoyancy
Grounding
Damage/NBV
Net Load
Shear
Moment
Shear 6,427
Moment -178,697
Moment x10^3 tonne.m
Shear x10^3 tonne
Load t/m
Long. Pos. m

| Name | Long. Pos. m | Mass t/m | Buoyancy t/m | Grounding t/m | Damage/NBV t/m | Net Load t/m | Shear x10^3 tonne | Moment x10^3 tonne.m |
|---|---|---|---|---|---|---|---|---|
| -1/4 | -5,304 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| 0 | -1,933 | 0,000 | -7,153 | 0,000 | 0,000 | -7,153 | -0,012 | -6,696 |
| 1/2 | 4,810 | 4,838 | -31,511 | 0,000 | 0,000 | -26,673 | -0,121 | -26,055 |
| 1 | 11,552 | 20,277 | -65,277 | 0,000 | 0,000 | -45,001 | -0,278 | -46,505 |
| 1 1/2 | 18,295 | -2,708 | -102,812 | 0,000 | 0,000 | -105,520 | -0,738 | -69,236 |
| 2 | 25,037 | -95,672 | -149,177 | 0,000 | 0,000 | -244,850 | -1,076 | -94,633 |
| 2 1/2 | 31,780 | -240,029 | -236,524 | 0,000 | 0,000 | -476,553 | 3,792 | -88,724 |
| 3 | 38,522 | -382,542 | -302,433 | 0,000 | 0,000 | -684,975 | 2,546 | -84,363 |
| 4 | 52,007 | 518,635 | -391,378 | 0,000 | 0,000 | 127,257 | 0,475 | -96,120 |
| 5 | 65,492 | 550,360 | -445,327 | 0,000 | 0,000 | 105,033 | 1,089 | -127,900 |
| 6 | 78,977 | 133,646 | -480,676 | 0,000 | 0,000 | -347,029 | 2,147 | -147,341 |
| 7 | 92,462 | -297,798 | -488,010 | 0,000 | 0,000 | -785,808 | 1,840 | -156,662 |
| 8 | 105,947 | 966,328 | -493,594 | 0,000 | 0,000 | 472,734 | 1,577 | -167,436 |
| 9 | 119,432 | 528,361 | -500,804 | 0,000 | 0,000 | 27,557 | 2,562 | -176,111 |
| 10 | 132,917 | 79,464 | -506,988 | 0,000 | 0,000 | -427,524 | 3,274 | -177,065 |
| 11 | 146,402 | 998,225 | -504,378 | 0,000 | 0,000 | 493,847 | 3,672 | -162,367 |
| 12 | 159,887 | 934,783 | -501,370 | 0,000 | 0,000 | 433,412 | 4,083 | -141,750 |
| 13 | 173,372 | 489,939 | -492,539 | 0,000 | 0,000 | -2,600 | 4,778 | -117,047 |
| 14 | 186,857 | 63,003 | -479,936 | 0,000 | 0,000 | -416,933 | 5,781 | -84,574 |
| 15 | 200,342 | 1210,572 | -459,020 | 0,000 | 0,000 | 751,552 | 4,860 | -46,453 |
| 16 | 213,827 | 716,972 | -420,771 | 0,000 | 0,000 | 296,201 | 5,750 | -10,525 |
| 17 | 227,312 | 310,506 | -354,644 | 0,000 | 0,000 | -44,138 | 6,052 | 29,250 |
| 17 1/2 | 234,055 | -68,711 | -311,715 | 0,000 | 0,000 | -380,426 | 5,267 | 48,604 |
| 18 | 240,797 | -171,157 | -263,546 | 0,000 | 0,000 | -434,703 | 3,712 | 59,149 |
| 18 1/2 | 247,540 | -235,183 | -217,588 | 0,000 | 0,000 | -452,770 | 2,348 | 60,974 |
| 19 | 254,282 | 219,874 | -160,401 | 0,000 | 0,000 | 59,473 | 1,289 | 54,514 |
| 19 1/2 | 261,025 | 116,070 | -100,811 | 0,000 | 0,000 | 15,259 | 0,694 | 42,580 |
| 20 | 267,767 | 64,448 | -58,694 | 0,000 | 0,000 | 5,755 | 0,355 | 26,997 |
| 20 1/4 | 271,138 | -69,155 | -56,123 | 0,000 | 0,000 | -125,278 | 0,152 | 18,458 |
| 20 1/2 | 274,510 | -126,373 | -25,791 | 0,000 | 0,000 | -152,164 | 0,071 | 9,378 |
| st 1 | -11,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 2 | -9,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 3 | -7,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 4 | -5,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 5 | -3,933 | 0,000 | -3,825 | 0,000 | 0,000 | -3,825 | -0,001 | -1,057 |
| st 6 | -1,933 | 0,000 | -7,153 | 0,000 | 0,000 | -7,153 | -0,012 | -6,696 |
| st 7 | 0,067 | 5,344 | -13,298 | 0,000 | 0,000 | -7,955 | -0,030 | -12,362 |
| st 8 | 2,067 | -1,851 | -19,998 | 0,000 | 0,000 | -21,850 | -0,063 | -18,082 |
| st 9 | 4,067 | 7,025 | -28,223 | 0,000 | 0,000 | -21,198 | -0,101 | -23,871 |
| st 10 | 6,067 | 1,135 | -37,548 | 0,000 | 0,000 | -36,413 | -0,168 | -29,808 |
| st 11 | 8,067 | -2,488 | -47,150 | 0,000 | 0,000 | -49,638 | -0,245 | -35,790 |
| st 12 | 10,067 | 64,637 | -57,430 | 0,000 | 0,000 | 7,207 | -0,244 | -41,936 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| st 13 | 12,067 | 5,651 | -67,999 | 0,000 | 0,000 | -62,347 | -0,319 | -48,138 |
| st 14 | 14,067 | -51,146 | -78,698 | 0,000 | 0,000 | -129,844 | -0,495 | -54,530 |
| st 15 | 16,067 | 120,922 | -90,106 | 0,000 | 0,000 | 30,816 | -0,644 | -61,424 |
| st 16 | 18,067 | 9,919 | -101,514 | 0,000 | 0,000 | -91,596 | -0,729 | -68,439 |
| st 17 | 20,067 | -101,085 | -113,379 | 0,000 | 0,000 | -214,463 | -0,869 | -75,519 |
| st 18 | 22,067 | 254,440 | -127,785 | 0,000 | 0,000 | 126,655 | -1,038 | -83,154 |
| st 19 | 24,067 | 18,674 | -142,191 | 0,000 | 0,000 | -123,517 | -1,064 | -90,884 |
| st 20 | 26,067 | -217,092 | -156,643 | 0,000 | 0,000 | -373,735 | 4,340 | -96,503 |
| st 21 | 27,067 | 481,048 | -170,626 | 0,000 | 0,000 | 310,421 | 4,097 | -95,110 |

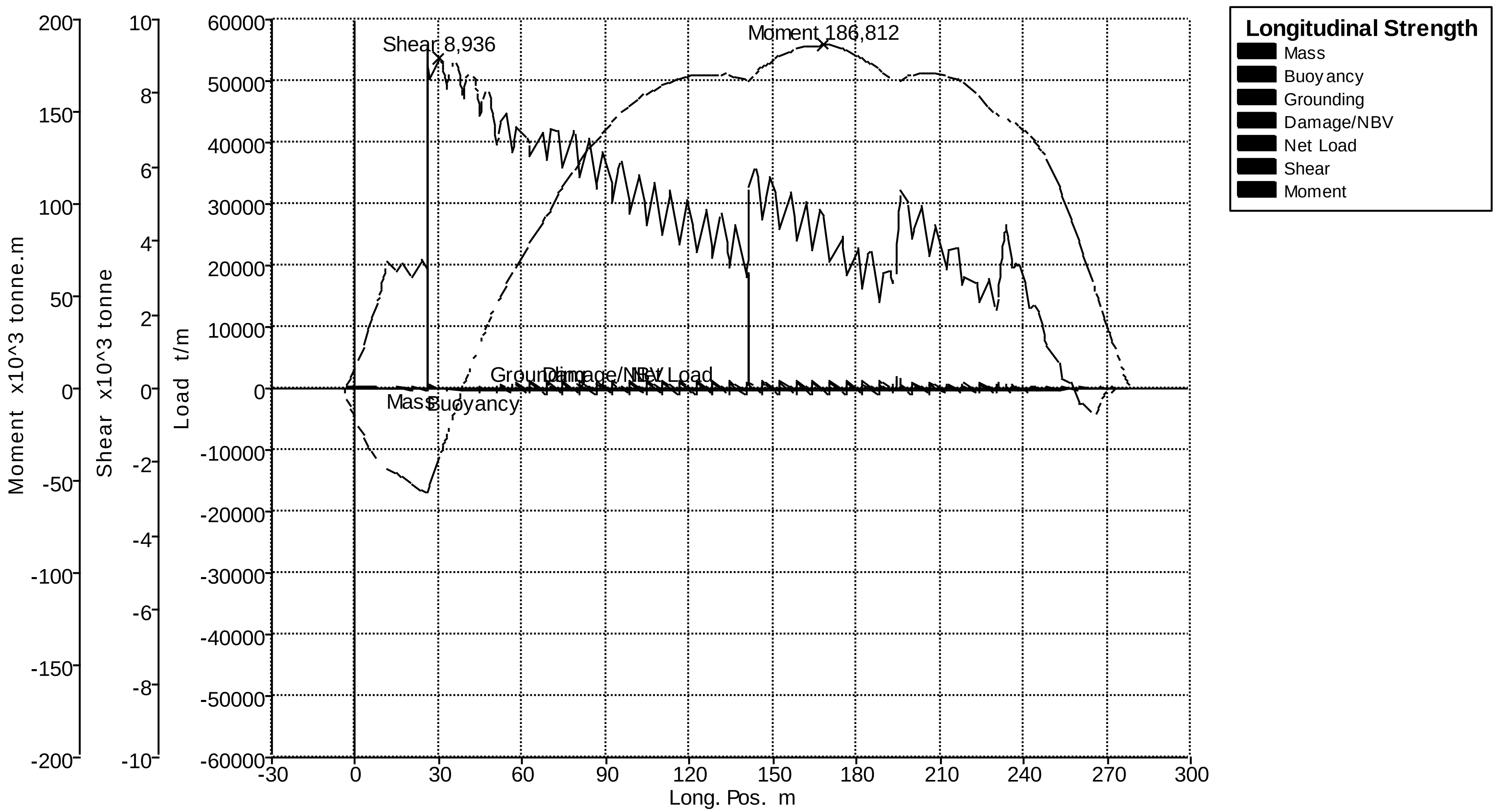
# Longitudinal Strength Calculation - Tanques final - copia (2)

Stability 20.00.04.9, build: 9
Model file: F:\TFM\CONTENIDO\TFG\CUADERNO 4\MÁSTER\Tanques final - copia (2) (Medium precision, 65 sections, Trimming off, Skin thickness not applied).
Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0,01000(0,100); Trim%(LCG-TCG): 0,01000(0,100); Heel%(LCG-TCG): 0,01000(0,100)

**Loadcase - C4 Llegada a puerto en lastre**
**Damage Case - Intact**
Free to Trim
Specific gravity = 1,025; (Density = 1,025 tonne/m^3)
Fluid analysis method: Simulate fluid movement

| **Item Name** | **Quantity** | **Unit Mass tonne** | **Total Mass tonne** | **Unit Volume m^3** | **Total Volume m^3** | **Long. Arm m** | **Aft. Limit m** | **Fwd. Limit m** | **Trans. Arm m** | **Vert. Arm m** |
|---|---|---|---|---|---|---|---|---|---|---|
| rosca | 1 | 36703,970 | 36703,970 | | | 114,365 | | | 0,000 | 13,409 |
| Total rosca | | | 36703,970 | | | 114,365 | | | 0,000 | 13,409 |
| | | | | | | | | | | |
| Tanque 4 | 0% | 16408,559 | 0,000 | 38159,440 | 0,000 | 54,366 | | | 0,000 | 3,032 |
| Tanque 3 | 0% | 18646,092 | 0,000 | 43363,003 | 0,000 | 97,873 | | | 0,000 | 3,032 |
| Tanque 2 | 0% | 18646,092 | 0,000 | 43363,003 | 0,000 | 146,898 | | | 0,000 | 3,032 |
| Tanque 1 | 0% | 11961,030 | 0,000 | 27816,349 | 0,000 | 195,860 | | | 0,000 | 3,032 |
| Total carga | 0% | 65661,773 | 0,000 | 152701,796 | 0,000 | 0,000 | | | 0,000 | 0,000 |
| | | | | | | | | | | |
| Pique PP BR | 100% | 1728,991 | 1728,991 | 1686,821 | 1686,821 | 4,740 | | | -7,841 | 14,783 |
| Pique PP ER | 100% | 1728,991 | 1728,991 | 1686,821 | 1686,821 | 4,740 | | | 7,841 | 14,783 |
| Cofferdam 5 | 0% | 2627,904 | 0,000 | 2563,809 | 0,000 | 51,416 | | | 0,000 | 3,032 |
| Cofferdam 4 | 0% | 2666,826 | 0,000 | 2601,782 | 0,000 | 94,851 | | | 0,000 | 3,032 |
| Cofferdam 3 | 0% | 2666,819 | 0,000 | 2601,774 | 0,000 | 143,876 | | | 0,000 | 3,032 |
| Cofferdam 2 | 100% | 2666,833 | 2666,833 | 2601,789 | 2601,789 | 194,272 | | | 0,000 | 17,036 |
| Cofferdam 1 | 100% | 1573,708 | 1573,708 | 1535,325 | 1535,325 | 232,175 | | | 0,000 | 17,045 |
| Pique PR BR | 100% | 581,031 | 581,031 | 566,859 | 566,859 | 268,686 | | | -1,906 | 16,155 |
| Pique PR ER | 100% | 581,031 | 581,031 | 566,859 | 566,859 | 268,686 | | | 1,906 | 16,155 |
| Lastre 4 BR | 100% | 5014,252 | 5014,252 | 4891,953 | 4891,953 | 73,863 | | | -15,611 | 9,342 |
| Lastre 4 ER | 100% | 5014,252 | 5014,252 | 4891,953 | 4891,953 | 73,863 | | | 15,611 | 9,342 |
| Lastre 3 BR | 100% | 6457,632 | 6457,632 | 6300,129 | 6300,129 | 119,611 | | | -15,946 | 8,500 |
| Lastre 3 ER | 100% | 6457,632 | 6457,632 | 6300,129 | 6300,129 | 119,611 | | | 15,946 | 8,500 |
| Lastre 2 BR | 100% | 6146,861 | 6146,861 | 5996,938 | 5996,938 | 167,618 | | | -15,733 | 8,698 |
| Lastre 2 ER | 100% | 6146,861 | 6146,861 | 5996,938 | 5996,938 | 167,618 | | | 15,733 | 8,698 |
| Lastre 1 BR | 100% | 4253,564 | 4253,564 | 4149,819 | 4149,819 | 213,247 | | | -13,942 | 11,812 |
| Lastre 1 ER | 100% | 4253,564 | 4253,564 | 4149,819 | 4149,819 | 213,247 | | | 13,942 | 11,812 |
| Total lastre | 86,85% | 60566,752 | 52605,202 | 59089,514 | 51322,149 | 140,146 | | | 0,000 | 10,513 |
| | | | | | | | | | | |
| Agua dulce BR | 5% | 77,236 | 3,862 | 77,236 | 3,862 | 9,583 | | | -1,750 | 18,463 |
| Agua dulce ER | 5% | 77,236 | 3,862 | 77,236 | 3,862 | 9,583 | | | 1,750 | 18,463 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Aceite BR | 5% | 49,417 | 2,471 | 54,908 | 2,745 | 32,040 | | | -17,140 | 18,395 |
| Aceite ER | 5% | 49,417 | 2,471 | 54,908 | 2,745 | 32,040 | | | 17,140 | 18,395 |
| FO UD BR | 100% | 96,398 | 96,398 | 99,380 | 99,380 | 36,305 | | | -16,700 | 20,610 |
| FO UD ER | 100% | 96,398 | 96,398 | 99,380 | 99,380 | 36,305 | | | 16,700 | 20,610 |
| FO Sed. BR | 100% | 146,884 | 146,884 | 151,427 | 151,427 | 41,235 | | | -16,300 | 20,960 |
| FO Sed. ER | 100% | 146,884 | 146,884 | 151,427 | 151,427 | 41,235 | | | 16,300 | 20,960 |
| Diesel BR | 5% | 383,795 | 19,190 | 426,439 | 21,322 | 47,499 | | | -15,200 | 18,488 |
| Diesel ER | 5% | 383,795 | 19,190 | 426,439 | 21,322 | 47,499 | | | 15,200 | 18,488 |
| Aguas grises | 100% | 247,326 | 247,326 | 164,884 | 164,884 | 46,898 | | | 0,000 | 1,435 |
| Lodos | 100% | 110,858 | 110,858 | 73,905 | 73,905 | 38,565 | | | 0,000 | 1,804 |
| FO Almacén BR | 3,52% | 3225,417 | 113,535 | 3325,172 | 117,046 | 240,009 | | | -4,124 | 3,038 |
| FO Almacén ER | 3,52% | 3225,417 | 113,535 | 3325,172 | 117,046 | 240,009 | | | 4,124 | 3,038 |
| Viveres | 1 | 0,438 | 0,438 | | | 57,000 | 57,000 | 57,000 | 0,000 | 39,200 |
| Total consumos | | | 1123,301 | | | 81,515 | | | 0,000 | 10,982 |
| | | | | | | | | | | |
| Tripulacion | 1 | 5,250 | 5,250 | | | 57,000 | 57,000 | 57,000 | 0,000 | 39,200 |
| Perterechos | 1 | 100,000 | 100,000 | | | 128,000 | 128,000 | 128,000 | 0,000 | 28,000 |
| Total pesos fijos | | | 105,250 | | | 124,458 | | | 0,000 | 28,559 |
| | | | | | | | | | | |
| Total Loadcase | | | 90537,723 | 220299,223 | 52352,501 | 128,949 | | | 0,000 | 11,714 |


Longitudinal Strength
Mass
Buoyancy
Grounding
Damage/NBV
Net Load
Shear
Moment
Shear 8,936
Moment 186,812
Mass
Buoyancy
Grounding
Damage/NBV
Net Load
Moment x10^3 tonne.m
Shear x10^3 tonne
Load t/m
Long. Pos. m
200
150
100
50
0
-50
-100
-150
-200
10
8
6
4
2
0
-2
-4
-6
-8
-10
60000
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
-60000
-30
0
30
60
90
120
150
180
210
240
270
300

| Name | Long. Pos. m | Mass t/m | Buoyancy t/m | Grounding t/m | Damage/NBV t/m | Net Load t/m | Shear x10^3 tonne | Moment x10^3 tonne.m |
|---|---|---|---|---|---|---|---|---|
| -1/4 | -5,304 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| 0 | -1,933 | 178,035 | -0,931 | 0,000 | 0,000 | 177,104 | 0,249 | -9,770 |
| 1/2 | 4,810 | 246,991 | -15,318 | 0,000 | 0,000 | 231,673 | 1,627 | -31,958 |
| 1 | 11,552 | 20,277 | -37,269 | 0,000 | 0,000 | -16,992 | 3,408 | -43,512 |
| 1 1/2 | 18,295 | -2,708 | -62,797 | 0,000 | 0,000 | -65,505 | 3,224 | -49,726 |
| 2 | 25,037 | -95,672 | -94,949 | 0,000 | 0,000 | -190,621 | 3,263 | -56,190 |
| 2 1/2 | 31,780 | -240,022 | -136,602 | 0,000 | 0,000 | -376,624 | 8,539 | -29,418 |
| 3 | 38,522 | -382,542 | -219,198 | 0,000 | 0,000 | -601,740 | 7,930 | -0,149 |
| 4 | 52,007 | 711,599 | -319,616 | 0,000 | 0,000 | 391,984 | 7,202 | 49,495 |
| 5 | 65,492 | 388,196 | -381,785 | 0,000 | 0,000 | 6,410 | 6,697 | 86,101 |
| 6 | 78,977 | -19,341 | -425,092 | 0,000 | 0,000 | -444,433 | 6,711 | 119,500 |
| 7 | 92,462 | -439,712 | -444,178 | 0,000 | 0,000 | -883,889 | 5,087 | 144,710 |
| 8 | 105,947 | 833,114 | -447,433 | 0,000 | 0,000 | 385,681 | 5,095 | 161,006 |
| 9 | 119,432 | 404,497 | -452,418 | 0,000 | 0,000 | -47,921 | 5,090 | 168,382 |
| 10 | 132,917 | -43,200 | -458,673 | 0,000 | 0,000 | -501,874 | 4,180 | 170,276 |
| 11 | 146,402 | 1265,293 | -455,363 | 0,000 | 0,000 | 809,930 | 4,634 | 174,149 |
| 12 | 159,887 | 803,546 | -454,486 | 0,000 | 0,000 | 349,061 | 4,470 | 184,464 |
| 13 | 173,372 | 349,053 | -447,857 | 0,000 | 0,000 | -98,803 | 3,919 | 185,171 |
| 14 | 186,857 | -96,844 | -435,669 | 0,000 | 0,000 | -532,513 | 3,057 | 174,941 |
| 15 | 200,342 | 1028,930 | -418,001 | 0,000 | 0,000 | 610,929 | 4,184 | 169,779 |
| 16 | 213,827 | 608,962 | -393,052 | 0,000 | 0,000 | 215,910 | 3,778 | 168,394 |
| 17 | 227,312 | 248,966 | -336,051 | 0,000 | 0,000 | -87,085 | 2,928 | 153,042 |
| 17 1/2 | 234,055 | -68,375 | -302,818 | 0,000 | 0,000 | -371,193 | 4,238 | 145,388 |
| 18 | 240,797 | -171,187 | -260,635 | 0,000 | 0,000 | -431,822 | 2,712 | 139,798 |
| 18 1/2 | 247,540 | -235,456 | -215,200 | 0,000 | 0,000 | -450,655 | 1,364 | 125,619 |
| 19 | 254,282 | 219,874 | -170,473 | 0,000 | 0,000 | 49,401 | 0,268 | 102,989 |
| 19 1/2 | 261,025 | 116,070 | -118,404 | 0,000 | 0,000 | -2,333 | -0,398 | 74,618 |
| 20 | 267,767 | 224,964 | -58,837 | 0,000 | 0,000 | 166,128 | -0,322 | 42,667 |
| 20 1/4 | 271,138 | 23,694 | -48,127 | 0,000 | 0,000 | -24,432 | -0,064 | 28,053 |
| 20 1/2 | 274,510 | -98,487 | -24,112 | 0,000 | 0,000 | -122,598 | 0,063 | 14,010 |
| st 1 | -11,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 2 | -9,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 3 | -7,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 4 | -5,933 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 | 0,000 |
| st 5 | -3,933 | 0,000 | -0,032 | 0,000 | 0,000 | -0,032 | 0,000 | -1,576 |
| st 6 | -1,933 | 178,035 | -0,931 | 0,000 | 0,000 | 177,104 | 0,249 | -9,770 |
| st 7 | 0,067 | 200,680 | -3,767 | 0,000 | 0,000 | 196,913 | 0,618 | -17,315 |
| st 8 | 2,067 | 213,012 | -8,287 | 0,000 | 0,000 | 204,725 | 1,021 | -23,991 |
| st 9 | 4,067 | 241,758 | -13,414 | 0,000 | 0,000 | 228,344 | 1,458 | -29,889 |
| st 10 | 6,067 | 255,847 | -19,298 | 0,000 | 0,000 | 236,549 | 1,921 | -34,992 |
| st 11 | 8,067 | 272,026 | -25,643 | 0,000 | 0,000 | 246,383 | 2,402 | -39,073 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| st 12 | 10,067 | 358,864 | -31,995 | 0,000 | 0,000 | 326,869 | 3,017 | -42,084 |
| st 13 | 12,067 | 5,651 | -39,097 | 0,000 | 0,000 | -33,446 | 3,375 | -43,968 |
| st 14 | 14,067 | -51,146 | -46,200 | 0,000 | 0,000 | -97,345 | 3,244 | -45,737 |
| st 15 | 16,067 | 120,922 | -53,302 | 0,000 | 0,000 | 67,620 | 3,314 | -47,540 |
| st 16 | 18,067 | 9,919 | -61,762 | 0,000 | 0,000 | -51,844 | 3,245 | -49,497 |
| st 17 | 20,067 | -101,085 | -70,857 | 0,000 | 0,000 | -171,941 | 3,062 | -51,516 |
| st 18 | 22,067 | 254,440 | -79,951 | 0,000 | 0,000 | 174,488 | 3,222 | -53,471 |
| st 19 | 24,067 | 18,674 | -89,575 | 0,000 | 0,000 | -70,902 | 3,394 | -55,345 |
| st 20 | 26,067 | -217,092 | -100,654 | 0,000 | 0,000 | -317,746 | 8,619 | -55,056 |
| st 21 | 27,067 | 481,048 | -106,193 | 0,000 | 0,000 | 374,855 | 8,454 | -50,649 |