UNIVERSIDADE DA CORUÑA

Escola Politécnica Superior

Trabajo Fin de Máster
CURSO 2017/2018

BUQUE BULKCARRIER DE 44.500 T.P.M.

Máster en Ingeniería Naval y Oceánica

ALUMNA

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FECHA

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Escola Politécnica Superior

TRABAJO FIN DE MÁSTER

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Máster en Ingeniería Naval y Oceánica

CUADERNO 8

CUADERNA MAESTRA

Escola Politécnica Superior
UNIVERSIDADE DA CORUÑA

DEPARTAMENTO DE INGENIERÍA NAVAL Y OCEÁNICA

PROYECTO FIN DE MASTER

CURSO 2.017-2.018

PROYECTO NÚMERO 18-03

TIPO DE BUQUE: Bulkcarrier

CLASIFICACIÓN, COTA Y REGLAMENTOS DE APLICACIÓN: ABS SOLAS MARPOL. DOBLE CASCO

CARACTERÍSTICAS DE LA CARGA: 44.500 T.P.M. Grano, mineral, carbón

VELOCIDAD Y AUTONOMÍA: 15 nudos en servicio AL 85% MCR +15%. MM 15.000 millas a la velocidad de servicio.

SISTEMAS Y EQUIPOS DE CARGA / DESCARGA: Escotillas de accionamiento hidráulico.

PROPULSIÓN: Motor diesel acoplado a una hélice de paso fijo

TRIPULACIÓN Y PASAJE: 28 personas

OTROS EQUIPOS E INSTALACIONES: Los habituales en este tipo de buque

Ferrol, Octubre de 2.017

ALUMNO: Dª Lucía Cachaza

ÍNDICE

1 INTRODUCCIÓN

El objetivo de este cuaderno es calcular el escantillonado de la cuaderna maestra.

El buque a proyectar tiene las siguientes características principales:

DWT = 44.500 t

Lpp = 180,14 m

B = 29,66 m

D = 16,13 m

T=12,07

2 DEFINICIÓN DE LAS DIMENSIONES DE ESCANTILLONADO

ESLORA DE ESCANTILLONADO (L)

La eslora de escantillonado viene definida en el apartado 3-1-1/3.1 del ABS como:

L_{sc}=max [0,96 ·L_{wl},min[0,97·L_{wl};Lpp]]

L_{wl}=183,49 m

0,97·L_{wl}=178,59 m

0,96·L_{wl}=176,75 m

L_{sc}=max [176,75;min[178,59;180,14]] → *L_{SC}=178,59 m≈178,60 m*

MANGA DE ESCANTILLONADO (B_{WL})

Se toma como manga de escantillonado la manga máxima del buque

$$B_{wl} = 29{,}66m$$

CALADO DE ESCANTILLONADO (d)

En el apartado 3-1-1/9 del ABS nos dice que se tomará como calado de escantillonado el calado en metros desde la línea de base hasta la línea de flotación de verano. En este caso se considerará el calado máximo que el buque es capaz de soportar en las condiciones de carga. Teniendo en cuenta los distintos calados del buque para las diferentes condiciones de carga estudiadas se establece un calado de escatillonado 12,071 y con el ánimo de ser más restrictivos a la hora de escantillonar la maestra tomaremos como calado de escantillonado *d= 12,50*.

PUNTAL DE ESCANTILLONADO (D)

En el apartado 3-1-1/7 del ABS se refiere al puntal de escantillonado:

$$D=16{,}13$$

DESPLAZAMIENTO (Δ)

Es el desplazamiento del buque medido en el calado de verano. De las hidrostáticas obtenemos el siguiente valor:

$$\Delta = 54.526\ t$$

COEFICIENTE DE BLOQUE (Cb)

El coeficiente de bloque al calado de escantillllonado será (apartado 3-1-1/11):

$$Cb=\frac{\Delta}{1{,}025 \cdot L \cdot Bwl \cdot d}=0{,}803$$

donde

Δ es el desplazamiento de diseño, Δ = 54.526 t

L es la eslora de escantillonado, L=178,60 m

B_{wl} es la manga de diseño al calado de verano, B_{wl}=29,66 m

d es el calado, d=12,50 m

3 DISEÑO CONCEPTUAL DE LA ESTRUCTURA

El escantillonado del buque proyecto se realizará siguiendo principalmente la Parte 3, Capítulo 2 ("*Estructura del casco y disposición*") y la Parte 5 del Reglamento ("*Tipos de buques especiales*"), Sección 3 del ABS.

La estructura del buque y sus escantillones son los que se muestran en el plano de la cuaderna maestra (*ANEXO V. Plano cuaderna maestra*)

El espaciado de cuadernas en las distintas zonas es el que se especifica en la siguiente tabla:

	S(mm)	CUADERNAS	Nº CUADERNAS
Pique de popa	500	Ppp(0)-15	15
Cámara de Maquinas	750	15-41	26
Bodega Nº7	750	41-69	28
Bodega Nº6	750	69-97	28
Bodega Nº5	750	97-125	28
Bodega Nº4	750	125-153	28
Bodega Nº3	750	153-181	28
Bodega Nº2	750	181-209	28
Bodega Nº1	750	209-233	24
Pique de proa	500	233-251	18

Comprobamos que los valores indicados son factibles según el reglamento del ABS que establece el siguiente máximo para espaciado entre cuadernas:

$$S=2{,}08\cdot L+438{,}0=809 \text{ mm} > 750 \text{ mm}$$

Se dispondrá bulárcamas cada 4 claras de cuaderna (2600 mm)

El anterior resultado debe de cumplir con la Parte 3, Sección 9 del reglamento ABS, que da el siguiente máximo para las bulárcamas: s_{max}=10ft=3048 mm

De acuerdo con lo especificado en el American Bureau of Shipping (Parte 3, Capítulo 2, Sección 4), la altura de doble fondo viene definida por la siguiente expresión:

$$d_{DB}=32\cdot B+190\sqrt{d}=32\cdot(29{,}66-2)+190\cdot\sqrt{d}=1650 \text{ mm}$$

Obtenemos así una altura de doble fondo de 1650 mm → Como este valor es un valor mínimo se incrementará un poco, por lo que el doble fondo se situará a 1700mm de altura.

Como se puede comprobar en los RPA de nuestro buque, este será de doble casco, las ventajas que se tendrán al haber optado por el doble casco son las siguientes:

- Mejor aprovechamiento de las bodegas ya que proporcionará un mejor acceso de la carga al tener mamparos lisos que facilitan las maniobras de estiba.
- Versatilidad en la disposición de tanques de lastre y combustible que facilitarán corregir escoras en las distintas condiciones de servicio.

En la cámara de máquinas se dispone una estructura transversal adecuada para asegurar la correcta resistencia y rigidez que requerirá el motor principal y el resto de maquinaria.

El reforzado interior del fondo y de las tolvas altas y bajas se dispone longitudinalmente.

En la zona de bodegas de carga, la cubierta principal es de estructura longitudinal.

La separación entre bodegas se realiza con mamparos con corrugas trapezoidales que disponen de una banqueta superior y una inferior.

El mamparo de proa de la cámara de máquinas es plano con refuerzos verticales. Los mamparos del pique de proa y de popa también son planos con refuerzos verticales en el interior de dichos tanques.

4 ESCANTILLONADO LOCAL

4.1 Cuadernas

Como indicábamos en el apartado anterior y cumpliendo con el reglamento ABS, el valor del espaciado entre cuadernas es de 750 mm.

4.2 Fondo

Como apuntaba en el *Diseño conceptual de la estructura*, la altura del doble fondo se obtendrá de acuerdo con lo especificado en el American Bureau of Shipping (Parte 3, Capítulo 2, Sección 4- 3.1.1(c)), por la siguiente expresión:

$$d_{DB} = 32 \cdot B + 190\sqrt{d} = 32 \cdot (29{,}66-2) + 190 \cdot \sqrt{d} = 1650 \text{ mm}$$

Obtenemos así una altura de doble fondo de 1650 mm → Como este valor es un valor mínimo se incrementará un poco, por lo que el doble fondo se situará a *1700 mm* de altura.

ESPESOR DE LA QUILLA VERTICAL

El espesor de la quilla vertical viene dado por la siguiente expresión (3-2-4/3.1.1 (a))

$$t = 0{,}056 \cdot L + 5{,}5 = 15{,}502 \text{ mm}$$

El espesor de las varengas llenas se calculará mediante la siguiente expresión (3-2-4/5.1):

$$t = 0{,}036 \cdot L + 4{,}7 + C = 12{,}630 \text{ mm}$$

donde

C= 1,5 mm (por tener el fondo y el doble fondo una estructura longitudinal).

DISTANCIA ENTRE VARENGAS

Estas varengas están asociadas a los longitudinales del doble fondo, y, en cada uno de ellos han de tener un refuerzo.

En este buque se colocarán varengas cada 3 cuadernas en zona de carga con una separación de 2475 mm.

ESPESOR DE LAS VAGRAS

Siguiendo el punto 3.2.4 / 3.1.1 (a) del Reglamento ABS:

- Vagra central: $t = 0{,}056 \cdot L + 5{,}5 = 15{,}502$ mm
- Vagra lateral: $t = (0{,}056 \cdot L + 5{,}5) \cdot 0{,}85 = 13{,}176$ mm

ESPESOR DEL FONDO

Siguiendo la expresión del ABS (3.2.2/3.13.2 (b)):

$$t = \left(\frac{s}{508}\right)\sqrt{(L-62{,}5)\frac{d}{Ds}} + 2{,}5 = 16{,}504 \text{ mm} \qquad 122 \text{ m} \leq L \leq 305 \text{ m}$$

En el caso de exceso de módulo en el fondo:

f_p (máxima tensión admisible) = 17,5 Kn/cm^2

K=0,34 (estructura longitudinal)

a=1,005 x 10^{-3}
H=0,0181·L + 3,516= 6,749 m
P_t= (0,638·H+d)·a = 0,017 kN/cm^2
σ_t= K·P_t(s/t)^2= 11,936 kN/cm^2

Si d/D ≥ 0,65 → R_n = $\sqrt{\frac{1}{\left(\frac{fp}{\sigma t}\right)\left(1-\frac{SMr}{SMa}\right)+1}}$

El valor de Rn debe ser mayor de 0,85→ R_n > 0,85
Si existiese exceso de módulo se debe de cumplir lo siguiente: $\frac{SMr}{SMa}$ > 0,7
El módulo mínimo (3-2-1/3.7.1b) se calcula como:

$$SM= C_1 \cdot C_2 L^2 \cdot B \cdot (Cb+0,7)=133836,618\ cm^2/m$$

donde:
C_1=9,412
C_2=0,01 (90 ≤ L ≤300)
En este caso tenemos un exceso de modulo en el fondo:
$\frac{SMr}{SMa}$ =0,902 > 0,7
Calculamos ahora el valor de nuestro R_n= 0,929
R_n= max (R_n ,0,85) = 0,929
t_{ms}=t· R_n=15,332 mm

Por otro lado, el reglamento indica además, que el espesor de la chapa no debe ser inferior al valor siguiente (3-2-2/3.17):

$$t_{min}=s \cdot \left(\frac{L-18,3}{42 \cdot L+1070}\right)$$

donde
s no será menor de 2,08·L + 438 mm →s=809,488 mm
s=max(s_0, min(0,88·s,813)) =max (825,min (712,350,813))=825 mm

Como decíamos antes existe un exceso de módulo, por este motivo el espesor del fondo debe obtenerse multiplicando la expresión de t_{min} por un factor R_b:

$$R_b=\sqrt{\frac{SMr}{SMa}} = 0,945 > 0,85$$

$$t_{ms\ min}= t_{min} \cdot R_b= 14,553\ mm$$

El espesor mínimo en los extremos de proa y popa se obtiene según la siguiente expresión (3-2-2/5.1):

$$t=0,035 \cdot (L+29)+0,009 \cdot s = 11766$$

s: espaciado entre cuadernas en los piques de proa y popa s= 500 mm
Como tanque profundo:

$$t=\left(\frac{s \cdot k \sqrt{q \cdot k}}{254}\right) + 2,5\ mm$$

α= 3000/ 825 = 3,636 >2 k=1
q= 235/235 =1 n/mm^2 (acero de resistencia normal)
h=17,805 m

$$t =\left(\frac{s \cdot k \sqrt{q \cdot k}}{254}\right) + 2,5 = 16,168\ mm$$

Por lo tanto la t= max (16168, 11766, 14553, 16504) =**16,504 mm**

LONGITUDINALES DE FONDO

Cada longitudinal del fondo con su plancha asociada tendrá un módulo no menos al obtenido con la expresión (3-2-4/11.3):

$$SM= 7{,}8 \cdot c \cdot h \cdot s \cdot l^2 = 640,549\ cm^3$$

donde:
c=1,3 (sin contrete)
s=0,825 m
h=12,5 m
l=2,475 m

Corrección por exceso de módulo de fondo:

$$R_l = \sqrt{\frac{1}{n+fp\left(1-\frac{SMr}{SMa}\right)}} = 0{,}830$$

$$SM= SM \cdot R_l = 531{,}656\ cm^3$$

Como tanque profundo:

$$SM= 7{,}8 \cdot c \cdot h \cdot s \cdot l^2 = 631{,}660\ cm^3$$

c= 0,9
s=0,825 m
h=16,13+0,375+1,3 = 17,805 m
l=2,475 m

Atendiendo a los requerimientos del ABS:

SM= max (640,549, 631,660) =**640,549 cm^3**

4.3 Doble fondo

ESPESOR DEL DOBLE FONDO

El espesor del doble fondo ha de ser como mínimo el obtenido mediante la expresión (3-2-4/9.1):

$$t=0{,}037 \cdot L+0{,}0009s-c$$

donde
c= 1,5 (estructura longitudinal)
s=825 mm

El espesor del doble fondo se corrige añadiendo 2 mm al espesor obtenido, calculamos a continuación → t=0,037·L+0,009 ·s-c= 14,533 mm

Al tratarse de un bulkcarrier el resultado obtenido mediante el apartado 3-2-4/9.1 debe incrementarse en 2,5 mm debido a la descarga en cucharas.

$$\Delta t=2{,}5\ mm \rightarrow t=14{,}533\ mm +2{,}5 =17{,}033\ mm$$

Calculamos también el espesor mínimo:

$$t_{min}=12,5+(19-12,5)\frac{(s-610)}{(915-610)}=17,082 \text{ mm}$$

Con taque profundo (3-2-10/3.1):

$$t=\left(\frac{s\cdot k\sqrt{q\cdot h}}{254}\right)+2,5=15,733 \text{ mm}$$

donde

k=1

q=1

h=16,13+0,375+1,8-1,7 = 16,605 m

s=825 mm

Debemos comprobar que este espesor no es menor de 6,5 mm o (s/150)+2,5→t=max (15,733,(s/150)+2,5) =15,733 mm

Podemos decir por lo tanto que el espesor del doble fondo corresponde a:

t=max (17,033; 17,082:15,733)= **17,082mm**

LONGITUDINALES DEL DOBLE FONDO

El módulo de los longitudinales del doble fondo con su plancha asociada debe tener un módulo mínimo no menos del 85% del requerido para los longitudinales del fondo (3-2-4/11.5):

$SM=0,85\cdot SM_b=0,85\cdot 640,549=544,467 \text{ cm}^3$

Como tanque profundo (3-2-10/3.3):

$SM=7,8\cdot c\cdot h\cdot s\cdot l^2=571,350 \text{ cm}^3$

donde:

c= 0,9

s=0,825 m

h=16,13+0,375+1,3-1,7=16,105 m

l=2,475 m

Con bodega inundable:

$SM=7,8\cdot c\cdot h\cdot s\cdot l^2=590 \text{ cm}^3$

donde:

c= 0,9

s=0,825 m

h=16,13+0,375+1,8-1,7=16,605 m

l=2,475 m

Atendiendo a los requerimientos del ABS:

SM= max (544,46; 571,350, 590) =**590 cm^3**

4.4 Cubierta

ESPESOR DE LA CUBIERTA

Atendiendo a la reglamentación ABS 3-2-3/5.1 el espesor de cubierta no debe ser menor al obtenido de las ecuaciones especificadas en el apartado 3-2-3/Tabla 1 del Reglamento ABS:

$t=0{,}009\cdot s_b+2{,}4 \rightarrow s_{cub}\leq 760$ mm (750 mm) → t= 9,15 mm

$t=\frac{Sb\cdot(L+48{,}76)}{26L+8681}\,mm \rightarrow L\leq 183$ m→t= 12,797 mm

Como techo de tanque de lastre alto (3-2-10/3.5):

$$t=\left(\frac{s\cdot k\,\sqrt{q\cdot h}}{254}\right)+2{,}5+1=7{,}321 \text{ mm}$$

donde

s=750 mm
k=1
$q=1\ N/mm^2$
h=0,375+1,3 = 1,675 m

Será por lo tanto el final de la cubierta el máximo de los valores calculados:

t=max (9,15; 12,797; 7,321) =**12,797 mm**

LONGITUDINALES DE CUBIERTA

Realizamos el cálculo del módulo necesario considerando los longitudinales del techo de tanque de lastre alto (3-2-7/3.1):

$SM=7{,}8\cdot c\cdot h\cdot s\cdot l^2=$ **621,938 cm³**

k=1 (cubierta principal)
$c=\frac{1}{1{,}709-0{,}651\cdot k}=0{,}945$
h= 12,50 m
s=0,750 m

4.5 Forro

ESPESOR DEL FORRO

- *Tanque lateral bajo*

El espesor del forro debe ser como mínimo en las zonas de proa y popa el siguiente (3-2-2/5.1):

$t_{min}=0{,}035\cdot(L+29)+0{,}009\cdot s=11{,}766$ mm

donde

s: espaciado entre cuadernas en la zona de los piques de proa y popa s= 500 mm

El espesor mínimo en la zona central del buque se calculará como (3-2-2/3.9):

$t=(\frac{s}{645})\sqrt{(L-15{,}2)\frac{d}{Ds}}+2{,}5 = 16{,}457$ mm

Como tanque profundo (3-2-10/3.1):

$t=\left(\frac{s\cdot k\sqrt{q\cdot h}}{254}\right)+2{,}5 = 15{,}140$ mm

q=1N/mm^2

α= 3000/800 = 3,75 > 2, por lo tanto el valor de k=1

h=16,105 mm

s=800 mm

Por lo tanto el espesor del forro en la zona del tanque lateral bajo, será como mínimo:

t= max (11,766;16,457;15,140) = **16,457 mm**

- *Zona de bodega*

El espesor del forro debe ser como mínimo en las zonas de proa y popa el siguiente (3-2-2/5.1):

t_{min}=0,035·(L+29) + 0,009·s= 11,766 mm

donde

s: espaciado entre cuadernas en la zona de los piques de proa y popa s= 500 mm

El espesor mínimo en la zona central del buque se calculará como (3-2-2/3.9):

$t=(\frac{s}{645})\sqrt{(L-15{,}2)\frac{d}{Ds}}+2{,}5 = 15{,}585$ mm

s es la separación entre cuadernas s= 750 mm

En el caso de la bodega inundable (3-2-10/3.1):

$t=\left(\frac{s\cdot k\sqrt{q\cdot h}}{254}\right)+2{,}5 = 13{,}823$ mm

q=1N/mm^2

α= 3000/800 = 3,75 > 2, por lo tanto el valor de k=1

h=14,705 mm

s=750 mm

Por lo tanto el espesor del forro en la zona de bodega, será:

t= max (11,766; 15,585; 13,823) = **15,585 mm**

- *Tanque lateral alto*

El espesor del forro debe ser como mínimo en las zonas de proa y popa el siguiente (3-2-2/5.1):

t_{min}=0,035·(L+29) + 0,009·s= 11,766 mm

donde

s: espaciado entre cuadernas en la zona de los piques de proa y popa s= 500 mm

El espesor mínimo en la zona central del buque se calculará como (3-2-2/3.9):

$t=(\frac{s}{645})\sqrt{(L-15{,}2)\frac{d}{Ds}}$ +2,5 = 16,457 mm

s es la separación entre los longitudinales del costado s= 800 mm

Como tanque profundo (3-2-10/3.1):

$t=\left(\frac{s\cdot k\sqrt{q\cdot h}}{254}\right)+2{,}5=$ 13,635 mm

q=1N/mm^2

α= 3000/800 = 3,75 > 2, por lo tanto el valor de k=1

h=d=12,5 mm

s=800 mm

Por lo tanto el espesor del forro en la zona del tanque lateral alto, será como mínimo:

t= max (11,766; 16,457; 13,635) = **16,457 mm**

LONGITUDINALES DEL COSTADO

- *Zona del tanque lateral bajo*

Atendiendo a lo establecido en el reglamento en el punto 3-2-5/3.17:

SM= 7,8·c·h·s·l^2 = 577,439 cm^3

donde:

c=0,95

h: Sobre 0,5·D (8,065 m) sobre la línea de base, la distancia vertical, en metros, desde el longitudinal hasta la cubierta resistente, pero no ha de ser menor de 2,13 metros. Y por debajo de 8,065 m sobre la línea de base, será 0,75 veces la distancia vertical en metros, desde el refuerzo longitudinal a la cubierta resistente, pero no menor de 0,5·D.

Teniendo en cuenta que el longitudinal más alejado de la cubierta resistente requerirá un módulo mayor según la fórmula, por lo que se efectuarán los cálculos para este caso:

h = 0,75· (16,13 −1.7) =10,823 m

s=0,800 m

l= 3 m

Como tanque profundo (3-2-10/3.3):

SM= 7,8·c·h·s·l^2 = 667,434 cm^3

donde:

c= 0,9

s=0,800 m

h=13,205 m

l=3 m

El módulo que deben tener los longitudinales del costado en el tanque lateral bajo es:

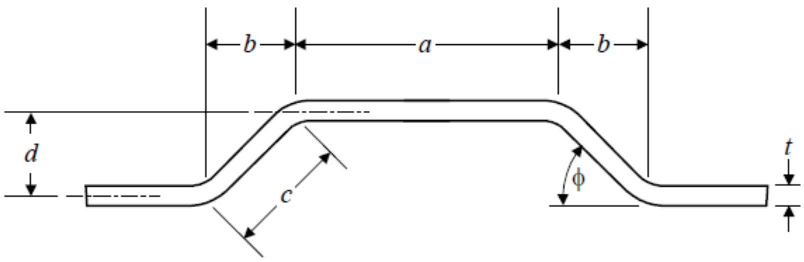
SM = max (577,439; 667,434) = **667,434 cm^3**

4.6 Escantillonado de mamparos corrugados

BODEGA INUNDABLE

Se pretende realizar el diseño del mamparo buscando el peso mínimo del mismo. El primer paso para conseguir esto es lograr el aprovechamiento óptimo del espesor de la plancha para una configuración dada, para ello se calcula el espesor del mamparo como si fuera una plancha y también, como si fuera un refuerzo de la siguiente forma: Se seguirá la nomenclatura del ABS para las diferentes partes de la corruga, que aparecen detalladas en la Figura:

FIGURE 3
Corrugated Bulkhead



Considerando el *mamparo corrugado como plancha* (apartado 3-2-10/3.1 del ABS):

3.1 Plating *(2017)*

Plating is to be of thickness obtained from the following equation:

$t = (sk\sqrt{qh}/254) + 2.5$ mm — but not less than 6.5 mm or $s/150 + 2.5$ mm, whichever is greater.

$t = (sk\sqrt{qh}/460) + 0.10$ in. — but not less than 0.25 in. or $s/150 + 0.10$ in., whichever is greater.

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donde:

s = máx.(a,c)

l_{corr}= D+ 0,5 − ($h_{doble\ fondo}$+ 3,57 + 3,00) = 8,36 m

α = l/a o l/c es siempre >2.0 ⇒ k =1

q = 1 para acero normal

h se calcula a partir de las dimensiones de la bodega:

h= D+ 0,5 + $h_{brazola}$ − ($h_{doble\ fondo}$+ 3,57) = 16,13+0,5+1,50-(1,7+3,570) = 12,860 m

Tomaremos las siguientes igualdades: a=c s=a

$$t_r=\left(\frac{a\cdot 1\sqrt{1\cdot 12,86}}{254}\right) + 2,5= 0,0142\cdot a + 2,5 \text{ mm}$$

Considerando el *mamparo corrugado como refuerzo* (apartado 3-2-10/3.3 del ABS):

3.3 Stiffeners

Each stiffener, in association with the plating to which it is attached, is to have section modulus *SM* not less than obtained from the following equation:

$SM = 7.8chs\ell^2$ cm^3

$SM = 0.0041chs\ell^2$ in^3

$$SM_r= 7,8\cdot c\cdot h\cdot s\cdot l^2 \text{ cm}^3$$

donde:

c = 0,9

b = a · cos(Φ) mm

s = (a + b)· 0,001 = a · 0,001· (1+ cos Φ) m

l_{corr}= D+ 0,5 − ($h_{doble\ fondo}$+ 3,57 + 3,00) = 8,36m

h= D+ 0,5 + $h_{brazola}$ − ($h_{doble\ fondo}$+ 3,57+ $\frac{lcorr}{2}$) = 8,85 m

Sustituyendo los parámetros anteriores en la expresión del módulo tenemos:

$$SM_r= 7,8\cdot c\cdot h\cdot s\cdot l^2 = 4,34 \text{ a} \cdot (1+ \cos \Phi) \text{ cm}^3$$

Calculamos ahora el (apartado 3-2-9/7.3):

$$SM_o=\frac{t\cdot d^2}{6} + \frac{a\cdot d\cdot t}{2} = \frac{t\cdot d}{2}\cdot\left(a + \frac{d}{3}\right) \text{ cm}^3$$

Teniendo en cuenta que d=c· sen Φ

La expresión queda de la siguiente forma:

$$SM_o=\frac{t\cdot a^2\cdot 0,001\cdot \text{sen}\Phi}{2}\cdot\left(1 + \frac{\text{sen }\Phi}{3}\right) \text{ cm}^3$$

El mamparo está diseñado óptimamente como refuerzo si se cumple: $SM_r = SM_o$

$$\frac{t \cdot a^2 \cdot 0{,}001 \cdot \text{sen}\Phi}{2} \cdot \left(1 + \frac{\text{sen } \Phi}{3}\right) = 4{,}34\ a \cdot (1 + \cos \Phi)$$

$$t_r \cdot a = \frac{8{,}68\ (1+\cos\Phi)}{0{,}001 \cdot \text{sen } \Phi (1 + \frac{\text{sen } \Phi}{3})}$$

Para obtener un diseño óptimo del mamparo impondremos dos condiciones que facilitarán el escantillonado del mamparo:

- El espesor obtenido como plancha y el obtenido como refuerzo, será el mismo por lo que podemos igualar las expresiones, obtenidas con anterioridad.
- El peso del mamparo será mínimo, por lo que se definirá el peso del mamparo en función de la variable Φ.

La superficie tapada por cada semionda es proporcional a → a+b luego el peso de metro de manga será proporcional a la función:

$W=\frac{(a+c) \cdot t}{a+b}$ cm²/cm→ a partir de las igualdades definidas anteriormente obtenemos que: $W=\frac{2a \cdot t}{a+b}$

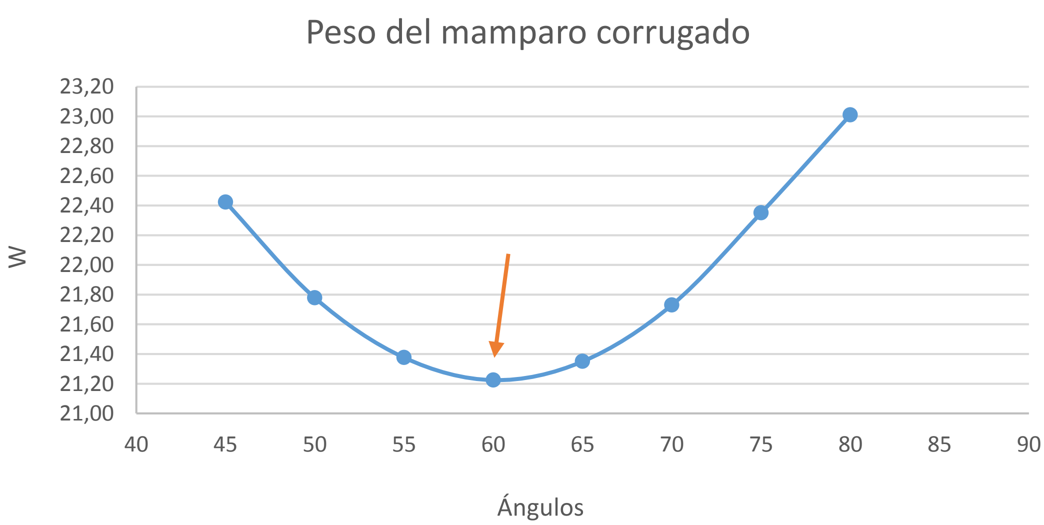
Podemos ahora calcular el ángulo Φ a partir de las expresiones obtenidas en los apartados anteriores. En este apartado se considerarán diversos valores del ángulo y, para cada uno de ellos, se calculará el peso del mamparo.

El reglamento del ABS propone un ángulo Φ de 45º o superior. Por lo tanto, se tomarán los valores que comprenden entre: 45º-85º

Φ (º)	45	50	55	60	65	70	75	80	85
a (mm)	1101,30	1018,11	954,83	902,75	859,25	827,25	786,25	756,25	1101,30
t (mm)	19,14	17,89	16,82	15,92	14,82	13,87	12,47	11,48	19,35
d (mm)	778,74	779,92	782,15	781,80	778,74	777,36	759,46	744,76	778,74
b (mm)	778,74	654,43	547,67	451,38	363,13	282,94	203,50	131,32	778,74
c(mm)	1101,30	1018,11	954,83	902,75	859,25	827,25	786,25	756,25	1101,30
W	22,42	21,78	21,38	21,22	21,35	21,73	22,35	23,01	22,42

Tabla 1 Peso del mamparo corrugado

De la anterior tabla desarrollada en Excel, obtenemos el siguiente gráfico que nos representa los diferentes pesos del mamparo corrugado para cada ángulo estudiado.



Como se puede observar en la anterior gráfica, el peso mínimo se consigue para un valor de Φ de 60º → W= 21,22 mm^2/mm.

El peso real del mamparo corresponderá a:

$$P_{mamparo} = W \cdot l_{corr} \cdot 7{,}85 = 8{,}36 \cdot 21{,}22 \cdot 7{,}85 = 1{,}392 \text{ t/m}$$

BODEGA NO INUNDABLE

El desarrollo seguido para el cálculo de las dimensiones de estos mamparos, que irán situados en aquellas bodegas dedicadas sólo a carga, es similar al seguido en el apartado anterior.

Considerando el *mamparo corrugado como plancha* (apartado 3-2-10/3.1 del ABS):

$$t = \left(\frac{s \cdot k\,\sqrt{q \cdot h}}{254}\right) + 2{,}5$$

donde:

s = máx.(a,c)

l_{corr}= D+ 0,5 − ($h_{doble\ fondo}$+ 3,57 + 3,00) = 8,36m

α = l/a o l/c es siempre >2.0 ⇒ k =1

q = 1 para acero normal

h se calcula a partir de las dimensiones de la bodega:

h= D+ 0,5 + − ($h_{doble\ fondo}$+ 3,57) = 16,13+0,5-(1,7+3,570) = 12,06 m

Tomaremos las siguientes igualdades: a=c   s=a

$$t_r = \left(\frac{a \cdot 1\,\sqrt{1 \cdot 12{,}06}}{254}\right) + 2{,}5 = 0{,}0137 \cdot a + 2{,}5 \text{ mm}$$

Considerando el *mamparo corrugado como refuerzo* (apartado 3-2-9/7.3 del ABS):

SM_r= 7,8·c·h·s·l^2

donde:

c = 0,9

b = a · cos(Φ) mm

s = (a + b)· 0,001 = a · 0,001· (1+ cos Φ) m

l_{corr}= D+ 0,5 − ($h_{doble\ fondo}$+ 3,57 + 3,00) = 8,36m

h= D+ 0,5 − ($h_{doble\ fondo}$+ 3,57+ $\frac{\text{lcorr}}{2}$) = 7,18 m

Sustituyendo los parámetros anteriores en la expresión del módulo tenemos:

SM_r= 7,8·c·h·s·l^2 = 3,523 a · (1+ cos Φ) cm^3

Calculamos ahora el (apartado 3-2-9/7.3):

$SM_o = \frac{t \cdot d^2}{6} + \frac{a \cdot d \cdot t}{2} = \frac{t \cdot d}{2} \cdot \left(a + \frac{d}{3}\right)$ cm^3

Teniendo en cuenta que d=c· sen Φ

La expresión queda de la forma siguiente:

$SM_o = \frac{t \cdot a^2 \cdot 0{,}001 \cdot \text{sen}\Phi}{2} \cdot \left(1 + \frac{\text{sen}\ \Phi}{3}\right)$ cm^3

El mamparo está diseñado óptimamente como refuerzo si se cumple: $SM_r = SM_o$

$\frac{t \cdot a^2 \cdot 0{,}001 \cdot \text{sen}\Phi}{2} \cdot \left(1 + \frac{\text{sen}\ \Phi}{3}\right)$ =3,523 a · (1+ cos Φ)

$$t_r = \frac{21138\ (1 + cos\Phi)}{a \cdot \text{sen}\ \Phi(3 + \text{sen}\Phi)}$$

Para obtener un diseño óptimo del mamparo impondremos dos condiciones que facilitarán el escantillonado del mamparo:

- El espesor obtenido como plancha y el obtenido como refuerzo será el mismo por lo que podemos igualar las expresiones, obtenidas con anterioridad.
- El peso del mamparo será mínimo, por lo que se definirá el peso del mamparo en función de la variable Φ.

La superficie tapada por cada semionda es proporcional a a+b luego el peso de metro de manga será proporcional a una función:

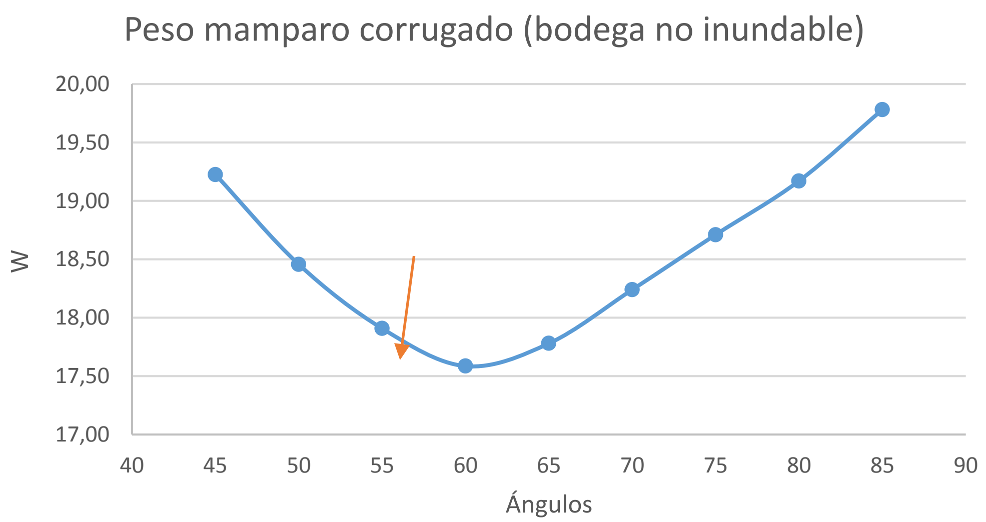
$W = \frac{(a+c) \cdot t}{a+b}$ cm^2/cm→ a partir de las igualdades definidas anteriormente obtenemos que: $W = \frac{2a \cdot t}{a+b}$

Podemos ahora calcular el ángulo Φ a partir de las expresiones obtenidas en los apartados anteriores. En este apartado se considerarán diversos valores del ángulo y, para cada uno de ellos, se calculará el peso del mamparo. El reglamento del ABS propone un ángulo Φ de 45º o superior. Por lo tanto, se tomarán los valores que comprenden entre: 45º-85º al igual que el apartado anterior.

Φ (º)	45	50	55	60	65	70	75	80	85
a (mm)	1015,30	984,89	960,34	845,17	801,42	762,16	626,73	596,73	1101,30
t (mm)	16,41	15,16	14,09	13,19	12,09	11,14	9,74	8,75	19,35
d (mm)	717,93	754,47	786,66	731,94	726,33	716,20	605,37	587,66	1097,11
b (mm)	717,93	633,08	550,83	422,59	338,69	260,67	162,21	103,62	95,98
c(mm)	1015,30	984,89	960,34	845,17	801,42	762,16	626,73	596,73	1101,30
W	19,23	18,46	17,91	17,59	17,78	18,24	18,71	19,17	19,78

Tabla 2 Peso del mamparo corrugado (Bodega no inundable)

De la anterior tabla desarrollada en Excel obtenemos el siguiente gráfico que nos representa lo diferentes pesos del mamparo corrugado para cada ángulo estudiado.



Como se puede ver en la gráfica “*Peso mamparo corrugado (bodega no inundable)”* el peso mínimo se consigue para un valor de Φ de 60º → W= 17,59 mm^2/mm

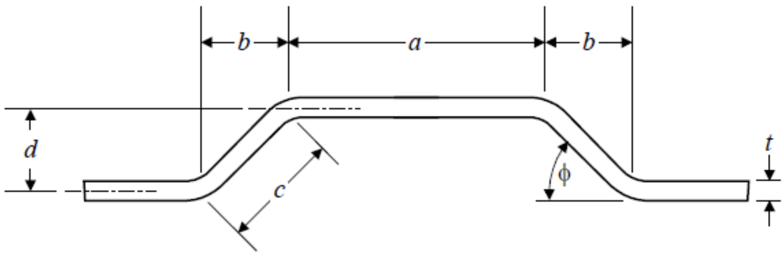
El pero real del mamparo corresponderá a:

$$P_{mamparo} = W \cdot l_{corr} \cdot 7{,}85 = 17{,}59 \cdot 8{,}36 \cdot 7{,}85 = 1{,}154 \text{ t/m}$$

Observando los resultados obtenidos para los mamparos de bodegas no inundables e inundables, se deduce que el valor más crítico lo presentan las bodegas inundables, por lo que las dimensiones finales de los mamparos corrugados serán:

a=c (mm)	902,75
b (mm)	451,38
d (mm)	781,80
t (mm^2/mm)	15,92
Φ (º)	60º

FIGURE 3
Corrugated Bulkhead



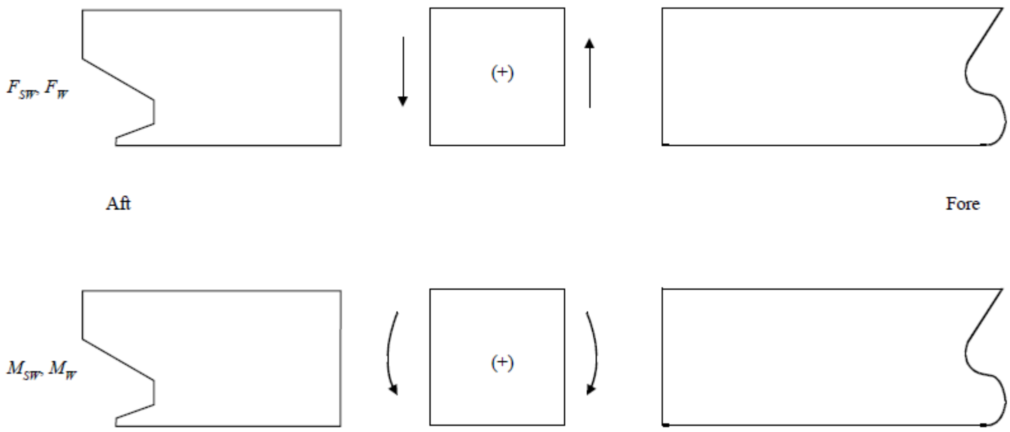
5 RESISTENCIA LONGITUDINAL

5.1 Momento flector inducido por la ola

El valor del momento flector máximo inducido por la ola viene indicado en la Regla 3-2-1/3.5 a partir de las siguientes expresiones:

Part 3 Hull Construction and Equipment
Chapter 2 Hull Structures and Arrangements
Section 1 Longitudinal Strength **3-2-1**

FIGURE 1
Sign Convention



M_{wh} (*Quebranto*) = $k_2 \cdot C_1 \cdot L^2 \cdot B \cdot C_b \cdot 10^{-3}$ =138474,2 *t·m*

M_{ws} (*Arrufo*) = $-k_1 \cdot C_1 \cdot L^2 \cdot B \cdot (C_b+0,7) \cdot 10^{-3}$= - 150132,78 *t·m*

donde

k_1 = 11,22

C_1 = 9,41

k_2 = 19,37

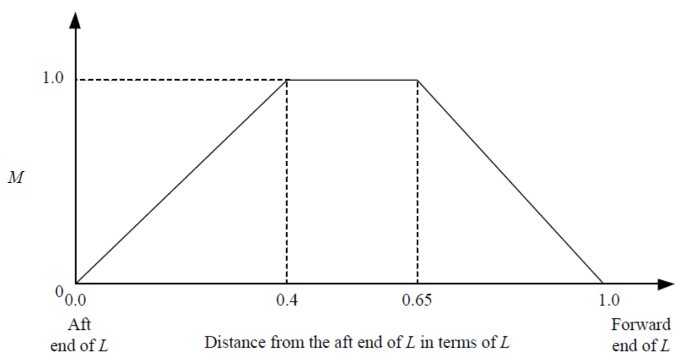
Podemos obtener la envolvente de momentos flectores multiplicando los valores obtenidos por la distribución del factor M. Hemos de tener en cuenta que hay que situar el extremo de la eslora de escantillonado en la perpendicular de proa.

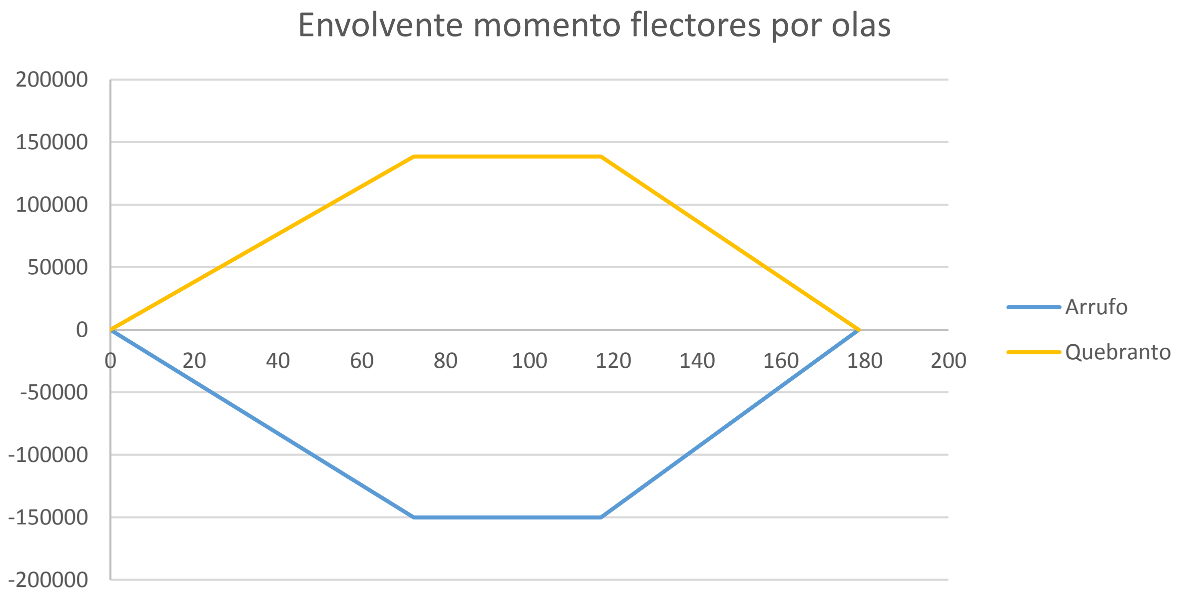
Para trazar la envolvente se determinan los siguientes puntos significativos:

0,40·L: 0,97 + L·0,40 = 73,026 m

0,65·L: 0,97 + L·0,65 = 118,061 m

FIGURE 2
Distribution Factor *M*

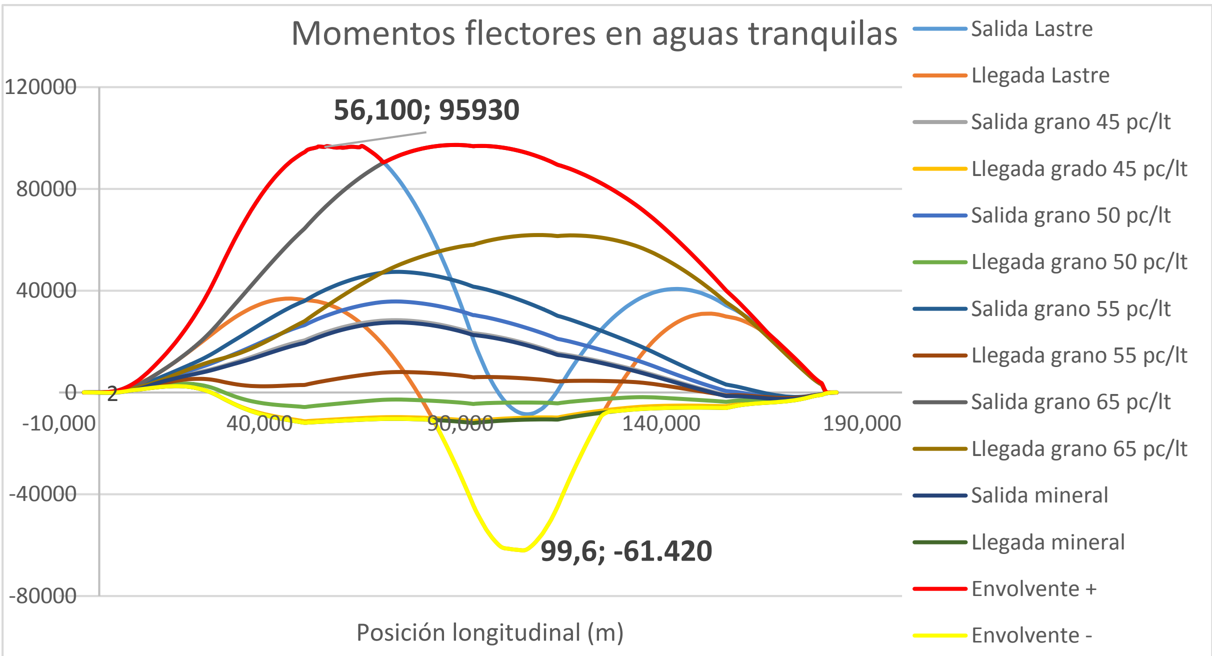




5.2 Momento flector en aguas tranquilas

El máximo momento flector en aguas tranquilas será el máximo momento flector obtenido de las condiciones de carga presentes en el cuaderno Nº5.

El gráfico siguiente recoge los valores máximos de los momentos flectores y su posición longitudinal para cada una de las condiciones de carga:



El máximo momento flector será:

Quebranto: M_{swhc}= 95930 t·m

Arrufo: M_{swsc}= -61420 t·m

5.3 Momento impuesto por el módulo mínimo reglamentario

El módulo mínimo reglamentario según el apartado 3-2-1/3.7 del ABS se calculará mediante la siguiente expresión:

$$SM_m=\frac{M_t}{f_p}\ m^3$$

donde:

f_p (máxima tensión admisible) = 1,784 t/cm^2=1,784·10^4 t/m^2

M_t (momento flector total) =M_{SWR}+M_W

M_{SWR}: momento flector en aguas tranquilas requerido por el reglamento

M_W: momento flector inducido por ola→ M_{ws} (Arrufo), M_{wh} (Quebranto)

Por lo tanto, si consideramos que el momento inducido por ola es el obtenido en el apartado anterior, podremos obtener el momento flector en aguas tranquilas requerido por el reglamento según lo siguiente:

Quebranto: $M_{swhr} = SM_m \cdot f_p - M_{wh}$

Arrufo: $M_{swsr} = SM_m \cdot f_p - M_{ws}$

El módulo mínimo requerido (SM_m) lo calcularemos según el apartado 3-2-1/3.7.1(b) del ABS:

$$SM = C_1 \cdot C_2 \cdot L^2 \cdot B \cdot (C_b+0,7) \cdot 10^{-4}$$

donde:

$C_1 = 10,75 - ((300-L)/100)^{1,5}$ (90≤ L ≤ 300)

$C_2 = 0,01$

De esta forma obtenemos los siguientes valores:

C_1 = 10,75 – ((300-173,84)/100)1,5 = 9,412

$SM_m = 9,41 \cdot 0,01 \cdot 178,60^2 \cdot 29,66 \cdot (0,80+0,7) \cdot 10^{-4}= 13,350\ m^3$

Sustituyendo en las fórmulas obtenemos:

Quebranto: $M_{swhr} = SM_m \cdot f_p - M_{wh}$= 99689,79 t·m

Arrufo: $M_{swsr} = SM_m \cdot f_p - M_{ws}$= - 88031,22 t·m

Para el diseño tomaremos los mayores momentos entre los calculados por las condiciones de carga y los impuestos por la Sociedad de Clasificación a través de la exigencia del módulo mínimo.

Quebranto: M_{swh} = max (M_{swhc}, M_{swhr}) = max (95930; 99689,79) = 99689,79 t·m

Arrufo: M_{sws} = max (M_{swsc}, M_{swsr}) = max **(**-61420; - 88031,22)= - 88031,22 t·m

5.4 Módulo reglamentario

Partiendo de los momentos en arrufo y quebranto calculados en el apartado anterior, obtendremos el módulo reglamentario para la sección maestra:

Quebranto: $SM_h=\frac{M_{wh}+M_{swh}}{f_p}$ = 13,350 m^3

Arrufo: $SM_s=\frac{M_{ws}+M_{sws}}{f_p}$ = 13,350 m^3

El modulo mínimo de la cuaderna maestra es el mayor de los tres valores de SM que hemos calculado:

$SM = \max(SM_m, SM_h, SM_s) = (13{,}350; 13{,}350; 13{,}350) = 13{,}350\ m^3$

Para los buques construidos con doble fondo, se puede suponer un exceso de módulo en el fondo de un 10%-12%, y en nuestro caso se ha considerado un exceso del 10%.

Cubierta→ $SM_d = SM = 13{,}350\ m^3$

Fondo→ $SM_b = 1{,}10 \cdot SM = 14{,}685\ m^3$

5.5 Inercia mínima reglamentaria

Según el apartado 3-2-1 /3.7.2 podemos calcular la inercia a través de la expresión:

$$I_R = \frac{L \cdot SM}{33{,}3} = 71{,}601\ m^4$$

5.6 Máxima fuerza cortante inducida por ola

Tal como se hizo con los momentos flectores se debe comprobar que el buque tiene capacidad suficiente para absorber las fuerzas cortantes que sufrirá para las distintas condiciones de carga.

En el apartado 3-2-1/3.5.3 del ABS se indica que la envolvente de fuerzas cortantes inducida por las olas viene definida a partir de las siguientes expresiones:

Quebranto: $F_{wn} = -k \cdot F_2 \cdot C_1 \cdot L \cdot B \cdot (C_b + 0{,}7) \cdot 10^{-2}$

Arrufo: $F_{wp} = +k \cdot F_1 \cdot C_1 \cdot L \cdot B \cdot (C_b + 0{,}7) \cdot 10^{-2}$

donde

$C_1 = 10{,}75 - ((300-173{,}84)/100)1{,}5 = 9{,}412$

k= 3,059

F_1: Factor de distribución reflejado en la figura 3 del apartado 3-2-1 (ABS)

F_2: Factor de distribución reflejado en la figura 4 del apartado 3-2-1 (ABS)

FIGURE 3
Distribution Factor F_1

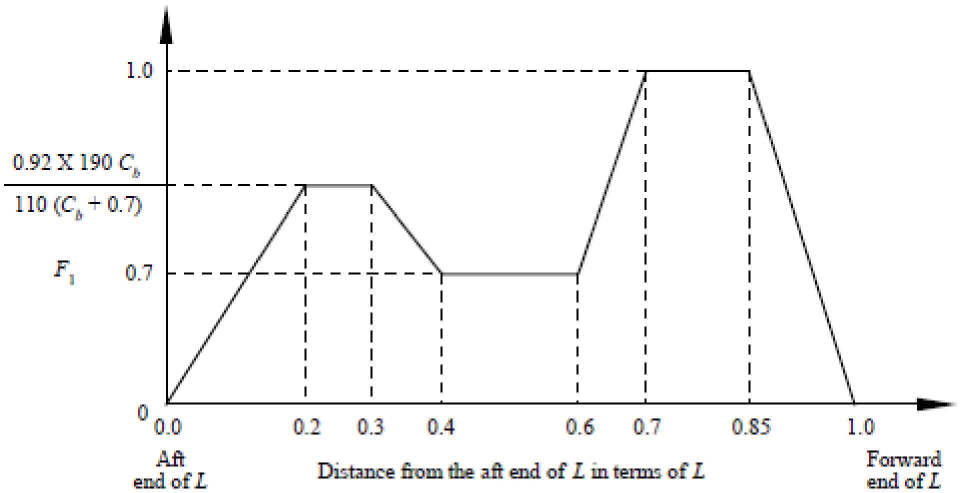
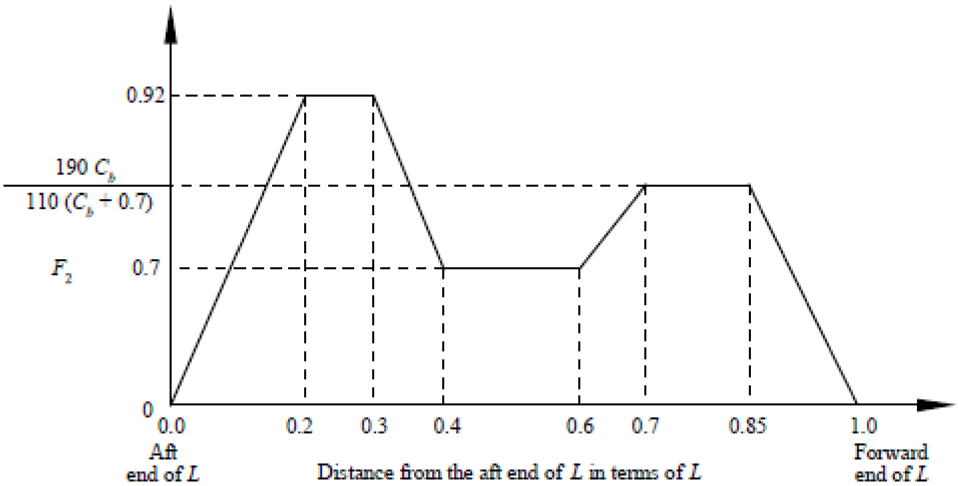


FIGURE 4
Distribution Factor F_2



La envolvente de fuerzas cortantes inducida por las olas se determina de la misma forma que la de momentos flectores.

Los puntos significativos son los siguientes:

0,20·L: 0,97 + L·0,20 = 36,998 m

0,30·L: 0,97 + L·0,30 = 55,012 m

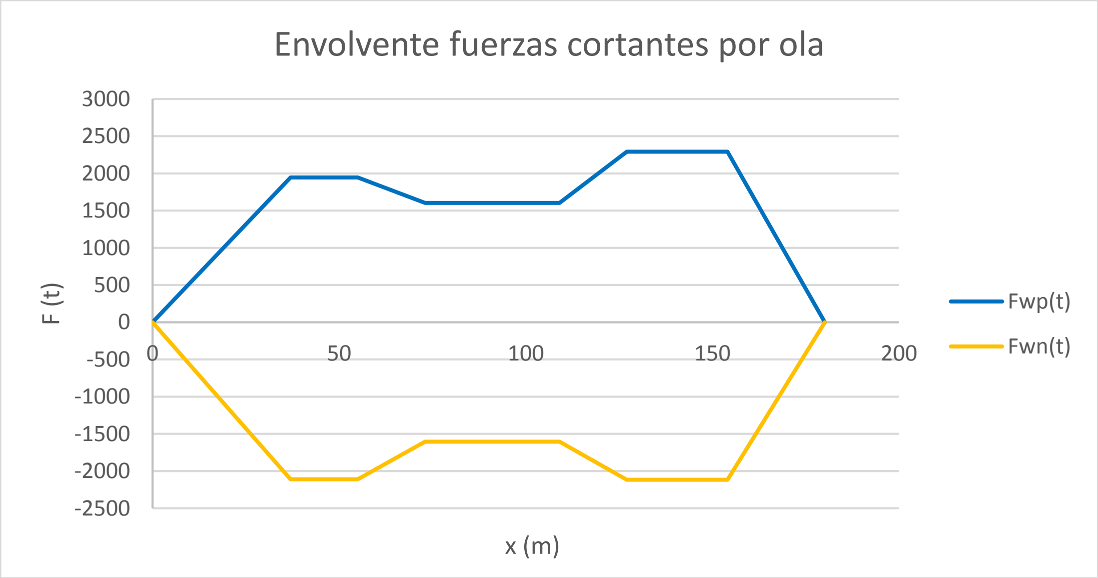
0,40·L: 0,97 + L·0,40 = 73,026 m

0,60·L: 0,97 + L·0,60 = 109,054 m

0,70·L: 0,97 + L·0,70 = 127,068 m

0,85·L: 0,97 + L·0,85 = 154,089 m

x(m)	F_1	F_2	Fwp(t)	Fwn(t)
0,000	0,000	0,000	0,000	0,000
36,998	0,849	0,920	1946,159	-2108,923
55,012	0,849	0,920	1946,159	-2108,923
73,026	0,700	0,700	1604,616	-1604,616
109,054	0,700	0,700	1604,616	-1604,616
127,068	1,000	0,923	2292,308	-2115,390
154,089	1,000	0,923	2292,308	-2115,390
180,140	0,000	0,000	0,000	0,000


Envolvente fuerzas cortantes por ola
3000
2500
2000
1500
1000
500
0
-500
-1000
-1500
-2000
-2500
F (t)
0
50
100
150
200
x (m)
Fwp(t)
Fwn(t)

6 CÁLCULO DE MÓDULO DE LA CUADERNA MAESTRA

Procederemos en este punto al cálculo del módulo de la cuaderna maestra así como al del eje neutro y la inercia total de la misma.

Los cálculos del módulo se mostrarán en una tabla desglosada en el *Anexo IV*, los resultados obtenidos de dicha tabla se resumen a continuación:

1. Altura del eje neutro respecto de la línea de base:

$$y_F = \frac{\sum A \cdot Y_G}{\sum A} = \frac{12861368,54}{19312,38} = 6,659 \text{ m}$$

2. Distancia del eje neutro a cubierta

$$y_c = D - y_F = 16,130 - 6,659 = 9,471 \text{ m}$$

3. Momento de inercia de la sección maestra con respecto al eje neutro

$$\frac{1}{2} = I_O + \sum A \cdot y^2 - A_t \cdot t^2 \ (cm^2m^2)$$

$$I = 153,489 \ m^4$$

4. Módulos resistentes en cubierta y fondo:

$$SM_F = \frac{I}{Y_F} = \frac{153,489}{6,659} = 23,048$$

$$SM_C = \frac{I}{Y_C} = \frac{153,489}{9,471} = 16,207$$

Cuaderna maestra	
Altura eje neutro respecto LB	6,659 m
Distancia eje neutro a cubierta	9,471 m
Inercia mínima de la maestra	71,601 m^4
Inercia de la maestra	153,489 m^4
Módulo mínimo en la cubierta	13,350 m^3
Módulo mínimo en el fondo	14,685 m^3
Módulo resistente en la cubierta	16,207 m^3
Módulo resistente en el fondo	23,048 m^3

Con estos datos procedemos a calcular los *momentos en aguas tranquilas* tanto en fondo como en cubierta escogiendo de ellos el menor debido a que de este modo calculamos el máximo momento flector en aguas tranquilas que puede resistir nuestra cuaderna:

ARRUFO

Cubierta:

$M_{WS} = SM \cdot 1,784 \cdot 10^4 - M_{WS} = 16,207 \cdot 1,784 \cdot 10^4 - 150132,78 = 139000,1$ t·m

Fondo:

$M_{WS} = SM \cdot 1,784 \cdot 10^4 - M_{WS} = 23,048 \cdot 1,784 \cdot 10^4 - 150132,78 = 261043,54$ t·m

$M_{WS} = -\ 261043,54$ t·m

QUEBRANTO

Cubierta:

$M_{WH} = SM \cdot 1,784 \cdot 10^4 - M_{WS} = 16,207 \cdot 1,784 \cdot 10^4 - 138474,2 = 150658,68$ t·m

Fondo:

M_{WH} = SM· 1,784 ·10^4 –M_{WS} =23,048·1,784·10^4–138474,2 =272702,12 t ·m

M_{WH} = 272702,12 t ·m

Obtenemos también el valor de la fuerza cortante total mediante la siguiente expresión correspondiente al apartado del ABS 3-2-1/3.9:

$$f_s = \frac{(\mathrm{Fsw} + F_W)\cdot m}{2\cdot t_S \cdot I}$$

donde:

F_{sw} es el esfuerzo en aguas tranquilas

F_W es el esfuerzo cortante inducido por las olas

f_s se tomará un valor de110 t/cm^2

m es el momento estático con respecto al eje neutro de la parte de la cuaderna situada por encima de él.

t_s es el espesor del costado en la zona del eje neutro (0,017)

I es el momento de inercia, dato que se calculó con el módulo de la cuaderna (153,489 m^4)

De esta expresión podemos despejar el esfuerzo cortante en aguas tranquilas.

$\mathrm{Fsw} + F_W = \frac{(f_s \cdot 2 \cdot t_S \cdot I)}{m}$ = 375033,281 t

6.1 Comprobación del módulo mínimo e inercia de la cuaderna maestro

Una vez obtenidos los valores del módulo e inercia de nuestra maestra, los comparamos con los obtenidos por el Reglamento y vemos si cumple o no.

SM_c = 16,207 m^3 > 13,350 m^3 → CUMPLE

SM_f = 23,048 m^3 > 14,685 m^3 → CUMPLE

Inercia cuaderna maestra = 153,489 m^4 > 71,601 m^4 → CUMPLE

7 PLANO CUADERNA MAESTRA

El plano de la cuaderna maestra se adjunta como *ANEXO V.*

8 REFERENCIAS

Alvariño, Ricardo; Azpiroz, Juan José; Meizoso, Manuel. *El Proyecto Básico Del Buque Mercante*. Fondo editorial de Ingeniería Naval, Colegio Oficial de Ingenieros Navales (edit.). Madrid: 1997. ISBN: 84-921750-2-8.

LAMB, T. *Ship Design and Construction.* Jersey City: The Society of Naval Architects and Marine Engineers, 2003. ISBN: 0-939773-40-6.

ANEXO I. REGLAMENTO ABS

TABLE 2
Tensile Properties of Ordinary Strength Hull Structural Steel 100 mm (4.0 in.) and Under *(2008)*

Grade	*Tensile Strength N/mm² (kgf/mm², ksi)*	*Yield Point min. N/mm² (kgf/mm², ksi)*	*Elongation* [1, 3, 4] *min. %*
A, B, D, E	400-520 [2] (41-53, 58-75)	235 (24, 34)	22

Notes:

1 Based on alternative A flat test specimen or alternative C round specimen in 2-1-1/Figure 2.

2 For Grade A sections, the upper limit of tensile strength may be 550 N/mm² (56 kgf/mm², 80 ksi).

3 Minimum elongation for alternative B flat specimen in 2-1-1/Figure 2 is to be in accordance with 2-1-2/Table 3.

4 *(2008)* Minimum elongation for ASTM E8M/E8 or A370 specimen is 2-1-2/Table 3 for 200 mm (8 in.) specimen and 22% for 50 mm (2 in.) specimen.

5 Steel ordered to cold flanging quality may have tensile strength range of 380-450N/mm² (39-46 kgf/mm², 55-65 ksi) and a yield point of 205N/mm² (21 kgf/mm², 30 ksi) minimum. See also 2-1-2/13.5 and 3-1-2/1.1 of the *Steel Vessel Rules*.

TABLE 3
Elongation Requirements for Alternative B Specimen *(1995)*

	Thickness in mm (in.)							
exceeding		5 (0.20)	10 (0.40)	15 (.60)	20 (.80)	25 (1.0)	30 (1.2)	40 (1.6)
not exceeding	5 (0.20)	10 (0.40)	15 (.60)	20 (.80)	25 (1.0)	30 (1.2)	40 (1.6)	50 (2.0)
elongation (min. %)	14	16	17	18	19	20	21	22

TABLE 4
Impact Properties of Ordinary-Strength Hull Structural Steel 100 mm (4.0 in.) and Under *(2008)*

		Average Absorbed Energy [1] *J (kgf-m, ft-lbf)*					
		t ≤ 50 mm (2.0 in.)		*50 mm (2.0 in) < t ≤ 70 mm (2.8 in.)*		*70 mm (2.8 in.) < t ≤ 100 mm (4.0 in)*	
Grade	*Temperature °C (°F)*	*Long'l* [2]	*Transv* [2]	*Long'l* [2]	*Transv* [2]	*Long'l* [2]	*Transv* [2]
A	20 (68)	—	—	34 (3.5, 25) [3]	24 (2.4, 17) [3]	41 (4.2, 30) [3]	27 (2.8, 20) [3]
B [4]	0 (32)	27 (2.8, 20)	20 (2.0, 14)	34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)
D	-20 (-4)	27 (2.8, 20)	20 (2.0, 14)	34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)
E	-40 (-40)	27 (2.8, 20)	20 (2.0, 14)	34 (3.5, 25)	24 (2.4, 17)	41 (4.2, 30)	27 (2.8, 20)

Notes:

1 The energy shown is minimum for full size specimen. See 2-1-2/ 11.5 for subsize specimen requirements.

2 Either direction is acceptable.

3 Impact tests for Grade A are not required when the material is produced using a fine grain practice and normalized.

4 CVN test requirements for Grade B apply where such test is required by 2-1-2/Table 5.

3.5 Wave Loads

3.5.1 Wave Bending Moment Amidships

The wave bending moment, expressed in kN-m (tf-m, Ltf-ft), may be obtained from the following equations:

$M_{ws} = -k_1 C_1 L^2 B(C_b + 0.7) \times 10^{-3}$ Sagging Moment

$M_{wh} = +k_2 C_1 L^2 B C_b \times 10^{-3}$ Hogging Moment

where

k_1 = 110 (11.22, 1.026)

k_2 = 190 (19.37, 1.772)

$C_1 = 10.75 - \left(\frac{300 - L}{100}\right)^{1.5}$ $\quad 90 \le L \le 300$ m

$= 10.75$ $\quad 300 < L < 350$ m

$= 10.75 - \left(\frac{L - 350}{150}\right)^{1.5}$ $\quad 350 \le L \le 500$ m

$C_1 = 10.75 - \left(\frac{984 - L}{328}\right)^{1.5}$ $\quad 295 \le L \le 984$ ft

$= 10.75$ $\quad 984 < L < 1148$ ft

$= 10.75 - \left(\frac{L - 1148}{492}\right)^{1.5}$ $\quad 1148 \le L \le 1640$ ft

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

B = breadth of vessel, as defined in 3-1-1/5, in m (ft)

C_b = block coefficient, as defined in 3-1-1/11.3, but is not to be taken less than 0.6

3.5.2 Envelope Curve of Wave Bending Moment

The wave bending moment along the length, L, of the vessel may be obtained by multiplying the midship value by the distribution factor M, given by 3-2-1/Figure 2.

3.5.3 Wave Shear Force

The envelopes of maximum shearing forces induced by waves, F_w, as shown in 3-2-1/Figure 3 and 3-2-1/Figure 4, may be obtained from the following equations.

$F_{wp} = +kF_1 C_1 L B (C_b + 0.7) \times 10^{-2}$ For positive shear force

$F_{wn} = -kF_2 C_1 L B (C_b + 0.7) \times 10^{-2}$ For negative shear force

where

F_{wp}, F_{wn} = maximum shearing force induced by wave, in kN (tf, Ltf)

C_1 = as defined in 3-2-1/3.5.1

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

B = breadth of vessel, as defined in 3-1-1/5, in m (ft)

C_b = block coefficient, as defined in 3-1-1/11.3, but not to be taken less than 0.6

k = 30 (3.059, 0.2797)

F_1 = distribution factor, as shown in 3-2-1/Figure 3

F_2 = distribution factor, as shown in 3-2-1/Figure 4

FIGURE 1
Sign Convention

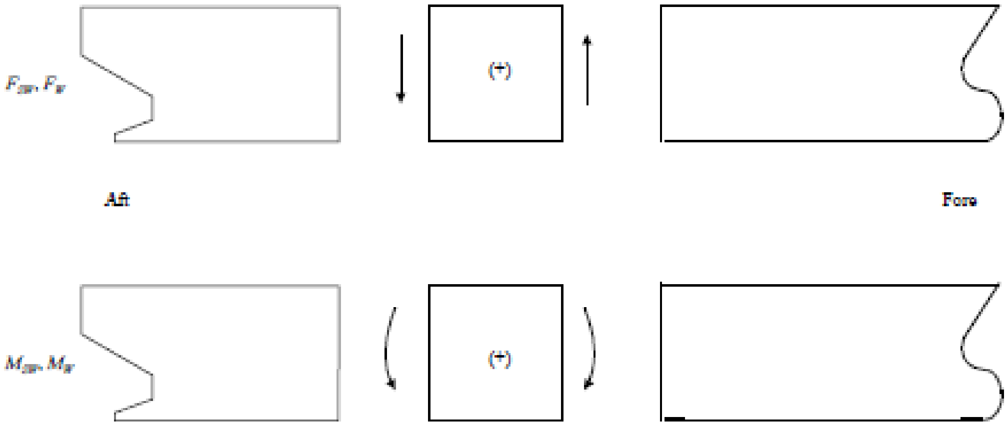
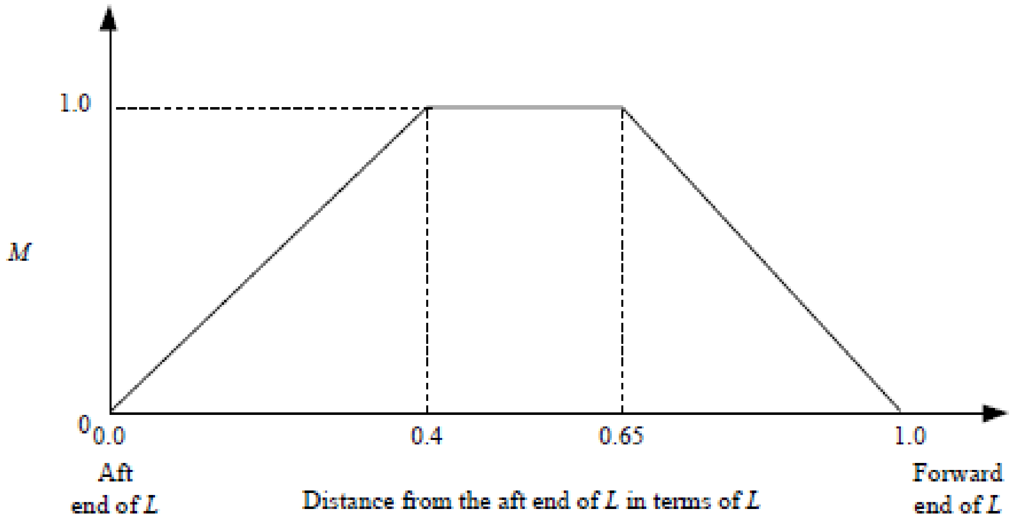


FIGURE 2
Distribution Factor M



3.7 Bending Strength Standard

3.7.1 Hull Girder Section Modulus

3.7.1(a) Section Modulus. The required hull girder section modulus for 0.4L amidships is to be the greater of the values obtained from the following equation or 3-2-1/3.7.1(b):

$$SM = M_t / f_p \quad \text{cm}^2\text{-m (in}^2\text{-ft)}$$

where

M_t = total bending moment, as obtained below

f_p = nominal permissible bending stress

= 17.5 kN/cm² (1.784 tf/cm², 11.33 Ltf/in²)

The total bending moment, M_t, is to be considered as the maximum algebraic sum (see sign convention in 3-2-1/3.1) of still-water bending moment and wave-induced bending moment, as follows:

$$M_t = M_{sw} + M_w$$

where

M_{sw} = still-water bending moment in accordance with 3-2-1/3.3, in kN-m (tf-m, Ltf-ft).

M_w = maximum wave-induced bending moment in accordance with 3-2-1/3.5.1

3.7.1(b) Minimum Section Modulus. The minimum hull girder section modulus amidships is not to be less than obtained from the following equation:

$$SM = C_1 C_2 L^2 B (C_b + 0.7) \quad \text{cm}^2\text{-m (in}^2\text{-ft)}$$

where

C_1 = as defined in 3-2-1/3.5

C_2 = 0.01 (0.01, 1.44 × 10^{-4})

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

B = breadth of vessel, as defined in 3-1-1/5, in m (ft)

C_b = block coefficient, as defined in 3-1-1/11.3, but is not to be taken less than 0.6

3.7.1(c) Extension of Midship Section Modulus. In general, where the still-water bending moment envelope curve is not submitted or where 3-2-1/3.7.1(b) governs, scantlings of all continuous longitudinal members of the hull girder are to be maintained throughout 0.4L amidships and then may be gradually tapered beyond.

Where the scantlings are based on the still-water bending moment envelope curves, items included in the hull girder section modulus amidships are to be extended as necessary to meet the hull girder section modulus required at the location being considered.

3.7.2 Hull Girder Moment of Inertia

The hull girder moment of inertia, I, amidships, is to be not less than:

$$I = L \cdot SM/33.3 \quad \text{cm}^2\text{-m}^2 \text{ (in}^2\text{-ft}^2\text{)}$$

where

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

SM = required hull girder section modulus, in cm²-m (in²-ft). See 3-2-1/3.7.1.

3.7.3 Hull Girder Strength Outside of 0.4L Amidships *(1 July 2011)*

The strength of the hull girder is to be checked at sections outside of 0.4*L* amidships. The required section modulus for the regions outside 0.4*L* amidships is to be obtained based on the total bending moment at the section considered and applying the permissible bending stress as given in 3-2-1/3.7.1(a). 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 the hull cross-section.
- At any locations where there are changes in the framing system.

Continuity of structure is to be maintained throughout the length of the ship. Where significant changes in the 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.

Buckling strength of members contributing to longitudinal strength and subjected to compressive and shear stresses is to be checked in accordance with 3-2-1/19, in particular in regions where changes in the framing system or significant changes in the hull cross-section occur.

Part 3 Hull Construction and Equipment
Chapter 2 Hull Structures and Arrangements
Section 1 Longitudinal Strength 3-2-1

5 Longitudinal Strength with Higher-Strength Materials

5.1 General

Vessels where the effective longitudinal material of either the upper or lower flanges of the main hull girder, or both, are constructed of materials having mechanical properties greater than those of ordinary-strength hull structural steel (see Section 2-1-2), are to have longitudinal strength generally in accordance with the preceding paragraphs of this section, but the value of the hull girder section modulus and permissible shear stress may be modified as permitted by 3-2-1/5.5 and 3-2-1/5.7. Application of higher-strength material is to be continuous over the length of the vessel to locations where the stress levels will be suitable for the adjacent mild-steel structure. Higher-strength steel is to be extended to suitable locations below the strength deck and above the bottom, so that the stress levels will be satisfactory for the remaining mild steel structure. Longitudinal framing members are to be continuous throughout the required extent of higher-strength steel.

5.3 Hull Girder Moment of Inertia *(2012)*

The hull girder moment of inertia is to be not less than required by 3-2-1/3.7.2 using the mild steel section modulus obtained from 3-2-1/3.7.1.

5.5 Hull Girder Section Modulus

When either the top or bottom flange of the hull girder, or both, is constructed of higher-strength material, the section modulus, as obtained from 3-2-1/3.7, may be reduced by the factor Q.

$$SM_{hts} = Q\,(SM)$$

where

SM = section modulus as obtained from 3-2-1/3.7

Q = 0.78 for H32 strength steel

Q = 0.72 for H36 strength steel

Q = 0.68 for H40 strength steel

H32, H36, H40 = as specified in Section 2-1-3.

Q factor for steels having other yield points or yield strengths will be specially considered.

5.7 Hull Girder Shearing Force

Where the side shell or longitudinal bulkhead is constructed of higher strength material, the permissible shear stresses indicated in 3-2-1/3.9 may be increased by the factor $1/Q$. For plate panel stability, see 3-2-1/19.

3.9 Side Shell Plating

The minimum thickness, t, of the side shell plating throughout the amidship 0.4L, for vessels having lengths not exceeding 427 m (1400 ft), is to be obtained from the following equations:

$$t = (s/645)\sqrt{(L - 15.2)(d/D_s)} + 2.5 \text{ mm} \qquad \text{for } L \le 305 \text{ m}$$

$$t = (s/828)\sqrt{(L + 175)(d/D_s)} + 2.5 \text{ mm} \qquad \text{for } 305 < L \le 427 \text{ m}$$

$$t = (s/1170)\sqrt{(L - 50)(d/D_s)} + 0.1 \text{ in.} \qquad \text{for } L \le 1000 \text{ ft}$$

$$t = (s/1500)\sqrt{(L + 574)(d/D_s)} + 0.1 \text{ in.} \qquad \text{for } 1000 < L \le 1400 \text{ ft}$$

where

s = spacing of transverse frames or longitudinals, in mm (in.)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

d = molded draft, as defined in 3-1-1/9, in m (ft)

D_s = molded depth, in m (ft), as defined in 3-2-2/3.1 through 3-2-2/3.7

The actual ratio of d/D_s is to be used in the above equations, except that the ratio is not to be taken less than 0.0433 L/D_s.

The side shell thickness amidships is to be not less than the thickness obtained by 3-2-2/5.1 using 610 mm (24 in.) as the frame spacing.

3.11 Sheer Strake

The minimum width, b, of the sheer strake throughout the amidship 0.4L is to be obtained from the following equations:

$$b = 5L + 800 \text{ mm} \qquad \text{for } L < 200 \text{ m}$$

$$b = 1800 \text{ mm} \qquad \text{for } 200 \le L \le 427 \text{ m}$$

$$b = 0.06L + 31.5 \text{ in.} \qquad \text{for } L < 656 \text{ ft}$$

$$b = 71 \text{ in.} \qquad \text{for } 656 \le L \le 1400 \text{ ft}$$

where

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

b = width of sheer strake, in mm (in.)

In general, the thickness of the sheer strake is not to be less than the thickness of the adjacent side shell plating, nor is it to be less than required by equation 1b or 2b in 3-2-3/Table 2, as appropriate, from *Decks-A* of 3-2-3/Table 1. The thickness of the sheer strake is to be increased 25% in way of breaks of superstructures, but this increase need not exceed 6.5 mm (0.25 in.). Where breaks in way of the forecastle or poop are appreciably beyond the amidship 0.5L, this requirement may be modified.

The top edge of the sheer strake is to be smooth and free of notches. Fittings and bulwarks are not to be welded to the top of the sheer strake within the amidships 0.8L, nor in way of superstructure breaks throughout.

3.13 Bottom Shell Plating Amidships

3.13.1 Extent of Bottom Plating Amidships

The term "bottom plating amidships" refers to the bottom shell plating from the keel to the upper turn of the bilge, extending over the amidships 0.4L.

3.13.2 Bottom Shell Plating

The thickness, t, of the bottom plating amidships is not to be less than obtained from the following equations or the thickness determined by 3-2-2/3.17, whichever is greater.

3.13.2(a) For Vessels with Transversely-framed Bottoms

$t = (s/519)\sqrt{(L-19.8)(d/D_s)} + 2.5$ mm for $L \le 183$ m

$t = (s/940)\sqrt{(L-65)(d/D_s)} + 0.1$ in. for $L \le 600$ ft

3.13.2(b) For Vessels with Longitudinally-framed Bottoms

$t = (s/671)\sqrt{(L-18.3)(d/D_s)} + 2.5$ mm for $L \le 122$ m

$t = (s/508)\sqrt{(L-62.5)(d/D_s)} + 2.5$ mm for $122 \le L \le 305$ m

$t = (s/661)\sqrt{(L+105)(d/D_s)} + 2.5$ mm for $305 < L \le 427$ m

$t = (s/1215)\sqrt{(L-60)(d/D_s)} + 0.1$ in. for $L < 400$ ft

$t = (s/920)\sqrt{(L-205)(d/D_s)} + 0.1$ in. for $400 \le L \le 1000$ ft

$t = (s/1197)\sqrt{(L+344.5)(d/D_s)} + 0.1$ in. for $1000 < L \le 1400$ ft

where L, d, s, and D_s are as defined in 3-2-2/3.9.

The actual ratio of d/D_s is to be used in the above equations, but the ratio is not to be taken less than $0.0433\,L/D_s$.

After all corrections have been made, the bottom shell thickness amidships is not to be less than the thickness obtained by 3-2-2/5.1 using 610 mm (24 in.) as the frame spacing.

Where the actual bottom hull girder section modulus SM_A is greater than required by 3-2-1/3.7.1, and still-water bending moment calculations are submitted, the thickness of the bottom shell may be obtained from the above equations multiplied by the factor R_n defined as follows:

$$R_n = \sqrt{\frac{1}{(f_p/\sigma_t)(1 - SM_R/SM_A) + 1}} \text{ but is not to be taken less than 0.85} \quad (d/D_s \ge 0.65)$$

$$= 1.0 \quad (d/D_s \le 0.0433L/D_s)$$

$$= \text{by linear interpolation} \quad (0.0433L/D_s < d/D_s < 0.65)$$

where

f_p = nominal permissible bending stress, in kN/cm² (tf/cm², Ltf/in²), as given in 3-2-1/3.7.1

σ_t = $KP_t(s/t)^2$, in kN/cm² (tf/cm², Ltf/in²)

K = 0.5 for transverse framing and 0.34 for longitudinal framing

P_t = $(0.638H + d)a$ kN/cm² (tf/cm², Ltf/in²)

a = 1.005×10^{-3} (1.025×10^{-4}, 1.984×10^{-4})

SM_R = hull girder section modulus required by 3-2-1/3.7.1, in cm²-m (in²-ft)

SM_A = bottom hull girder section modulus, in cm²-m (in²-ft), of the vessel with the greater of the bottom shell plating thickness obtained when applying R_n or R_b

t	=	bottom shell plating thickness required by 3-2-2/3.13.2(a) or 3-2-2/3.13.2(b), in mm (in.)	
H	=	wave parameter, in m (ft)	
	=	$0.0172L + 3.653$ m	$90 \le L \le 150$ m
	=	$0.0181L + 3.516$ m	$150 < L \le 220$ m
	=	$[4.50L - 0.0071L^2 + 103]10^{-2}$ m	$220 < L \le 305$ m
	=	8.151 m	$305 < L \le 427$ m
	=	$0.0172L + 11.98$ ft	$295 < L \le 490$ ft
	=	$0.0181L + 11.535$ ft	$490 \le L \le 720$ ft
	=	$[4.50L - 0.00216L^2 + 335]10^{-2}$ ft	$720 < L \le 1000$ ft
	=	26.750 ft	$1000 < L \le 1400$ ft

L, d and D_s are as defined in 3-2-2/3.9.

R_b is defined in 3-2-2/3.17.2.

SM_R/SM_A is not to be taken as less than 0.70

Special consideration will be given to vessels constructed of higher-strength steel.

3.15 Flat Plate Keel *(1997)*

The thickness of the flat plate keel is to be 1.5 mm (0.06 in.) greater than that required for the bottom shell plating at the location under consideration. This 1.5 mm (0.06 in.) increase in thickness is not required where the submitted docking plan specifies that all docking blocks are to be arranged clear of the flat plate keel. See 3-1-2/11 and 3-2-2/7.

3.17 Minimum Thickness

After all other requirements are met, the thickness, t_{min}, of the shell plating amidships below the upper turn of bilge is not to be less than obtained from the following equations:

3.17.1 Transverse Framing

$t_{min} = s(L + 45.73)/(25L + 6082)$ mm for $L \le 183$ m

$t_{min} = s(L + 150)/(25L + 19950)$ in. for $L \le 600$ ft

where

s	=	frame spacing, in mm (in.), but is not to be less than that given in 3-2-5/1.7
L	=	length of vessel, as defined in 3-1-1/3.1, in m (ft)

3.17.2 Longitudinal Framing

$t_{min} = s(L - 18.3)/(42L + 1070)$ mm for $L \le 427$ m

$t_{min} = s(L - 60)/(42L + 3510)$ in. for $L \le 1400$ ft

where

s	=	frame spacing, in mm (in.), but is not to be less than 88% of that given in 3-2-5/1.7 or 813 mm (32 in.), whichever is less
L	=	length of vessel, as defined in 3-1-1/3.1, in m (ft)

Where the bottom hull girder section modulus SM_A is greater than required by 3-2-1/3.7.1, and still-water bending moment calculations are submitted, the thickness of bottom shell plating amidships, obtained from the above equations, may be multiplied by the factor, R_b.

$R_b = \sqrt{SM_R / SM_A}$ but is not to be taken less than 0.85 $(d/D_s \geq 0.65)$

$= 1.0$ $(d/D_s \leq 0.0433L/D_s)$

$=$ by linear interpolation $(0.0433L/D_s < d/D_s < 0.65)$

where SM_R and SM_A are as defined in 3-2-2/3.13.2.

For transverse framing, R_b is to be not less than $1.2285 - L/533.55$ for SI or MKS units ($1.2285 - L/1750$ for US units), where L is as defined above, but is not to be taken as less than 122 m (400 ft).

Special consideration will be given to vessels constructed of higher-strength steel.

5 Shell Plating at Ends

5.1 Minimum Shell Plating Thickness

The minimum shell plating thickness t at the ends is to be obtained from the following equations and is not to extend for more than $0.1L$ at the ends. Between the amidship $0.4L$ and the end $0.1L$, the thickness of the plating may be gradually tapered.

$t = 0.035\,(L + 29) + 0.009\,s$ mm for $90 \leq L \leq 305$ m

$t = (11.70 + 0.009s)\sqrt{D/35}$ mm for $305 < L \leq 427$ m

$t = 0.00042(L + 95) + 0.009s$ in. for $295 \leq L \leq 1000$ ft

$t = (0.46 + 0.009s)\sqrt{D/114.8}$ in. for $1000 < L \leq 1400$ ft

where

s = fore or aft peak frame spacing, in mm (in.)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

D = molded depth, in m (ft), as defined in 3-1-1/7.1 or 35 m (114.8 ft), whichever is greater

Where the strength deck at the ends is above the freeboard deck, the thickness of the side plating above the freeboard deck may be reduced to the thickness given for forecastle and poop sides at the forward and after ends respectively.

5.3 Immersed Bow Plating

The thickness t of the plating below the load waterline forward of $0.16L$ from the stem is not to be less than is given by the following equation, but need not be greater than the thickness of the side shell plating amidships.

$t = 0.05(L + 20) + 0.009s$ mm for $90 \le L \le 305$ m

$t = (16.25 + 0.009s)\sqrt{D/35}$ mm for $305 < L \le 427$ m

$t = 0.0006(L + 66) + 0.009s$ in. for $295 \le L \le 1000$ ft

$t = (0.64 + 0.009s)\sqrt{D/114.8}$ in. for $1000 < L \le 1400$ ft

where

s = fore peak frame spacing, in mm (in.)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

D = molded depth, in m (ft), as defined in 3-1-1/7.1 or 35 m (114.8 ft), whichever is greater

3.11 Deck Plating

Deck plating is to be of not less thickness than is required for purposes of longitudinal hull girder strength. The thickness of the stringer plate is to be increased 25% in way of breaks of superstructures, but this increase need not exceed 6.5 mm (0.25 in.). This requirement may be modified where the breaks of poop or forecastle are appreciably beyond the midship 0.5*L*. The required deck area is to be maintained throughout the amidship 0.4*L* of the vessel and is to be suitably extended into superstructures located at or near the amidship 0.4*L*. From these locations to the ends of the vessel, the deck area contributing to the hull girder strength may be gradually reduced in accordance with 3-2-1/11.3. Where bending moment envelope curves are used to determine the required hull girder section modulus, the foregoing requirements for deck area may be modified in accordance with 3-2-1/11.3. Where so modified, the strength deck area is to be maintained a suitable distance from superstructure breaks and is to be extended into the superstructure to provide adequate structural continuity. The thickness of the deck plating is also not to be less than given in 3-2-3/5.1.

5 Deck Plating *(1997)*

5.1 Thickness *(1997)*

The thickness of deck plating is to be not less than obtained from the equations specified in 3-2-3/Table 1.

5.3 Effective Lower Decks

For use as an effective lower deck in calculating the hull girder section modulus, the thickness of the plating is to be not less than obtained from 3-2-3/5.1, appropriate to the depth D_S, according to 3-2-3/Table 1. In no case is the plating to be less than obtained from I or J in 3-2-3/Table 1, as appropriate. Stringer plates of effective decks are to be connected to the shell.

5.5 Reinforcement at Openings *(1997)*

5.5.1 Openings in Strength Decks

Unless otherwise specifically required, openings in the strength deck are, in general, to have a minimum corner radius of 0.125 times the width of the opening, but need not exceed a radius of 600 mm (24 in.). In other decks, the radius is to be 0.09375 times the width of the opening, but need not exceed a radius of 450 mm (18 in.). Additionally, the minimum radius in way of narrow deck transverse ligaments between adjacent hatch openings having the same width is not to be less than 150 mm (6 in.).

5.5.2 Openings in Effective Decks

At the corners of hatchways or other openings in effective decks, generous radii are to be provided.

5.5.3 In Way of Machinery Space

In way of the machinery spaces, special attention is to be paid to the maintenance of lateral stiffness by means of webs and heavy pillars in way of deck opening and casings.

5.7 Platform Decks

Lower decks, which are not considered to be effective decks for longitudinal strength, are termed platform decks. The plating thickness is not to be less than obtained from *Decks* I or J of 3-2-3/Table 1, as appropriate.

5.9 Superstructure Decks

See 3-2-11/1.3.

5.11 Decks Over Tanks

For decks over tanks see 3-2-10/3.5.

5.13 Watertight Flats

The thickness of watertight flats over tunnels, or watertight flats forming recesses or steps in bulkheads, is to be not less than the thickness required for the plating of ordinary bulkheads at the same level, plus 1 mm (0.04 in.).

5.15 Retractable Tween Decks

The thickness of retractable tween deck plating is not to be less than required by equation 6 of 3-2-3/Table 2. The edges of the deck panels are to be stiffened to provide the necessary rigidity.

The beams and girders, in association with the plating to which they are attached, are to have section modulus, *SM*, not less than obtained from the following equation.

$$SM = kchs\ell^2 \quad \text{cm}^3 \ (\text{in}^3)$$

where

k = 7.8 (0.0041)

c = 0.81 for the section modulus to the flange or face bar

= 1.00 for the section modulus to the deck plating

h = $p/7.04$ m ($p/715$ m, $p/45$ ft)

p = uniform loading, in kN/m^2 (kgf/m^2, lbf/ft^2)

s = spacing of the beam or girder, in m (ft)

ℓ = unsupported length of the beam or girder, in m (ft)

In general, the depth of beams and girders is not to be less than 4% of the unsupported length.

When retractable decks are intended for the operation or stowage of vehicles having rubber tires, the thickness of the deck plating is to be not less than required by 3-2-15/13.7. The retractable decks are to be secured against movement and effectively supported by the hull structure.

5.17 Wheel Loading *(2014)*

Where provision is to be made for the operation or stowage of vehicles having rubber tires, and after all other requirements are met, the thickness of the plating of an effective lower deck (see 3-2-3/5.3) is not to be less than obtained from the following equation:

$$t = kKn\sqrt{CW} \quad \text{mm (in.)}$$

where

k = 8.05 (25.2, 1.0)

K = $[21.99 + 0.316(a/s)^2 - 5.328(a/s) + 2.6(a/s)(b/s) - 0.895(b/s)^5 - 7.624(b/s)]10^{-2}$, derived from the curves indicated in 3-2-3/Figure 1

n = 1.0 where $\ell/s \geq 2.0$ and 0.85 where $\ell/s = 1.0$, for intermediate values of ℓ/s, n is to be obtained by interpolation

C = 1.5 for wheel loads of vehicles stowed at sea and 1.1 for vehicles operating in port

W = static wheel load, in kN (tf, Ltf)

a = wheel imprint dimension, in mm (in.), parallel to the longer edge, ℓ, of the plate panel

b = wheel imprint dimension, in mm (in.), perpendicular to the longer edge, ℓ, of the plate panel

s = spacing of deck beams or deck longitudinals, in mm (in.)

ℓ = length of the plate panel, in mm (in.)

For wheel loading, the strength deck plating thickness is not to be less than 110% of that required by the above equation, and platform deck plating thickness is not to be less than 90% of that required by the above equation.

Where the wheels are close together, special consideration will be given to the use of a combined imprint and load. Where the intended operation is such that only the larger dimension of the wheel imprint is perpendicular to the longer edge of the plate panel, then b above may be taken as the larger wheel imprint dimension, in which case a is to be the lesser dimension.

TABLE 1
Applicable Thickness Equations *(1997)*

Decks	*Minimum Thickness Equation in Table 2*
A. Strength Deck Outside Line of Openings	
1. With Transverse Beams	1a and 1b (note 1)
2. With Longitudinal Beams	2a and 2b (note 1)
B. Exposed Strength Deck within Line of Openings	3 (note 2)
C. Enclosed Strength Deck within Line of Openings	5
D. Effective Lower Decks	
1. Second Deck:	
a. $D_S > 15.2$ m (50 ft)	1a
b. 15.2 m (50 ft) $\geq D_S \geq$ 12.8 m (42 ft)	2a
c. $D_S < 12.8$ m (42 ft)	3
2. Third Deck:	
a. $D_S > 17.7$ m (58 ft)	1a
b. 17.7 m (58 ft) $\geq D_S \geq$ 13.4 m (44 ft)	2a
c. 13.4 m (44 ft) $\geq D_S \geq$ 9.8 m (32 ft)	3
d. $D_S < 9.8$ m (32 ft)	4
E. Exposed Forecastle Decks	
1. $L > 122$ m (400 ft)	2a
2. $L \leq 122$ m (400 ft)	3
F. Exposed Poop Decks	
1. $L > 100$ m (330 ft)	3
2. $L \leq 100$ m (330 ft)	5
G. Exposed Bridge Deck	4
H. Long Deckhouse Top	5
I. Platform Decks in Enclosed Cargo Spaces	6 (note 3)
J. Platform Decks in Enclosed Accommodation Spaces	7 (note 3)

Notes:

1. In small vessels where the required area is relatively small, it may be disposed in the stringer and alongside openings in plating of not less thickness than obtained from the equations in 1a and 1b; in such cases the remainder of the plating may be obtained from the equation in 5.
2. Equation 3 applies amidships. At the forward and aft ends, plating is to be as required for exposed forecastle and poop deck.
3. Where the platform decks are subjected to hull girder bending, special consideration is to be given to the structural stability of deck supporting members.

TABLE 2
Minimum Thickness Equations *(1977)*

Equation Number	*Equation*	
1a (notes 1,2)	$t = 0.01s_b + 2.3$ mm	for $s_b \le 760$ mm
	$t = 0.0066s_b + 4.9$ mm	for $s_b > 760$ mm
	$t = 0.01s_b + 0.09$ in.	for $s_b \le 30$ in.
	$t = 0.0066s_b + 0.192$ in.	for $s_b > 30$ in.
1b (notes 1,3)	$t = \dfrac{s_b(L + 45.73)}{25L + 6082}$ mm	
	$t = \dfrac{s_b(L + 150)}{25L + 19950}$ in.	
2a (notes 1,2)	$t = 0.009s_b + 2.4$ mm	for $s_b \le 760$ mm
	$t = 0.006s_b + 4.7$ mm	for $s_b > 760$ mm
	$t = 0.009s_b + 0.095$ in.	for $s_b \le 30$ in.
	$t = 0.006s_b + 0.185$ in.	for $s_b > 30$ in.
2b (notes 1,3)	$t = \dfrac{s_b(L + 48.76)}{26L + 8681}$ mm	for $L \le 183$ m
	$t = \dfrac{24.38s_b}{1615.4 - 1.1L}$ mm	for $183 < L \le 427$ m
	$t = \dfrac{s_b(L + 160)}{26L + 28482}$ in.	for $L \le 600$ ft
	$t = \dfrac{80s_b}{5300 - 1.1L}$ in.	for $600 < L \le 1400$ ft
3	$t = 0.01s_b + 0.9$ mm	for $s_b \le 760$ mm
	$t = 0.0067s_b + 3.4$ mm	for $s_b > 760$ mm
	$t = 0.01s_b + 0.035$ in.	for $s_b \le 30$ in.
	$t = 0.0067s_b + 0.134$ in.	for $s_b > 30$ in.
4	$t = 0.01s_b + 0.25$ mm	for $s_b \le 760$ mm
	$t = 0.0043s_b + 4.6$ mm	for $s_b > 760$ mm
	$t = 0.01s_b + 0.01$ in.	for $s_b \le 30$ in.
	$t = 0.0043s_b + 0.181$ in.	for $s_b > 30$ in.
5	$t = 0.009s_b + 0.8$ mm	for $s_b \le 760$ mm
	$t = 0.0039s_b + 4.3$ mm	for $s_b > 760$ mm
	$t = 0.009s_b + 0.032$ in.	for $s_b \le 30$ in.
	$t = 0.0039s_b + 0.17$ in.	for $s_b > 30$ in.
6	$t = Ks_b\sqrt{h} + a$ mm (in.) but not less than 5.0 mm (0.20 in.) $K = 0.00394$ (0.00218) $a = 1.5$ mm (0.06 in.) h = tween deck height in m (ft). When a design load is specified, h is to be taken as p/n where p is the specified design load in kN/m² (kgf/m², lbf/ft²) and n is defined as 7.05 (715, 45)	
7	$t = 0.0058s_b + 1.0$ mm $t = 0.0058s_b + 0.04$ in. but not less than 4.5 mm (0.18 in.)	

L = scantling length of the vessel as defined in 3-1-1/3.1 in m (ft) s_b = spacing of deck beams, in mm (in.)

3.1.1(a) Thickness Amidships

$t = 56L \cdot 10^{-3} + 5.5$ mm for $L \le 427$ m

$t = 67L \cdot 10^{-5} + 0.22$ in. for $L \le 1400$ ft

3.1.1(b) Thickness at Ends

85% of the thickness required amidships

3.1.1(c) Depth

$d_{DB} = 32B + 190\sqrt{d}$ mm for $L \le 427$ m

$d_{DB} = 0.384B + 4.13\sqrt{d}$ in. for $L \le 1400$ ft

where

t = thickness of plating, in mm (in.)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

d_{DB} = depth of double bottom, in mm (in.)

d = molded draft of vessel, as defined in 3-1-1/9, in m (ft)

B = breadth of vessel, as defined in 3-1-1/5, in m (ft)

3.3 Pipe Tunnels *(Note: An alternative arrangement of center girders)*

A pipe tunnel, or tunnels, may be substituted for the center girder provided that the thickness of the sides of the pipe tunnel(s) is not less than is required for tank-end floors. The construction arrangement and details of pipe tunnels are to be clearly shown on the plans submitted for approval.

3.5 Docking Brackets *(Note: Not only for center girder but also for side girders) (1999)*

Docking brackets are to be provided on the center girder where the spacing of the floors exceeds 2.28 m (7.5 ft), unless calculations are submitted to verify that the girder provides sufficient stiffness and strength for docking loads. Where the docking arrangement is such that the side girders or bulkheads are subject to docking loads, such arrangement is to be indicated on the submitted structural plan, and docking brackets are to be fitted on those members where the spacing of floors exceeds the foregoing limit.

3.7 Side Girders

Amidships and aft, side girders of the thickness obtained from the equation of 3-2-4/5 are to be so arranged that the distance from the center girder to the first side girder, the distance between the girders, and the distance from the outboard girder to the center of the margin plate does not exceed 4.57 m (15 ft). At the fore end, they are to be arranged as required by 3-2-4/13.5 or 3-2-4/13.7, as appropriate. Additional full or half-depth girders are to be fitted beneath the inner bottom as required in way of machinery and thrust seatings and beneath wide-spaced pillars. Where the bottom and inner bottom are longitudinally framed, this requirement may be modified.

5 Solid Floors *(1997)*

5.1 General *(2001)*

Solid floors (see 3-2-4/Figure 1) of the thickness obtained from the following equations (and 3-2-4/5.5, where applicable), are to be fitted on every frame under machinery and transverse boiler bearers, under the outer ends of bulkhead stiffener brackets and at the forward end (see 3-2-4/13.5 or 3-2-4/13.7, as appropriate). Elsewhere, they may have a maximum spacing of 3.66 m (12 ft) in association with intermediate open floors (see 3-2-4/7), or longitudinal framing of the bottom or inner bottom plating. With the latter, the floors are to have stiffeners at each longitudinal, or an equivalent arrangement is to be provided. Where floors are fitted on every frame, the thickness need not exceed 14.0 mm (0.55 in.), provided the buckling strength is proven adequate (see 5C-1-A2/3, 5C-3-A2/3 or 5C-5-A2/3, as appropriate, where t_n = 12.5 mm (0.49 in.) in FOT or 12.0 mm (0.47 in.) for others). Where boilers are mounted on the tank top, the floors and intercostals in way of the boilers are to have an additional 1.5 mm (0.06 in.) added to their thickness after all other requirements have been satisfied.

$t = 0.036L + 4.7 + c$ mm for $L \le 427$ m

$t = 0.00043L + 0.185 + c$ in. for $L \le 1400$ ft

where

t = thickness, in mm (in.)

L = length of vessel, as defined in 3-1-1/3.1, in m (ft)

c = 1.5 mm (0.06 in.) for floors where the bottom shell and inner bottom are longitudinally framed

= 0 mm (0 in.) for side girders and brackets, and for floors where the bottom shell and inner bottom are transversely framed

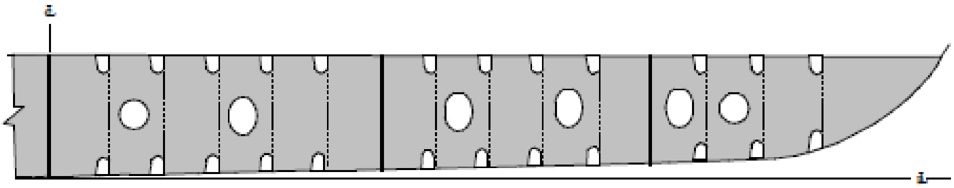
5.3 Tank-end Floors *(1997)*

Tank-end floor thickness is to be not less than required for deep tank bulkhead plating or 3-2-4/5.1, whichever is greater.

5.5 Floor Stiffeners

Stiffeners spaced not more than 1.53 m (5 ft) apart are to be fitted on every solid floor. Where the depth of the double bottom exceeds 0.915 m (3 ft), stiffeners on tank-end floors are to be of the sizes required for stiffeners on deep-tank bulkheads, and the spacing is not to exceed 915 mm (36 in.). Stiffeners may be omitted on non-tight floors with transverse framing, provided the thickness of the floor plate is increased 10% above the thickness obtained from 3-2-4/5.1.

FIGURE 1
Double-bottom Solid Floors



9 Inner-bottom Plating

9.1 Inner-bottom Plating Thickness *(1997)*

Inner-bottom plating thickness is not to be less than obtained from the following equation or as required by 3-2-10/3.5, or by 3-2-1/19, whichever is the greatest:

$t = 37.0L \cdot 10^{-3} + 0.009s - c$ mm for $L \leq 427$ m

$t = 44.4L \cdot 10^{-5} + 0.009s - c$ in. for $L \leq 1400$ ft

where

L = scantling length of vessel, as defined in 3-1-1/3.1, in m (ft)

s = frame spacing, in mm (in.)

c = 0.5 mm (0.02 in.) with transverse framing

= 1.5 mm (0.06 in.) with longitudinal framing

Where close ceiling, as defined in 3-2-18/1, is not fitted on the inner bottom in way of hatchways, the thickness t, as determined above, is to be increased by 2.0 mm (0.08 in.), except in holds designated exclusively for the carriage of containers on the inner bottom.

9.3 Center Strakes

Center strakes are to have a thickness determined from 3-2-4/9.1; in way of pipe tunnels, the thickness may require to be suitably increased.

9.5 Under Boilers *(2017)*

Under boilers, there is to be a clear space of at least 460 mm (18 in.). Where the clear space is necessarily less as per 4-4-1/19.3, the thickness of the plating is to be increased as may be required.

9.7 In Way of Engine Bed Plates or Thrust Blocks

In way of engine bed plates or thrust blocks which are bolted directly to the inner bottom, the thickness of the inner bottom plating is to be at least 19.0 mm (0.75 in.). This thickness may be required to be increased according to the size and power of the engine(s). Holding-down bolts are to pass through angle flanges of sufficient breadth to take the nuts.

9.9 Margin Plates *(1997)*

Where margin plates are approximately vertical, the plates amidships are to extend for the full depth of the double bottom with a thickness not less than obtained from the equation in 3-2-4/9.1 plus 2.0 mm (0.08 in.). Where approximately horizontal, margin plates may be of the thickness required for tank-top plating at that location.

9.11 Recommendations Where Cargo is Handled by Grabs

For vessels regularly engaged in trades where the cargo is handled by grabs, or similar mechanical appliances, it is recommended that flush inner-bottom plating be adopted throughout the cargo space, and that the plating requirements of 3-2-4/9.1 be suitably increased, but the increase need not exceed 5.0 mm (0.20 in.) It is also recommended that the minimum thickness be not less than 12.5 mm with 610 mm (0.50 in. with 24 in.) frame spacing and 19.0 mm with 915 mm (0.74 in. with 36 in.) frame spacing, and the thickness for intermediate frame spacing is to be obtained by linear interpolation.

9.13 Wheel Loading

Where provision is to be made for the operation or stowage of vehicles having rubber tires, and after all other requirements are met, the thickness of the inner bottom plating is to be not less than obtained from 3-2-3/5.15.

11 Bottom and Inner-bottom Longitudinals

11.1 General

Bottom and inner-bottom longitudinals are to be continuous or attached at their ends to effectively develop their sectional area and their resistance to bending.

11.3 Bottom Longitudinals

Each bottom longitudinal frame similar to that shown in 3-2-4/Figure 3, in association with the plating to which it is attached, is to have a section modulus *SM* not less than that obtained from the following equation:

$$SM = 7.8chs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0041chs\ell^2 \quad \text{in}^3$$

where

c	=	1.3	without struts
	=	0.715	with effective struts
h	=	distance, in m (ft), from the keel to the load line, or two-thirds of the distance to the bulkhead or freeboard deck, whichever is the greater.	
s	=	spacing of longitudinals, in m (ft)	
ℓ	=	distance, in m (ft), between the supports, but is not to be taken as less than 1.83 m (6 ft) without struts or 2.44 m (8 ft) with struts. Where effective struts are fitted and the tank top is intended to be uniformly loaded with cargo, ℓ may be taken as 81% of the distance between supports subject to above minimum.	

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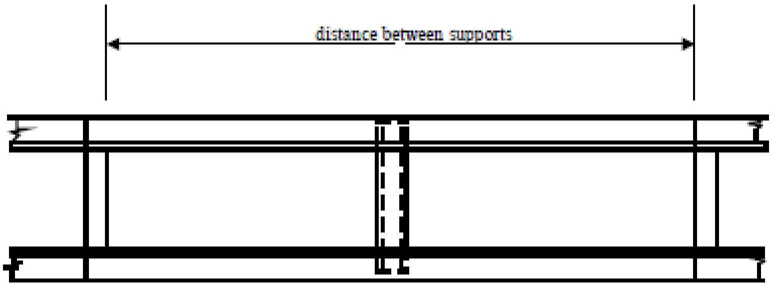
FIGURE 3
Bottom Longitudinal Frame



The section modulus *SM* of the bottom longitudinals may be obtained from the above equations multiplied by the factor R_ℓ where,

i) The bottom hull girder section modulus SM_A is greater than required by 3-2-1/3.7.1, at least throughout 0.4*L* amidships,

ii) Still-water bending moment calculations are submitted, and

iii) Adequate buckling strength is maintained.

$R_\ell = n/[n + f_p(1 - SM_R/SM_A)]$ but is not to be taken less than 0.69

where

n = 8.278 (0.852, 5.36)

f_p = nominal permissible bending stress, as given in 3-2-1/3.7.1

SM_R = hull girder section modulus required by 3-2-1/3.7.1, in cm^2-m (in^2-ft)

SM_A = bottom hull girder section modulus, in cm^2-m (in^2-ft), with the longitudinals modified as permitted above.

Bottom longitudinals, with this modified section modulus are to meet all other Rule requirements including side longitudinals in 3-2-5/3.17.

11.5 Inner-bottom Longitudinals

Inner-bottom longitudinals are to have values of *SM* at least 85% of that required for the bottom longitudinals.

PART
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CHAPTER 2 Hull Structures and Arrangements

SECTION 5 Frames

1 General

1.1 Basic Considerations

The required sizes and arrangements of frames are to be in accordance with this section and as shown in 3-2-5/Figure 1. The equations apply to vessels which have well-rounded lines, normal sheer and bulkhead support not less effective than that specified in Section 3-2-9. Additional stiffness will be required where bulkhead support is less effective, where sheer is excessive or where flat surface areas are abnormally large. Frames are not to have less strength than is required for bulkhead stiffeners in the same location in association with heads to the bulkhead deck, and in way of deep tanks they are not to have less strength than is required for stiffeners on deep-tank bulkheads. Framing sections are to have sufficient thickness and depth in relation to the spans between supports.

1.3 Holes in Frames

The calculated section modulus for frames is based upon the intact section being used. Where it is proposed to cut holes in the outstanding flanges or large openings in the webs of any frame, the net section is to be used in determining the section modulus for the frame, in association with the plating to which it is attached.

1.5 End Connections

At the ends of unbracketed frames, both the web and the flange are to be welded to the supporting member. At bracketed end connections, continuity of strength is to be maintained at the connection to the bracket and at the connection of the bracket to the supporting member. Welding is to be in accordance with 3-2-19/Table 1. Where longitudinal frames are not continuous at bulkheads, end connections are to effectively develop their sectional area and resistance to bending. Where a structural member is terminated, structural continuity is to be maintained by a suitable back-up structure, fitted in way of the end connection of frames, or the end connection is to be effectively extended by a bracket or flat bar to an adjacent beam, stiffener, etc.

1.7 Standard and Cant Frame Spacing *(1997)*

The standard frame spacing, S, amidships for vessels with transverse framing, may be obtained from the following equations. In vessels of fine form or high power, a closer spacing is to be considered within and adjacent to the peaks. The spacing of cant frames is not to exceed the standard frame spacing.

$S = 2.08L + 438$ mm   for $L \leq 270$ m

$S = 1000$ mm   for $270 < L \leq 427$ m

$S = 0.025L + 17.25$ in.   for $L \leq 890$ ft

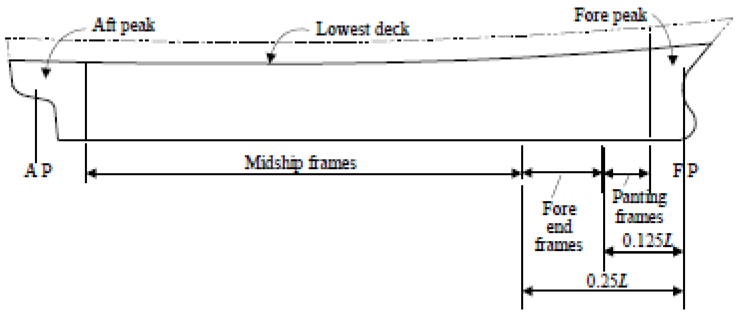
$S = 39.5$ in.   for $890 < L \leq 1400$ ft

where

S = standard frame spacing, in mm (in.)

L = scantling length of vessel, as defined in 3-1-1/3.1, in m (ft)

FIGURE 1
Zones of Framing



3 Hold Frames

3.1 Transverse Frames *(1997)*

3.1.1 Strength Requirement

The section modulus *SM* of each transverse frame amidships and aft below the lowest deck is to be obtained from the following equation, where ℓ is the span in m (ft) as shown in 3-2-5/Figure 2, 3-2-5/Figure 3, and 3-2-5/Figure 4 between the toes of brackets. The value of ℓ for use with the equation is not to be less than 2.10 m (7 ft).

$$SM = s\ell^2(h + bh_1/30)\,(7 + 45/\ell^3)\ \text{cm}^3$$

$$SM = s\ell^2(h + bh_1/100)\,(0.0037 + 0.8/\ell^3)\ \text{in}^3$$

where

s = frame spacing, in m (ft)

h = vertical distance, in m (ft), from the middle of ℓ to the load line or 0.4ℓ, whichever is the greater.

b = horizontal distance, in m (ft), from the outside of the frames to the first row of deck supports

h_1 = vertical distance, in m (ft), from the deck at the top of the frame to the bulkhead or freeboard deck plus the height of all cargo tween-deck spaces and one-half the height of all passenger spaces above the bulkhead or freeboard deck, or plus 2.44 m (8 ft), if that be greater. Where the cargo load differs from 7.04 kN/m³ (715 kgf/m³, 45 lbf/ft³) multiplied by the tween-deck height in m (ft), the height of that tween-deck is to be proportionately adjusted in calculating h_1.

3.1.2 Deck Longitudinals with Deep Beams

Where the decks are supported by longitudinal beams in association with wide-spaced deep transverse beams, the value of h_1 for the normal frames between the deep beams may be taken as equal to zero; for the frames in way of the deep beams, the value of h_1 is to be multiplied by the number of frame spaces between the deep beams.

3.1.3 Sizes Increased for Heavy Load

Where a frame may be subject to special heavy loads, such as may occur at the ends of deep transverse girders which in turn carry longitudinal deck girders, the section modulus is to be suitably increased in proportion to the extra load carried.

3.17 Longitudinal Frames *(1995)*

The section modulus *SM* of each longitudinal side frame is to be not less than obtained from the following equation:

$$SM = 7.8\, chs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0041\, chs\ell^2 \quad \text{in}^3$$

where

s = spacing of longitudinal frames, in m (ft)

c = 0.95

h = above 0.5D from the keel, the vertical distance, in m (ft), from the longitudinal frame to the bulkhead or freeboard deck, but is not to be taken as less than 2.13 m (7.0 ft).

= at and below 0.5D from the keel, 0.75 times the vertical distance, in m (ft), from the longitudinal frame to the bulkhead or freeboard deck, but not less than 0.5D.

ℓ = the unsupported span, in m (ft)

3.19 Machinery Space *(1997)*

Care is to be taken to provide sufficient transverse strength and stiffness in the machinery space by means of webs and heavy pillars in way of deck openings and casings.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 7 Beams

1 General

1.1 Arrangement

Transverse beams are to be fitted on every frame. Beams, transverses and girders are to have adequate structural stability.

1.3 Design Head

Where decks are designed to scantling heads less than those specified in this Section, a notation indicating the restricted deck loading will be entered in the *Record*.

3 Beams

3.1 Strength Requirement

Each beam, in association with the plating to which it is attached, is to have a section modulus SM as obtained from the following equation:

$$SM = 7.8chs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0041chs\ell^2 \quad \text{in}^3$$

where

c = 0.540 for half beams, for beams with centerline support only, for beams between longitudinal bulkheads, and for beams over tunnels or tunnel recesses

= 0.585 for beams between longitudinal deck girders. For longitudinal beams of platform decks and between hatches at all decks

= 0.90 for beams at deep-tank tops supported at one or both ends at the shell or on longitudinal bulkheads

= 1.00 for beams at deep-tank tops between longitudinal girders

= $1/(1.709 - 0.651k)$ for longitudinal beams of strength decks and of effective lower decks

k = SM_RY/I_A

SM_R = required hull girder section modulus amidships in 3-2-1/3.7.1 or 3-2-1/5.5, whichever is applicable, in cm²-m (in²-ft)

Y = distance, in m (ft), from the neutral axis to the deck being considered, always to be taken positive

I_A = hull girder moment of inertia of the vessel amidships, in cm²-m² (in²-ft²)

The values of I_A and Y are to be those obtained using the area of the longitudinal beams given by the above equation.

s = spacing of beams, in m (ft)

ℓ = distance, in m (ft), from the inner edge of the beam knee to the nearest line of girder support or between girder supports, whichever is greater. Normally ℓ is not to be less than $0.2B$. Under the top of deep tanks and in way of bulkhead recesses, the supports are to be arranged to limit the span to not over 4.57 m (15 ft)

h = height, in m (ft), as follows

= is normally to be the height measured at the side of the vessel, of the cargo space wherever stores or cargo may be carried. Where the cargo load differs from 7.04 kN/m^3 (718 kgf/m^3, 44.8 lbf/ft^3) multiplied by the tween-deck height, in m (ft), the height is to be proportionately adjusted.

= for bulkhead recesses and tunnel flats is the height, in m (ft), to the bulkhead deck at the centerline; where that height is less than 6.10 m (20 ft), the value of h is to be taken as 0.8 times the actual height plus 1.22 m (4 ft).

= for deep-tank tops is not to be less than two-thirds of the distance from the top of the tank to the top of the overflow; it is not to be less than given in column (e) of 3-2-7/Table 1, appropriate to the length of the vessel, the height to the load line or two-thirds of the height to the bulkhead or freeboard deck, whichever is greatest. The section modulus is not to be less than would be required for cargo beams.

Elsewhere, the value of h may be taken from the appropriate column of 3-2-7/Table 1, as follows.

Elsewhere, the value of h may be taken from the appropriate column of 3-2-7/Table 1, as follows.

Weather deck and decks covered only by houses:	*Column*
Freeboard decks having no decks below	a
Freeboard decks having decks below	b
Forecastle decks (first above freeboard deck) See Note 1	c
Bridge decks (first above freeboard deck)	c
Short bridges, not over $0.1L$ (first above freeboard deck)	d
Poop decks (first above freeboard deck)	d
Long superstructures (first above freeboard deck) forward of midship half-length	b
Long superstructures (first above freeboard deck) abaft midship half-length forward and forward of midship 3/5 length aft	c
Long superstructures (first above freeboard deck) abaft midship 3/5 length	d
Superstructure decks (second above freeboard deck) See Note 2	d
Superstructure decks (third and higher above freeboard deck) which contain only accommodation spaces	f
Lower decks and decks within superstructures:	
Decks below freeboard decks	c
Freeboard decks	c
Superstructure decks	d
Accommodation decks	f
Decks to which side shell plating does not extend, tops of houses, etc.:	
First tier above freeboard deck	d
Second tier above freeboard deck See Note 3	e
Third and higher tiers above freeboard deck See Note 3	f

Notes

1 See also 3-2-11/9.

2 Where superstructures above the first superstructure extend forward of the amidship $0.5L$, the value of h may be required to be increased.

3 Where decks to which the side shell does not extend and are generally used only as weather covering, the value of h may be reduced, but in no case is it to be less than in column (g).

4 Buckling strength of the plating and framing of all decks is to be considered where they are part of the hull girder.

TABLE 1
Values of *h* for Beams

Meters

L	*a*	*b*	*c*	*d*	*e*	*f*	*g*
90	2.56	2.26	1.51	1.20	1.05	0.90	0.46
100	2.76	2.29	1.69	1.30	1.15	0.91	0.46
110	2.90	2.29	1.90	1.44	1.15	0.91	0.46
120	2.90	2.29	1.98	1.64	1.27	0.91	0.46
122 and above	2.90	2.29	1.98	1.68	1.30	0.91	0.46

Feet

L	*a*	*b*	*c*	*d*	*e*	*f*	*g*
300	8.50	7.50	5.00	4.00	3.50	3.00	1.50
325	9.00	7.50	5.50	4.25	3.75	3.00	1.50
350	9.50	7.50	6.00	4.50	3.75	3.00	1.50
375	9.50	7.50	6.50	5.00	4.00	3.00	1.50
400 and above	9.50	7.50	6.50	5.50	4.25	3.00	1.50

Values of *h* for an intermediate length of vessel are to be obtained by interpolation.

5.7 Girders and Webs

5.7.1 Strength Requirements

Each girder and web which supports bulkhead stiffeners is to have section modulus *SM* not less than obtained from the following equation:

$$SM = 4.74chs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0025chs\ell^2 \quad \text{in}^3$$

where

c = 1.0

h = *(1998)* vertical distance, in m (ft), to the deepest equilibrium waterline in the one compartment damaged condition from the middle of s in the case of girders and from the middle of ℓ in the case of webs.

- For passenger vessels, h is to be taken as not less than the distance to the margin line.
- For cargo vessels, h is to be not less than the distance to the bulkhead deck at center unless a deck lower than the uppermost continuous deck is designated as the freeboard deck, as allowed in 3-1-1/13.1, in which case h is to be not less than the distance to the designated freeboard deck at center.
- For all vessels, where the distance indicated above is less than 6.10 m (20 ft), the value of h is to be 0.8 times the distance plus 1.22 m (4 ft).

s = sum of half lengths (on each side of girder or web) of the stiffeners supported, in m (ft)

ℓ = span measured between the heels of the end attachments, in m (ft).Where brackets are fitted, the length ℓ may be modified as indicated in 3-2-6/7.1.

The section modulus *SM* of each girder and web on the collision bulkheads is to be at least 25% greater than required for similar supporting members on watertight bulkheads.

5.7.2 Proportions

Girders and webs are to have depths not less than 0.0832ℓ (1 in. per ft of span ℓ) plus one-quarter of the depth of the slots for the stiffeners; the thickness is not to be less than 1 mm per 100 mm (0.01 in. per in.) of depth plus 3 mm (0.12 in.) but need not exceed 11.5 mm (0.46 in.).

5.7.3 Tripping Brackets *(1994)*

Tripping brackets are to be fitted at intervals of about 3 m (10 ft), and near the change of section. Where the width of the face flange exceeds 200 mm (8 in.) on either side of the girder or web, tripping brackets are to be arranged to support the flange.

PART
3

CHAPTER 2 Hull Structures and Arrangements

SECTION 10 Deep Tanks

1 General

1.1 Application

This Section applies to all deep tanks where the requirements in this Section exceed those of Section 3-2-9.

1.3 Arrangement

The arrangement of all deep tanks, together with their intended service and the height of the overflow pipes, is to be clearly indicated on the plans submitted for approval.

Tanks for fresh water or fuel oil or those that are not intended to be kept entirely filled in service, are to have divisions or deep swashes as may be required to minimize the dynamic stress on the structure. Oil or other liquid substances that are flammable are not to be carried in tanks forward of the collision bulkhead.

1.5 Construction

The boundary bulkheads of all deep tanks are to be constructed in accordance with the requirements of this Section.

Longitudinal tight divisions, which are fitted for reasons of stability in tanks which are to be entirely filled or empty in service, may be of the scantlings required for watertight bulkheads by Section 3-2-9. In such cases, the tanks are to be provided with feed tanks or deep hatches, fitted with inspection plugs in order to ensure that the tanks on both sides of the bulkhead so designed are kept full when in service.

1.7 Drainage and Air Escape

Limber and air holes are to be cut in all parts of the structure, as required, to ensure the free flow to the suction pipes and the escape of air to the vents. Efficient arrangements are to be made for draining the spaces above deep tanks.

1.9 Testing

Requirements for testing are contained in Part 3, Chapter 7.

3 Construction of Deep Tank Bulkheads

Where the specific gravity of the liquid exceeds 1.05, the design head, *h*, in this section is to be increased by the ratio of the specific gravity of the liquid to be carried, to 1.05.

3.1 Plating *(2017)*

Plating is to be of thickness obtained from the following equation:

$t = (sk\sqrt{qh}/254) + 2.5$ mm but not less than 6.5 mm or $s/150 + 2.5$ mm, whichever is greater.

$t = (sk\sqrt{qh}/460) + 0.10$ in. but not less than 0.25 in. or $s/150 + 0.10$ in., whichever is greater.

where

t = thickness, in mm (in.)

s = stiffener spacing, in mm (in.)

k = $(3.075\sqrt{\alpha} - 2.077)/(\alpha + 0.272)$ where $1 \le \alpha \le 2$

= 1.0 where $\alpha > 2$

α = aspect ratio of the panel (longer edge/shorter edge)

q = $235/Y$ N/mm^2 ($24/Y$ kgf/mm^2, $34{,}000/Y$ psi)

Y = specified minimum yield point or yield strength, in N/mm^2 (kgf/mm^2, psi), as defined in 2-1-1/13, for the higher-strength material or 72% of the specified minimum tensile strength, whichever is the lesser

h = the greatest of the following distances, in m (ft), from the lower edge of the plate to:

- a point located two-thirds of the distance from the top of the tank to the top of the overflow
- a point located above the top of the tank at a distance not less than given in column (*e*) of 3-2-7/Table 1, appropriate to the vessel's length
- the load line
- a point located at two-thirds of the distance to the bulkhead or freeboard deck

3.3 Stiffeners

Each stiffener, in association with the plating to which it is attached, is to have section modulus *SM* not less than obtained from the following equation:

$$SM = 7.8chs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0041chs\ell^2 \quad \text{in}^3$$

where

c = 0.594 for stiffeners having effective bracket attachments at both ends

= 0.747 for stiffeners having effective bracket attachment at one end and supported by clip connections or by horizontal girders at the other end

c = 0.900 for stiffeners having clip attachments to decks or flats at both ends or having such attachments at one end with the other end supported by horizontal girders

= 1.00 for stiffeners supported at both ends by horizontal girders

s = spacing of the stiffeners, in m (ft)

h = greatest of the following distances, in m (ft), from the middle of ℓ to:

- a point located at two-thirds of the distance from the top of the tank to the top of the overflow
- a point located above the top of the tank a distance not less than given in column (*e*) of 3-2-7/Table 1, appropriate to the vessel's length
- the load line
- a point located at two-thirds of the distance to the bulkhead or freeboard deck

ℓ = distance, in m (ft), between the heels of the end attachments; where horizontal girders are fitted, ℓ is the distance from the heel of the end attachment to the first girder or the distance between the horizontal girders.

An effective bracket for the application of these values of c is to have the scantlings not less effective than shown in 3-2-9/Table 1 and is to extend onto the stiffener for a distance at least one-eighth of the length ℓ of the stiffener.

3.5 Tank-top Plating

Tops of tanks are to have plating 1 mm (0.04 in.) thicker than would be required for vertical plating at the same level; the thickness is not to be less than required for deck plating. Beams, girders and pillars are to be as required by Section 3-2-7 and Section 3-2-8.

3.7 Girders and Webs

3.7.1 Strength Requirements

Each girder and web which support frames or beams in deep tanks is to have section modulus *SM* as required by Section 3-2-6 and Section 3-2-8 or as required by this paragraph, whichever is the greater; those which support bulkhead stiffeners are to be as required by this paragraph. The section modulus *SM* is to be not less than obtained from the following equation.

$$SM = 4.74chs\ell^2 \quad \text{cm}^3$$

$$SM = 0.0025chs\ell^2 \quad \text{in}^3$$

where

c = 1.50

h = vertical distance, in m (ft), from the middle of s in the case of girders and from the middle of ℓ in the case of webs to the same heights to which h for the stiffeners is measured (see 3-2-10/3.3)

s = sum of half lengths (on each side of girder or web) of the frames or stiffeners supported, in m (ft)

ℓ = span measured between the heels of the end of the attachments, in m (ft). Where effective brackets are fitted, ℓ may be modified as indicated in 3-2-6/7.1.

Where efficient struts are fitted across tanks connecting girders on each side of the tanks and spaced not more than four times the depth of the girder, the value for the section modulus *SM* for each girder may be one-half that given above.

3.7.2 Proportions

Girders, except deck girders (see 3-2-8/5.13), and webs are to have depths not less than 0.145ℓ where no struts or ties are fitted, and 0.0833ℓ where struts are fitted, plus one-quarter of the depth of the slots for the frames or stiffeners. In general, the depth is not to be less than 3 times the depth of the slots; the thickness is not to be less than 1% of the depth plus 3 mm (0.12 in.) but need not exceed 11.5 mm (0.46 in.).

3.7.3 Tripping Brackets *(1994)*

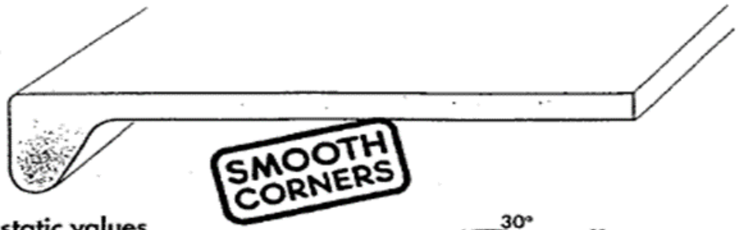
Tripping brackets are to be fitted at intervals of about 3 m (10 ft) and near the change of section. Where the width of the face flange exceeds 200 mm (8 in.) on either side of the girder or web, tripping brackets are to be arranged to support the flange.

3.9 Corrugated Bulkheads

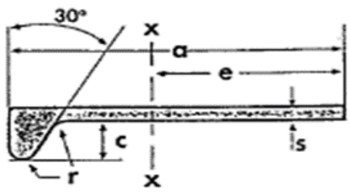
Where corrugated bulkheads are used as deep-tank boundaries, the scantlings may be developed from 3-2-9/7. The plating thickness t and value of *SM* are to be as required by 3-2-10/3.1 and 3-2-10/3.3, respectively, with $c = 0.90$.

ANEXO II. TABLA DE PERFILES TIPO BULBO

Bulb Flats



Dimension range, weight/m and static values



Width a mm	Thickness s mm	Height c mm	Radius r mm	Area A cm²	Weight kg/m	e cm	I_x cm⁴	W_x* cm³
60	4	13	3.5	3.58	2.81	3.82	12.2	13
	5	13	3.5	4.18	3.28	3.70	14.4	14
	6	13	3.5	4.78	3.75	3.62	16.4	16
80	5	14	4	5.40	4.24	4.89	33.8	23
	6	14	4	6.20	4.87	4.78	39.0	25
	7	14	4	7.00	5.50	4.69	43.3	27
		Delivery by special agreement. Standard lengths 6–12 m						
100	6	15.5	4.5	7.74	6.08	5.98	76.1	38
	7	15.5	4.5	8.74	6.86	5.87	85.3	41
	8	15.5	4.5	9.74	7.65	5.78	94.3	45
120	6	17	5	9.31	7.31	7.20	133	54
	7	17	5	10.5	8.25	7.07	148	59
	8	17	5	11.7	9.19	6.96	164	63
140	7	19	5.5	12.4	9.74	8.31	241	80
	8	19	5.5	13.8	10.8	8.18	266	87
	9	19	5.5	15.2	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

* Inclusive plate as noted

Plate cross sectional area 60 cm² (widths 100–180)

Plate cross sectional area 100 cm² (widths 200–370)

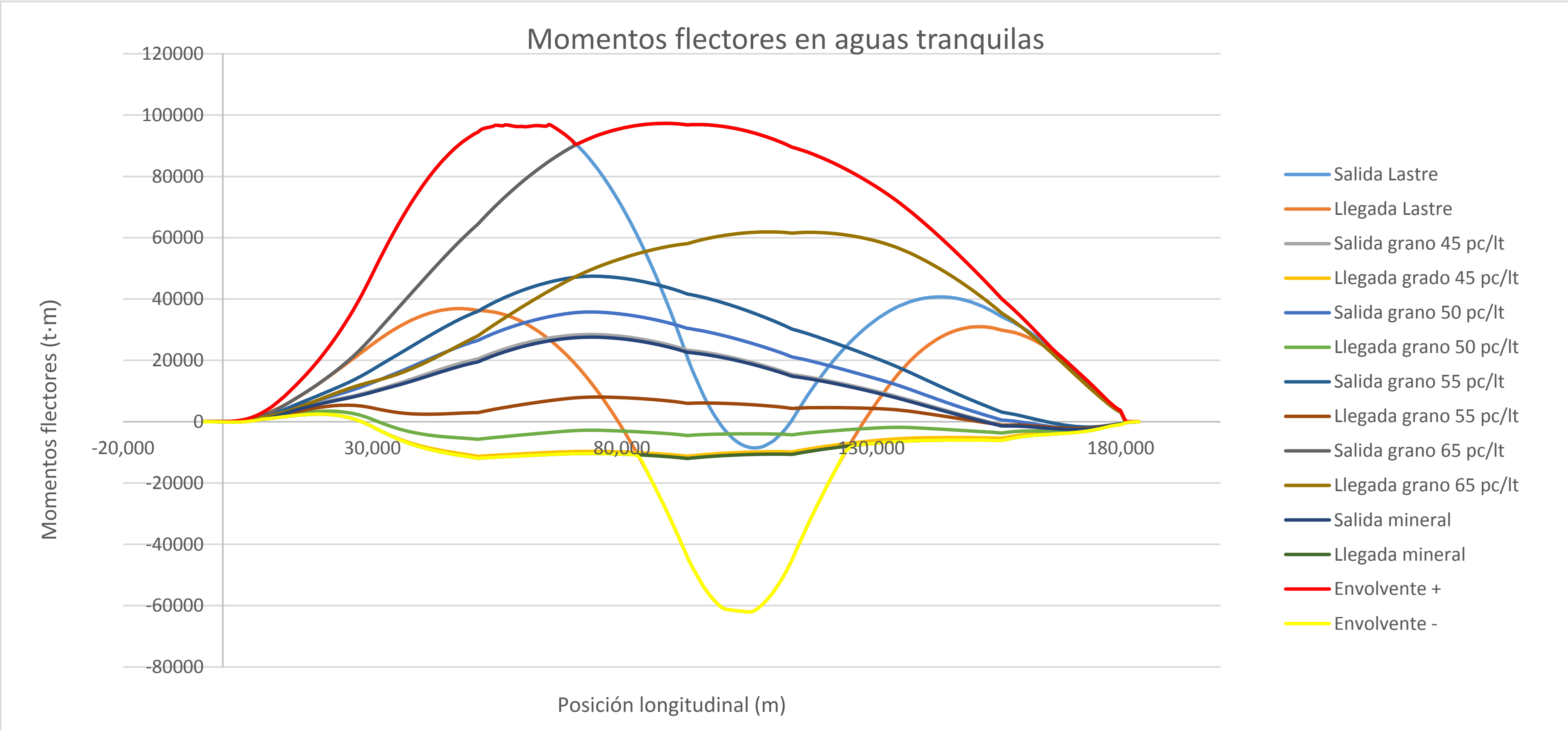
Plate cross sectional area 150 cm² (widths 400–430)

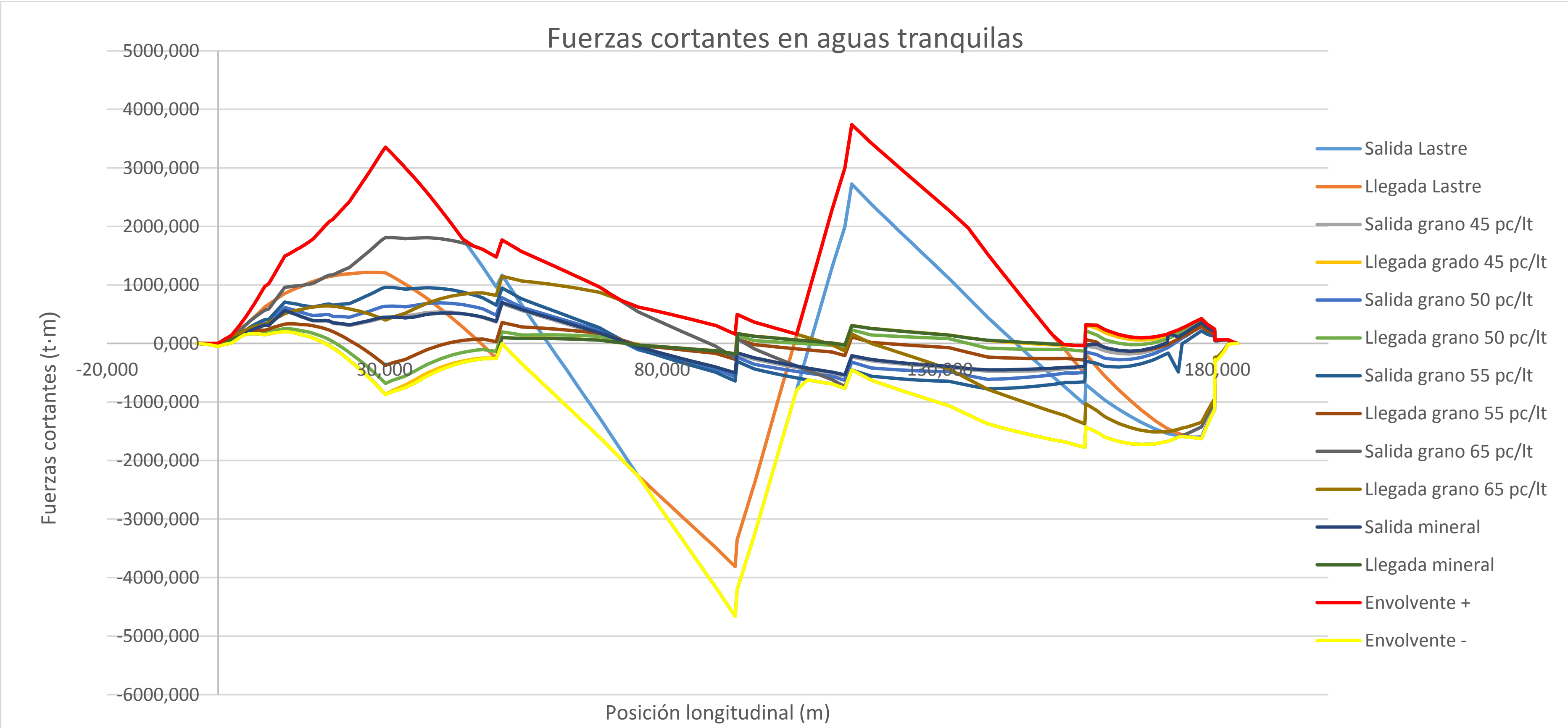
Standard lengths
6–18 m.
Other lengths by special agreeme

Orders
must include the following measurements:
a x s.

INEXA PROFIL 9

ANEXO III. GRÁFICOS MOMENTO FLECTORES Y FUERZAS CORTANTES EN AGUAS TRANQUILAS




Fuerzas cortantes en aguas tranquilas
5000,000
4000,000
3000,000
2000,000
1000,000
0,000
-1000,000
-2000,000
-3000,000
-4000,000
-5000,000
-6000,000
-20,000
30,000
80,000
130,000
180,000
Fuerzas cortantes (t·m)
Posición longitudinal (m)
Salida Lastre
Llegada Lastre
Salida grano 45 pc/lt
Llegada grado 45 pc/lt
Salida grano 50 pc/lt
Llegada grano 50 pc/lt
Salida grano 55 pc/lt
Llegada grano 55 pc/lt
Salida grano 65 pc/lt
Llegada grano 65 pc/lt
Salida mineral
Llegada mineral
Envolvente +
Envolvente -

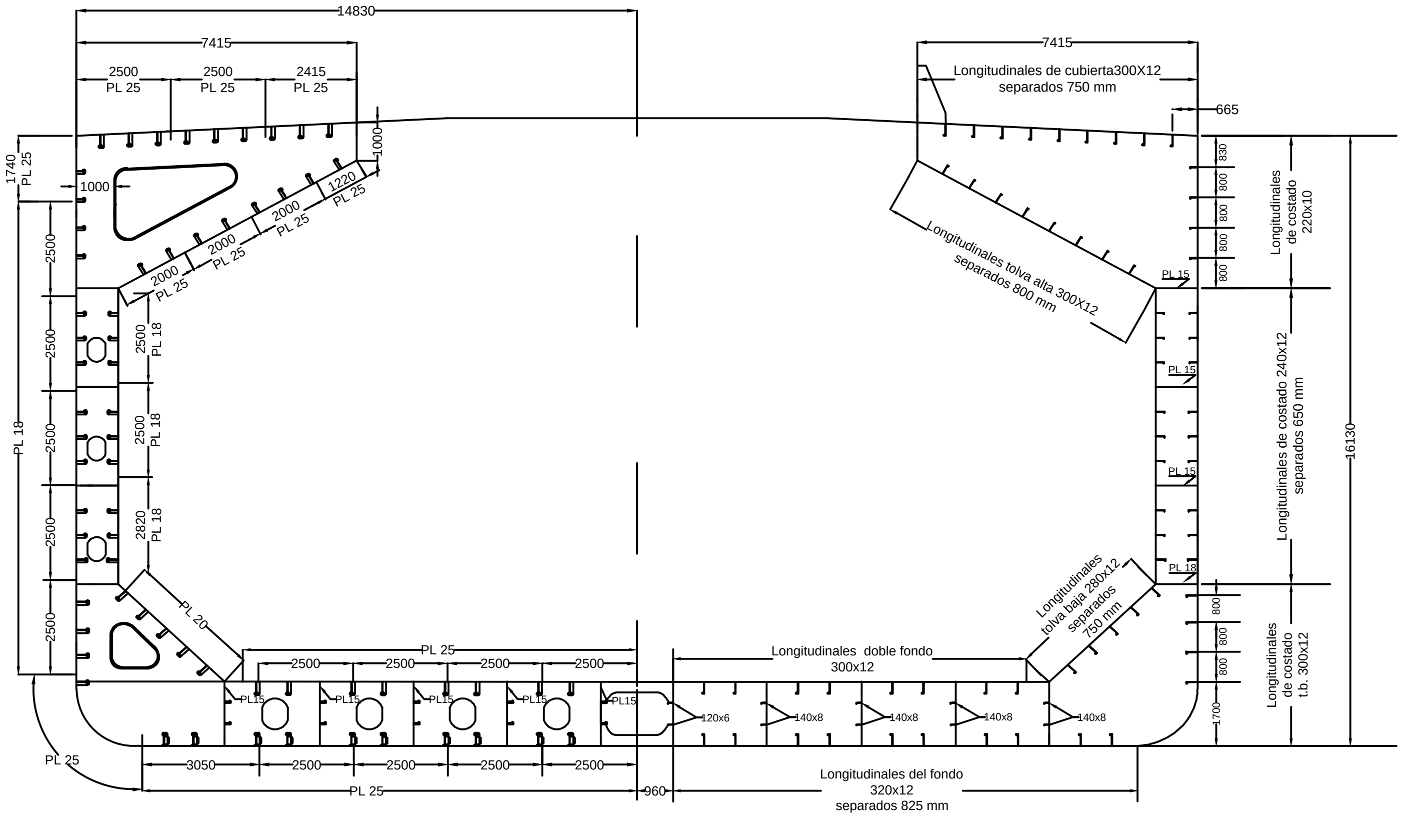
ANEXO IV. MÓDULO RESISTENTE DE LA CUADERNA MAESTRA

Elemento	Cantidad	Definición	Características	heq (mm)	Ancho (mm)	Alto (mm)	Area (cm2)	yg(cm)	YG(CM)	A*YG(cm3)	A*YG2(cm4)	Io (cm4)
Fondo	4	plancha	-	25,00	2500,00	25,00	2500,00	-1,25	-1,25	-3125,00	3906,25	325,52
	1	plancha		25,00	3050,00	25,00	762,50	-1,25	-1,25	-953,13	1191,41	397,14
Pantoque	1	plancha	-	1798,00			322,01	58,80	58,80	18934,97	1113330,25	8660868,29
Costado	1	plancha	-	2500,00	18,00	2500,00	450,00	125,00	439,00	197550,00	86724450,00	2343750,00
	1	plancha	-	2500,00	18,00	2500,00	450,00	125,00	689,00	310050,00	213624450,00	2343750,00
	1	plancha	-	2500,00	18,00	2500,00	450,00	125,00	939,00	422550,00	396774450,00	2343750,00
	1	plancha	-	2500,00	18,00	2500,00	450,00	125,00	1189,00	535050,00	636174450,00	2343750,00
	1	plancha	-	2500,00	18,00	2500,00	450,00	125,00	1439,00	647550,00	931824450,00	2343750,00
	1	plancha	-	1740,00	25,00	1740,00	435,00	87,00	1613,00	701655,00	1131769515,00	1097505,00
Cubierta	1	plancha	-	25,00	2500,00	25,00	625,00	1,25	1624,80	1015500,00	1649984400,00	325,52
	1	plancha	-	25,00	2500,00	25,00	625,00	1,25	1636,60	1022875,00	1674037225,00	325,52
	1	plancha	-	25,00	2415,00	25,00	603,75	1,25	1648,40	995221,50	1640523120,60	314,45
Doble Fondo	1	plancha	-	25,00	900,00	25,00	225,00	1,25	170,00	38250,00	6502500,00	117,19
	4	plancha	-	25,00	2500,00	25,00	2500,00	1,25	170,00	425000,00	72250000,00	325,52
Tolva Baja	1	plancha	-	3900,00	20,00	3900,00	780,00	195,00	419,40	327132,00	137199160,80	9886500,00
Doble Casco	1	plancha	-	2820,00	18,00	2820,00	507,60	141,00	710,18	360486,35	256009477,06	3363865,20
	1	plancha	-	2500,00	18,00	2500,00	450,00	125,00	960,18	432080,10	414873806,26	2343750,00
	1	plancha	-	2500,00	18,00	2500,00	450,00	125,00	1196,21	538292,25	643907880,91	2343750,00
Tolva Alta	1	plancha	-	25,00	2000,00	25,00	500,00	1,25	1304,45	652225,00	850794901,25	260,42
	1	plancha	-	25,00	2000,00	25,00	500,00	1,25	1398,69	699343,50	978162661,98	260,42
	1	plancha	-	25,00	2000,00	25,00	500,00	1,25	1490,56	745280,00	1110884556,80	260,42
	1	plancha	-	25,00	1220,00	25,00	305,00	1,25	1546,68	471737,40	729626801,83	158,85
Vagras	5	plancha	-	1700,00	15,00	1700,00	1275,00	85,00	85,00	108375,00	9211875,00	614125,00

Palmejares de costado	1	plancha	-	18,00	110,00	18,00	19,80	0,90	428,22	8478,68	3630705,06	5,35
	1	plancha	-	15,00	110,00	15,00	16,50	0,75	688,87	11366,36	7829940,97	3,09
	1	plancha	-	15,00	110,00	15,00	16,50	0,75	949,52	15667,15	14876331,14	3,09
	1	plancha	-	15,00	110,00	15,00	16,50	0,75	1210,14	19967,31	24163240,52	3,09
Long. Doble Fondo	8	bulbo	HP 300X12				397,60	18,70	170,00	67592,00	11490640,00	35680,00
Long. Costado t.b	1	bulbo	HP 300X12				49,70	18,70	170,00	8449,00	1436330,00	4460,00
	1	bulbo	HP 300X12				49,70	18,70	250,00	12425,00	3106250,00	4460,00
	1	bulbo	HP 300X12				49,70	18,70	330,00	16401,00	5412330,00	4460,00
	1	bulbo	HP 300X12				49,70	18,70	410,00	20377,00	8354570,00	4460,00
Long. Costado	1	bulbo	HP 240X12				37,30	14,40	494,00	18426,20	9102542,80	2130,00
	1	bulbo	HP 240X12				37,30	14,40	559,00	20850,70	11655541,30	2130,00
	1	bulbo	HP 240X12				37,30	14,40	624,00	23275,20	14523724,80	2130,00
	1	bulbo	HP 240X12				37,30	14,40	689,00	25699,70	17707093,30	2130,00
	1	bulbo	HP 240X12				37,30	14,40	754,00	28124,20	21205646,80	2130,00
	1	bulbo	HP 240X12				37,30	14,40	819,00	30548,70	25019385,30	2130,00
	1	bulbo	HP 240X12				37,30	14,40	884,00	32973,20	29148308,80	2130,00
	1	bulbo	HP 240X12				37,30	14,40	949,00	35397,70	33592417,30	2130,00
	1	bulbo	HP 240X12				37,30	14,40	1014,00	37822,20	38351710,80	2130,00
	1	bulbo	HP 220X10				29,00	13,40	1094,00	31726,00	34708244,00	1400,00
	1	bulbo	HP 220X10				29,00	13,40	1174,00	34046,00	39970004,00	1400,00
	1	bulbo	HP 220X10				29,00	13,40	1254,00	36366,00	45602964,00	1400,00
	1	bulbo	HP 220X10				29,00	13,40	1337,00	38773,00	51839501,00	1400,00
Long. Cubierta	1	bulbo	HP 300X12				49,70	18,70	1616,51	80340,55	129871297,63	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1620,02	80514,99	130435900,58	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1623,53	80689,44	131001728,15	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1627,05	80864,39	131570397,61	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1630,57	81039,08	132139488,30	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1634,08	81213,68	132709482,23	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1637,59	81388,27	133280702,88	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1641,10	81562,87	133853150,24	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1644,62	81737,46	134426824,31	4460,00
Long.Fondo	10	bulbo	HP 320X12				542,00	20,10	21,60	11707,20	252875,52	55300,00

Long. Tolva baja	1	bulbo	HP 280 X 12				45,50	17,20	214,08	9740,64	2085276,21	3550,00
	1	bulbo	HP 280 X 12				45,50	17,20	264,86	12051,04	3191814,09	3550,00
	1	bulbo	HP 280 X 12				45,50	17,20	314,78	14322,49	4508433,40	3550,00
	1	bulbo	HP 280 X 12				45,50	17,20	366,63	16681,67	6115998,84	3550,00
	1	bulbo	HP 280 X 12				45,50	17,20	417,86	19012,63	7944617,57	3550,00
Long. Doble casco	1	bulbo	HP 240X12				37,30	14,40	494,00	18426,20	9102542,80	2130,00
	1	bulbo	HP 240X12				37,30	14,40	559,00	20850,70	11655541,30	2130,00
	1	bulbo	HP 240X12				37,30	14,40	624,00	23275,20	14523724,80	2130,00
	1	bulbo	HP 240X12				37,30	14,40	689,00	25699,70	17707093,30	2130,00
	1	bulbo	HP 240X12				37,30	14,40	754,00	28124,20	21205646,80	2130,00
	1	bulbo	HP 240X12				37,30	14,40	819,00	30548,70	25019385,30	2130,00
	1	bulbo	HP 240X12				37,30	14,40	884,00	32973,20	29148308,80	2130,00
	1	bulbo	HP 240X12				37,30	14,40	949,00	35397,70	33592417,30	2130,00
	1	bulbo	HP 240X12				37,30	14,40	1014,00	37822,20	38351710,80	2130,00
Long. Tolva alta	1	bulbo	HP 300X12				49,70	18,70	1247,78	62014,47	77380163,82	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1286,03	63915,69	82197496,10	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1323,52	65779,09	87060142,64	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1361,18	67650,65	92084706,32	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1398,45	69502,97	97196421,40	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1436,16	71377,15	102509010,62	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1473,88	73251,64	107963830,03	4460,00
	1	bulbo	HP 300X12				49,70	18,70	1511,60	75126,66	113561683,37	4460,00
Long. Vagras	1	bulbo	HP 120X6				9,31	7,20	56,50	526,02	29719,85	133,00
	1	bulbo	HP 120X6				9,31	7,20	113,30	1054,82	119511,45	133,00
	1	bulbo	HP 140X8				13,80	8,18	56,50	779,70	44053,05	266,00
	1	bulbo	HP 140X8				13,80	8,18	113,30	1563,54	177149,08	266,00
	1	bulbo	HP 140X8				13,80	8,18	56,50	779,70	44053,05	266,00
	1	bulbo	HP 140X8				13,80	8,18	113,30	1563,54	177149,08	266,00
	1	bulbo	HP 140X8				13,80	8,18	56,50	779,70	44053,05	266,00
	1	bulbo	HP 140X8				13,80	8,18	113,30	1563,54	177149,08	266,00
	1	bulbo	HP 140X8				13,80	8,18	56,50	779,70	44053,05	266,00
	1	bulbo	HP 140X8				13,80	8,18	113,30	1563,54	177149,08	266,00
∑							**19312,38**			**12861368,54**	**16199387835,18**	**40280923,08**

ANEXO V. PLANO CUADERNA MAESTRA



<u>CARACTERÍSTICAS PRINCIPALES</u>

ESLORA ENTRE PERPENDICULARES	180,14m
MANGA DE TRAZADO	29,66m
PUNTAL DE TRAZADO	16,13m
CALADO DE DISEÑO	12,07m
PESO MUERTO	44500 t

UNIVERSIDADE DA CORUÑA

ESCUELA POLITÉCNICA SUPERIOR

PROYECTO NÚMERO: 18-03

TÍTULO DEL PROYECTO:

BULKCARRIER DE 44500 TPM

TÍTULO DEL PLANO:

CUADERNA MAESTRA

FECHA: SEPTIEMBRE-2018

ESCALA: 1:200

PLANO Nº01

AUTOR:

LUCÍA CACHAZA VÁZQUEZ