Escola Politécnica Superior

Trabajo Fin de Máster
CURSO 2016/2017

BUQUE LNG DE MEMBRANA DE 145.000 m³

Máster en Ingeniería Naval y Oceánica

ALUMNA/O

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FECHA

SEPTIEMBRE DE 2017

CUADERNO 1

En este cuaderno realizaremos un dimensionamiento preliminar del buque estudiando diferentes alternativas y seleccionando la más favorable y económica respecto a nuestras características.

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BUQUE LNG DE MEMBRANA DE 145.000 m³

Máster en Ingeniería Naval y Oceánica

CUADERNO 1

ELECCIÓN DE LA CIFRA DE MÉRITO Y DEFINICIÓN DE ALTERNATIVAS. SELECCIÓN DE LA MÁS FAVORABLE

Escola Politécnica Superior
UNIVERSIDADE DA CORUÑA

DEPARTAMENTO DE INGENIERÍA NAVAL Y OCEÁNICA

TRABAJO FIN DE MÁSTER

CURSO 2016-2017

PROYECTO NÚMERO: 17-32 P

TIPO DE BUQUE: Buque tanque LNG de membrana

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

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

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

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

PROPULSIÓN: Propulsión Diesel eléctrico. Dos líneas de ejes

TRIPULACIÓN Y PASAJE: 35 tripulantes en camarotes individuales.

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

Ferrol, Abril de 2017

ALUMNO: D. Ismael Grandal Mouriz

ÍNDICE:

1-INTRODUCCIÓN. GAS NATURAL Y BUQUES GASEROS

Definición

El gas natural es una fuente de energía no renovable de origen fósil, que se encuentra normalmente en el subsuelo continental o marino. Se formó hace millones de años cuando una serie de organismos descompuestos, como animales y plantas, quedaron sepultados bajo lodo y arena, en lo más profundo de los antiguos lagos y océanos. En la medida que se acumulaba lodo, arena y sedimento, se fueron formando capas de roca a gran profundidad. La presión causada por el peso sobre estas capas más el calor de la Tierra, transformaron lentamente el material orgánico en petróleo crudo y gas natural.

El gas natural se acumula en bolsas entre la porosidad de las rocas subterráneas. Pero en ocasiones, se queda atrapado debajo de la tierra por rocas sólidas que evitan que el gas fluya, formándose lo que se conoce como un yacimiento.

La composición del gas natural incluye diversos hidrocarburos gaseosos, con predominio del metano (sobre el 90%), y en proporciones menores etano, propano, butano, pentano y pequeñas proporciones de gases inertes como dióxido de carbono y nitrógeno.

Es una de las fuentes de energía más limpias y respetuosas con el medio ambiente, ya que contiene menos dióxido de carbono y lanza menos emisiones a la atmósfera. Es, además, una energía económica y eficaz. Una alternativa segura y versátil capaz de satisfacer la demanda energética en los sectores doméstico, comercial e industrial.

El transporte de gas natural licuado

Realizaremos primeramente una pequeña introducción acerca del transporte de gas licuado desde diferentes perspectivas con la finalidad de familiarizarnos con este tipo de buques.

Se denomina LNG al gas natural que ha sido refrigerado por enfriamiento a aproximadamente -160 ºC.

El hecho de que el gas natural ocupe un volumen 600 veces menor licuado que en estado gaseoso, hace muy práctico su transporte en buques.

Se tratará la cadena de proceso de LNG, su evolución y demanda mundial y los diferentes tipos de buques destinados a su transporte.

Cadena integrada del proceso del LNG

Existen cuatro procesos principales que componen la cadena integrada del LNG:

Exploración y explotación del LNG

Comprende todas las operaciones relacionadas desde las reservas hasta las plantas de LNG.

Plantas de LNG

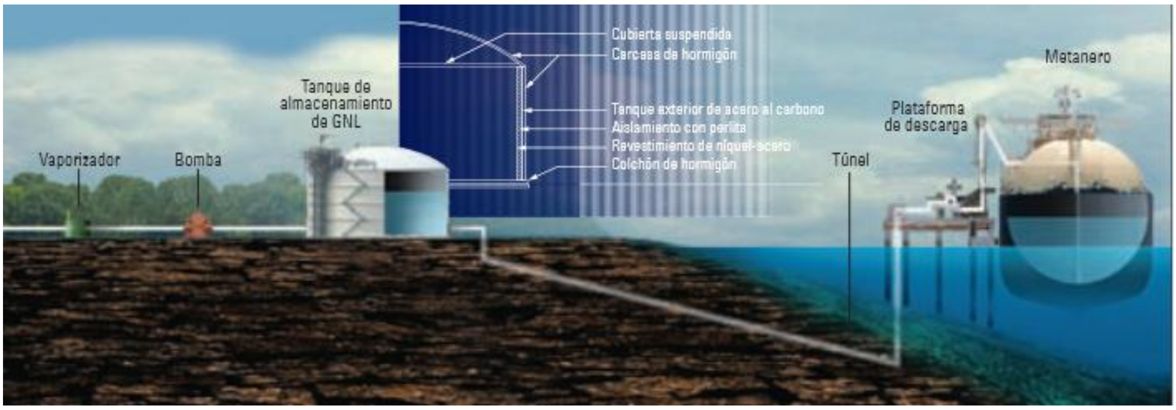
Incluye el tratamiento del gas natural, la licuefacción propiamente dicha y el almacenamiento de LNG.

Transporte

El transporte en buques metaneros es el tercer eslabón de la cadena integrada del LNG. Estos buques son menos contaminantes que otros medios de transporte, ya que pueden quemar gas natural en lugar de fuel oil como fuente de propulsión.

Terminales de recepción

Incluye la descarga, el almacenamiento, la regasificación y la distribución. El último eslabón de la cadena de suministro de LNG es la terminal de importación. Estas terminales descargan LNG y lo almacenan en tanques aislados hasta que esté preparado para ser sometido al proceso de regasificación.



Componentes de una terminal de importación. Los buques metaneros llegan por transporte marino a las plataformas de descarga de las terminales de importación, en tierra firme o en áreas marinas. Si las instalaciones de atraque y la plataforma de descarga asociada son marinas, el LNG proveniente de la embarcación se bombea a través de tuberías submarinas hasta los tanques de almacenamiento aislados, emplazados en tierra firme. Los tanques de acero aislados se utilizan comúnmente con fines de almacenamiento.

En la figura se muestra un esquema simplificado de dicha cadena:

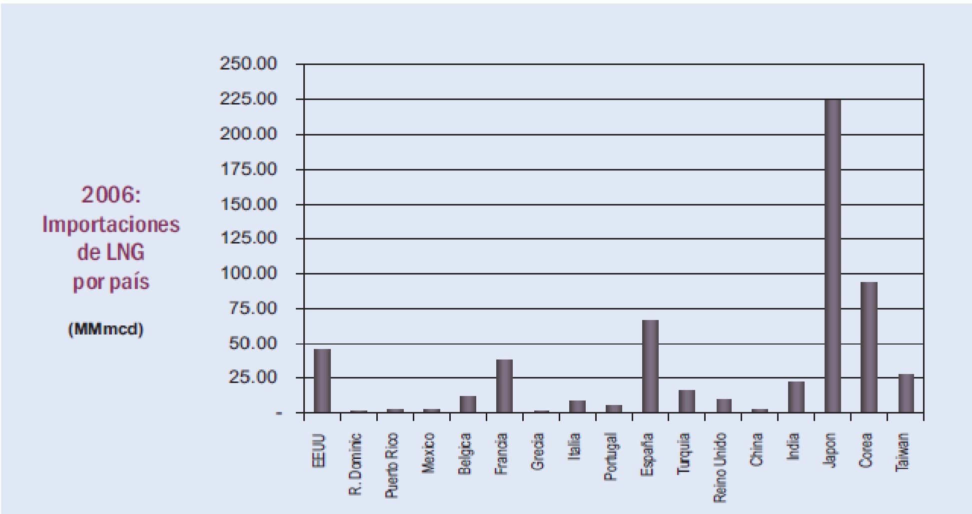
Evolución de la demanda mundial de LNG

El LNG es un mercado en alza debido sobre todo a la explotación de bolsas de gas en zonas de perforación en las que previamente han agotado sus reservas de petróleo. La aparición de economías emergentes, como China o La India, han provocado un incremento continuado de la demanda de gas natural licuado.

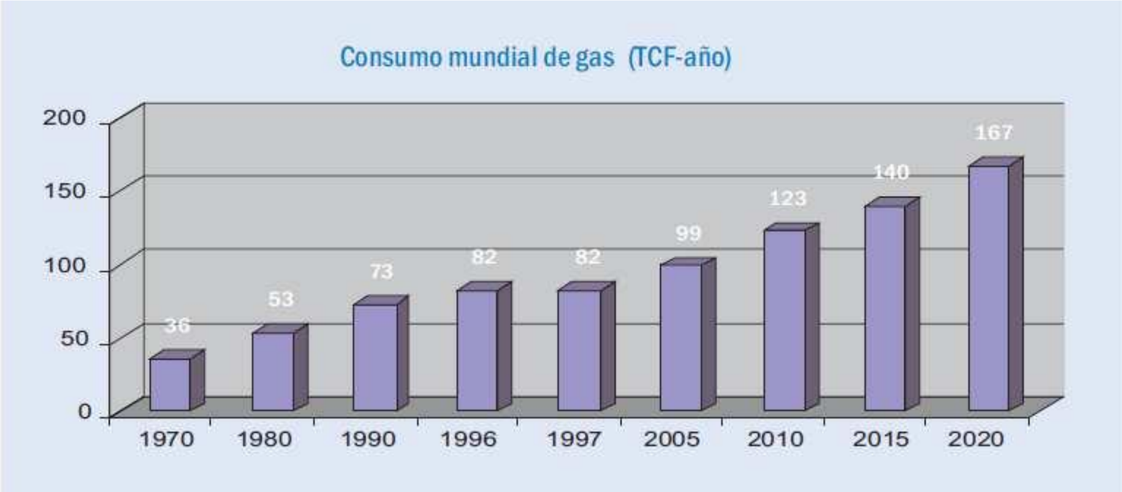
La comercialización del gas licuado está concentrándose mayoritariamente en Asia. Solamente Japón representa el 52% del total de importaciones por barco.

En el gráfico adjunto podemos observas las principales rutas de transporte del gas natural licuado:

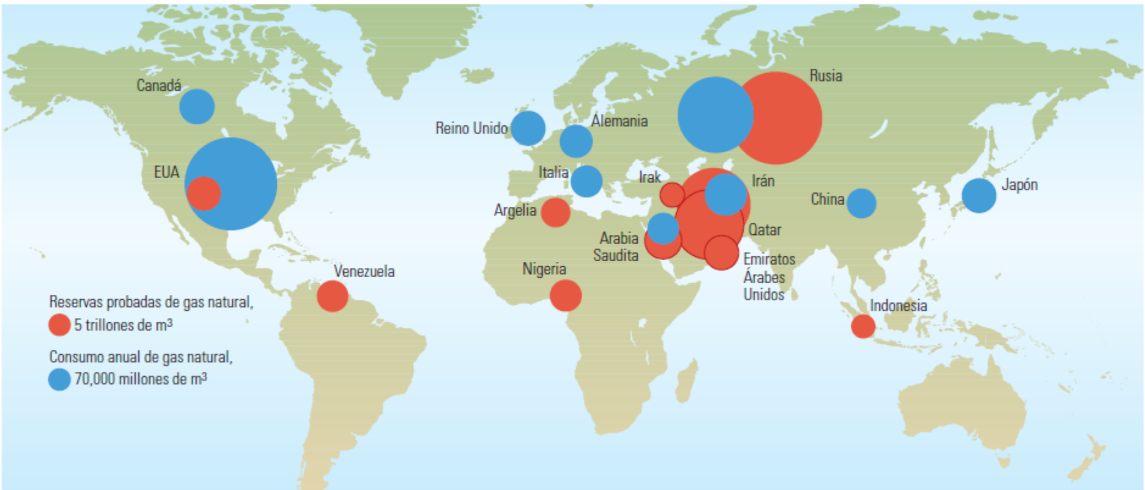
En la gráfica adjunta podemos ver las importaciones por países:



En la figura puede observarse el crecimiento histórico hasta el año 2010 de la demanda mundial de LNG, y su correspondiente pronóstico hasta el 2020. Como vemos, las previsiones son halagüeñas, aunque deberá tenerse en cuenta la crisis financiera que se vive en la actualidad, que previsiblemente rebajará estas estimaciones.



Reservas mundiales



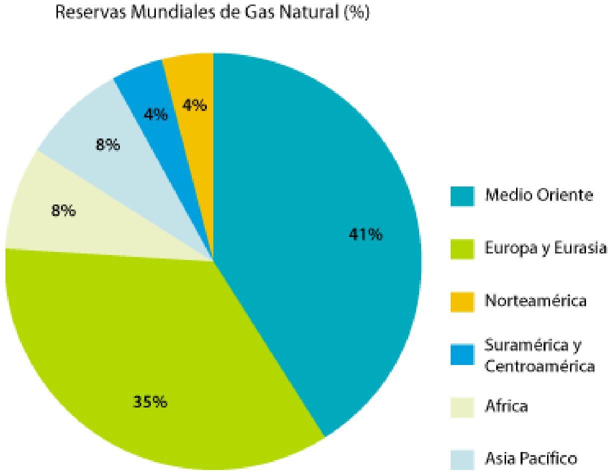
La búsqueda de gas natural se inicia con exploraciones, que consisten básicamente en realizar perforaciones en zonas donde existen indicios de la existencia de gas. Una vez que se encuentra un yacimiento de gas natural, el próximo paso es analizarlo para determinar tanto la cantidad como la calidad del gas natural contenido en ese yacimiento, calculándose así la duración de explotación del mismo de acuerdo a la cantidad de gas que contenga y a una estimación del consumo. Una vez que estos análisis son efectuados, el gas natural de ese yacimiento pasa a ser una "reserva probada" de gas natural.

Pero, dado el alto costo que implica este proceso, no todos los yacimientos son analizados. Lo que sí se realiza constantemente son perforaciones para localizar yacimientos, de manera que en el momento que se necesiten probar las reservas, éstas se tengan ubicadas y lo único necesario por realizar sea un análisis para determinar la calidad y la duración del gas natural.

Como norma, las empresas productoras de gas natural deben mantener reservas probadas por lo menos para cumplir con los contratos de extracción y suministro que mantenga vigentes.

Respecto a las reservas mundiales de gas natural, éstas son aproximadamente de 145 trillones de metros cúbicos. Estas reservas están localizadas principalmente en la ex Unión Soviética y Oriente Medio. Y dentro de la ex Unión Soviética, Rusia tiene el

85% de esas reservas. En el caso de Oriente Medio, Irán es el país que tiene mayor cantidad de reservas, con un 47%.



Proceso de licuefacción en tierra

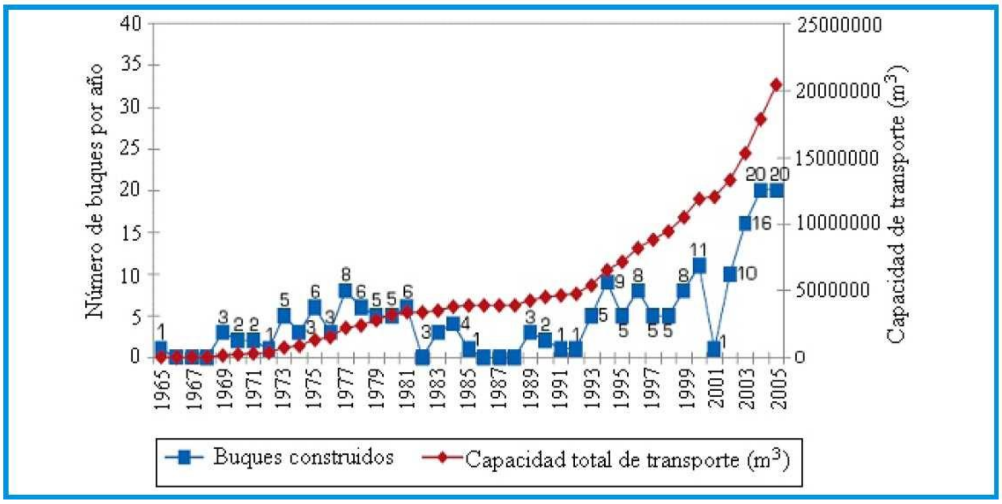
El LNG ocupa aproximadamente 600 veces menos volumen que el gas natural, gracias al proceso de licuefacción al que es sometido

El proceso de licuefacción tiene un rendimiento del 90%. Esto quiere decir que el 10% del gas natural que ingresa a la planta de LNG, se utiliza como fuente de energía para el proceso.

Se almacena en tanques criogénicos de 100.000 m³ de capacidad, que permiten mantener el gas en su forma líquida, aún en un clima cálido.

Evolución de los buques metaneros en el mundo

En esta figura se observa la evolución de la flota metanera en el mundo, desde 1965 hasta el 2006.



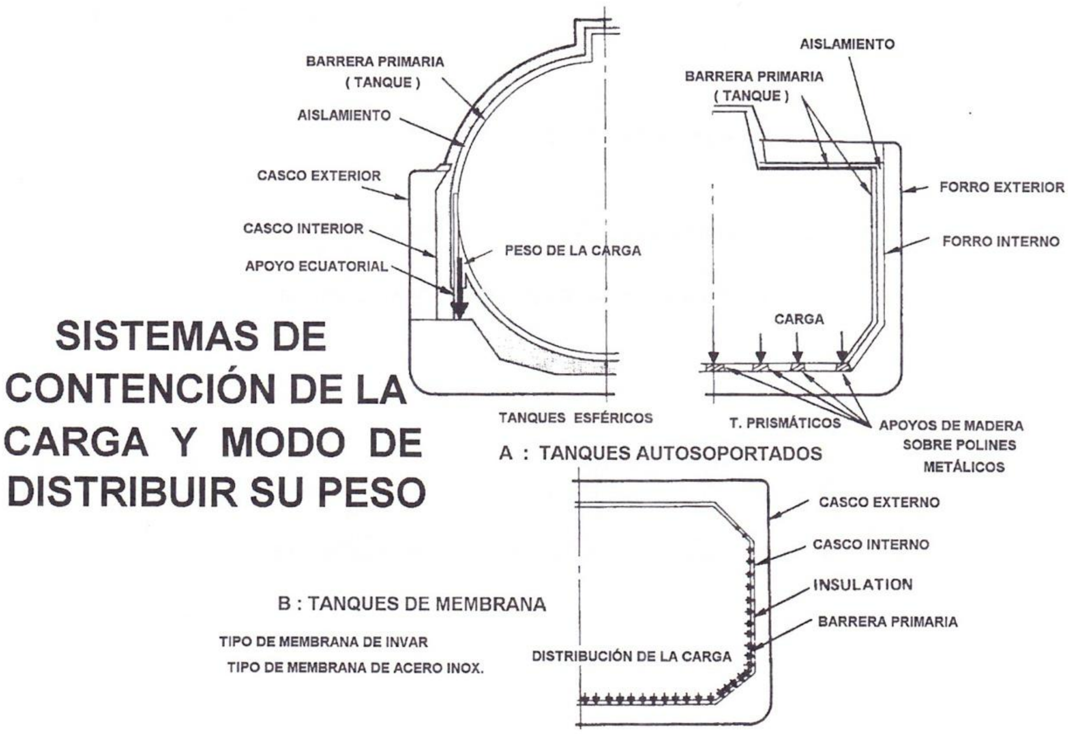
En el mundo, son 8 las empresas principales que construyen los buques metaneros, de las cuales 3 está en Japón, 3 en Corea y las otras 2 en Europa. Sin embargo, La India, China y Polonia están en condiciones tecnológicas para unirse a este grupo de constructores, al igual que sucede con otros países.

España parece haber cerrado su etapa en la construcción de buques metaneros con la desmantelación de los almacenes que se construyeron para la catalogación y almacenaje de las cajas de perlita.

Diferentes tipos de buques para el transporte de gas

Estos tipos de buques transportan gas licuado a la presión atmosférica y a una temperatura de -161 º C.

El gas metano o “gas grisú” de las minas, o gas de los pantanos, es extremadamente peligroso por el riesgo de explosión. Esto obliga a que este tipo de buques incorporen grandes medidas de seguridad. Puede afirmarse que en el momento actual es el buque mercante de más alta tecnología.



Desde el punto de vista del sistema de contención de la carga, pueden distinguirse dos tipos diferentes:

-Los metaneros de tanques autosoportados.

-Los metaneros de membrana.

Dentro de los metaneros de tanques independientes existen dos tipos de tecnología diferentes:

-La de General Dynamics, de tanques autosoportados prismáticos (patente EEUU).

-La de Moss Rosemberg, de tanques autosoportados esféricos (patente Dinamarca).

En ambos casos el material de los tanques es aluminio aleado (5083).

Los tanques autosoportados de forma prismática se apoyan sobre polines de acero aleado (9% Ni) que van soldados al doble fondo. Los tanques sufrirán grandes dilataciones a causa del gran salto térmico de aproximadamente 200 º C, a pesar del bajo coeficiente de dilatación del aluminio. Ello obliga a que el sistema de contención de la carga permita las libres dilataciones sin ofrecer resistencia, pero sin dejar de tener sujeto al tanque. Esto se logra por un sistema de llaves en cruz situadas en el fondo (transversal y longitudinal) que dejan expandir o contraer libremente al tanque hacia proa y popa de la línea de llaves, pero al mismo tiempo impidiendo el libre movimiento del tanque respecto del buque. En dirección vertical también es preciso contar con unas guías sobre los mamparos de proa y popa que permitan la expansión o contradicción del tanque en sentido vertical, pero sin dejar a este libre respecto del buque. La sección del tanque es octogonal, sobresaliendo su parte alta sobre la cubierta, la cual se cubre con una cubierta tronco con el fin de evitar el impacto de los rayos solares sobre el mismo tanque, lo que aumentaría la evaporación y mayores pérdidas del gas durante el transporte (12oíl-off).

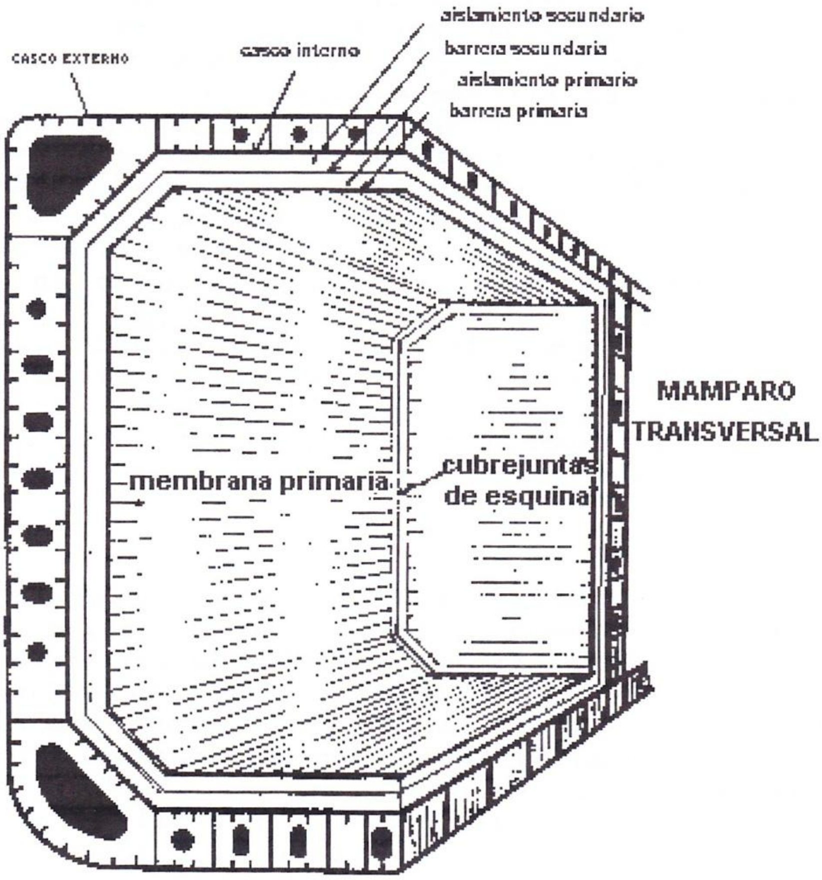
Los metaneros de tanques autosoportados esféricos, dan apoyo a las esferas contenedoras de la carga con anillos estructurales ecuatoriales, como se puede ver en la FIGURA. Produciéndose la libre dilatación del tanque en dirección a sus polos. Hace pocos años se hizo algún intento de fabricar el contenedor esférico con acero aleado al 9 % Ni, pero resultó un procedimiento inefectivo, a causa de las incontrolables tensiones térmicas que aparecían en sus soldaduras, las cuales provocaban grietas, fisuras y deformaciones.

La membrana es una lámina delgada que se apoya en toda su superficie en las cajas de madera que contienen el aislamiento. Coexisten dos tecnologías en las membranas de metaneros:

-Membrana de INVAR de acero aleado al 36 % Ni con bajísimo coeficiente de dilatación, su espesor es de 0.4 mm. Tecnología francesa de la firma Gaz Transport. (Ver figura).

-Membrana corrugada de acero inoxidable de 2/3 mm de espesor. Las corrugas se disponen perpendicularmente para poder absorber las libres dilataciones. Las zonas planas entre corrugas son las únicas que están apoyadas sobre las cajas de aislamiento. También es de tecnología francesa, de la firma Technigaz, en la actualidad fusionada con Gaz Transport.

TÉCNICA DE MEMBRANA DE GAZ-TRANSPORT DE INVAR (36 % Ni)



Los buques para el transporte de Gas Natural Licuado (GNL o LNG), tienen una ventaja muy importante desde el punto de vista de contaminación atmosférica: queman el propio gas natural en lugar de fuel oil como fuente de propulsión, con la consiguiente reducción de emisiones (aproximadamente un 90 %), altamente contribuyentes al efecto invernadero.

Además, dentro de los distintos tipos, podemos establecer las siguientes apreciaciones:

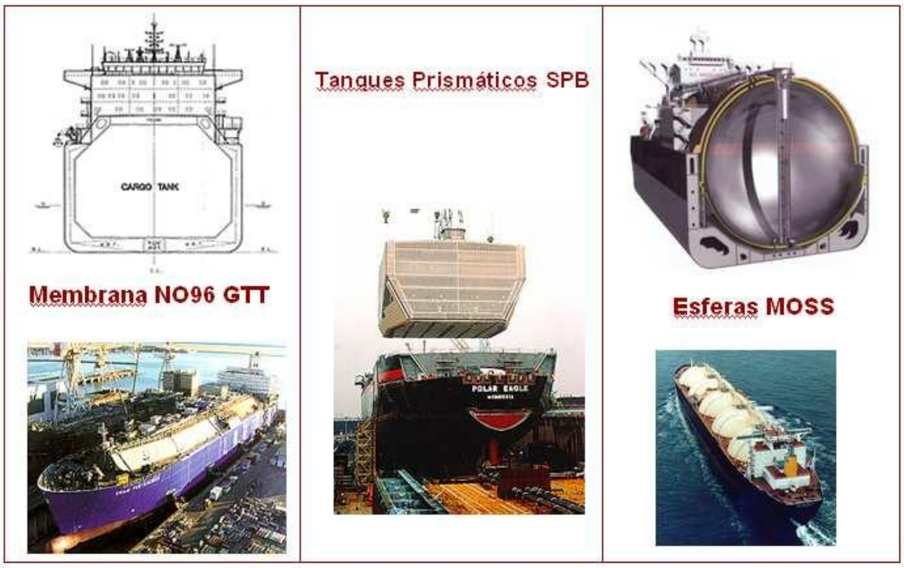
Los tanques de esferas tipo Moss tienen más superficie expuesta al viento, con lo que su resistencia al viento es elevada.

El precio de construcción de los buques con tanques esféricos es más elevado que el de los buques de membrana.

Los tanques prismáticos SPB presentan mayor manga en la parte superior del tanque, con lo que su momento por superficies libres es mayor que en los tanques de membrana.

Los tanques de membrana ofrecen más capacidad de carga que los tanques esféricos.

En los tanques de membrana el enfriamiento de los mismos es más rápido que en los esféricos.



2-BASE DE DATOS

Hemos seleccionado una serie de buques transportadores de LNG con membranas con unas características similares a las de nuestro buque proyecto, con un volumen de carga en una franja que va desde los 138.000 hata los 177.400 m³.

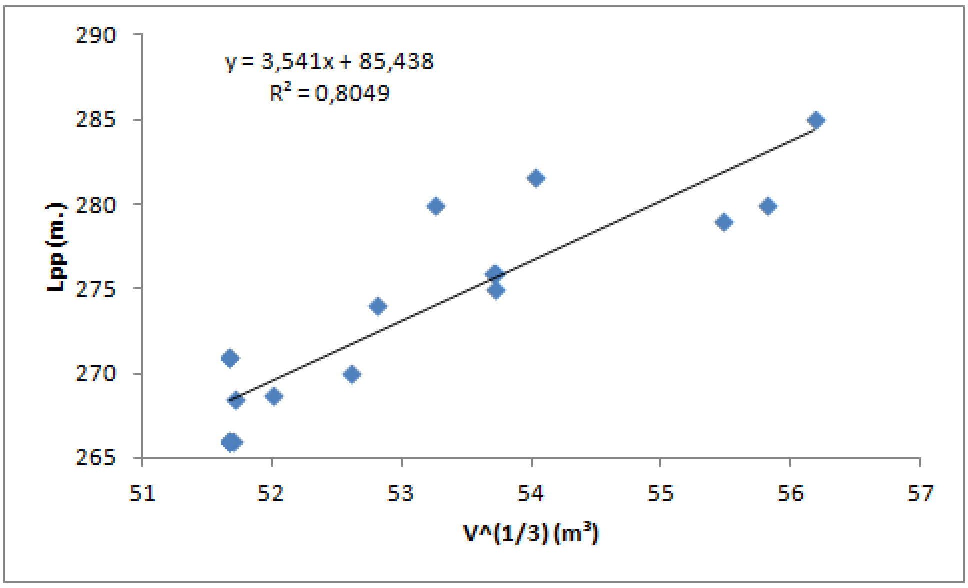
Toda la documentación correspondiente a los barcos que forman parte de la base de datos se adjunta como anexo.

Buque	V (m³)	Lpp (m.)	B (m.)	D (m.)	T (m.)	v (kn.)
Abdelkader	177400	285	46	26,8	11,9	19,6
Castillo de Santisteban	173887	280	46	26	11,5	20,42
Barcelona Knutsen	170723	279	45,8	26,5	11,95	19,5
Seri Balhaf	157720	281,6	46,5	25,8	11,15	19,5
British Emerald	155000	275	44,2	26	11,47	20
Trinity Arrow	154982	276	44,7	26	11,37	19,5
GDF Suez Point Fortin	154913	276	44,7	26	11,73	19,5
Express	151000	280	43,4	26	11,6	19,2
Dapeng Sung	147337	274,1	43,35	26,25	11,45	19,5
Maersk Qatar	145600	270	43,4	26	11,4	20,6
Fernando Tapias	140627	268,8	43,4	26	11,42	19,5
Hanjin Muscat	138366	268,5	43	26,2	11,3	20,3
British Trader	138200	266	42,6	26	11,35	20,1
Excelsior	138000	266	43,4	26	11,5	19,1
Berge Everett	138000	266	43,4	26	11,4	19,5
SK Summit	138000	266	43,4	26	11,3	20,3
Sestao Knutsen	138000	271	42,5	25,4	11,4	19,5

Iñigo Tapias	138000	271	42,5	25,4	11,4	21

3-CÁLCULO DE LA ESLORA (Lpp)

En la gráfica posterior se representa la eslora y la raíz cúbica del volumen de los buques de carga de nuestra base de datos:



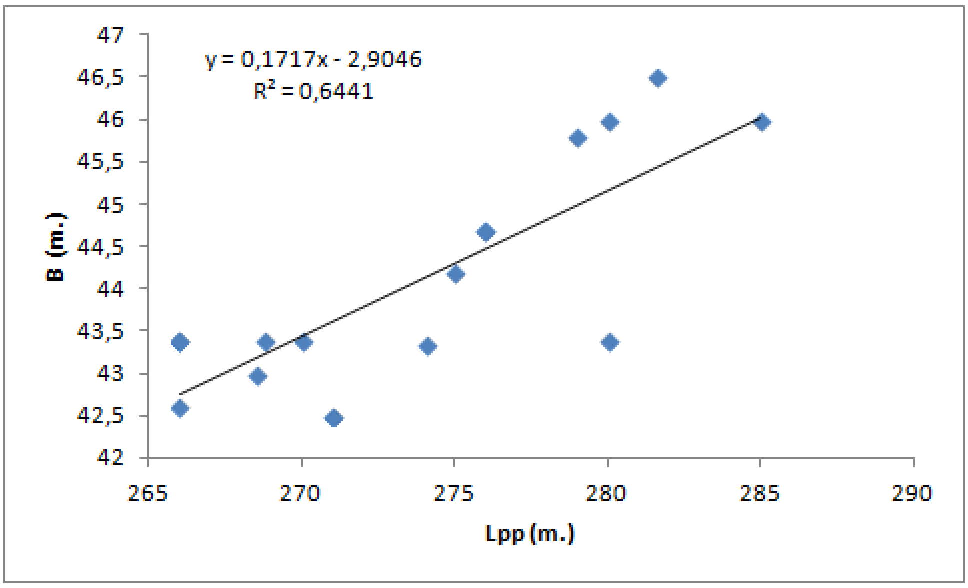
$$Lpp = 3{,}541 \cdot \sqrt[3]{V} + 85{,}438$$

<u>Lpp = 271,5 m.</u>

Donde:

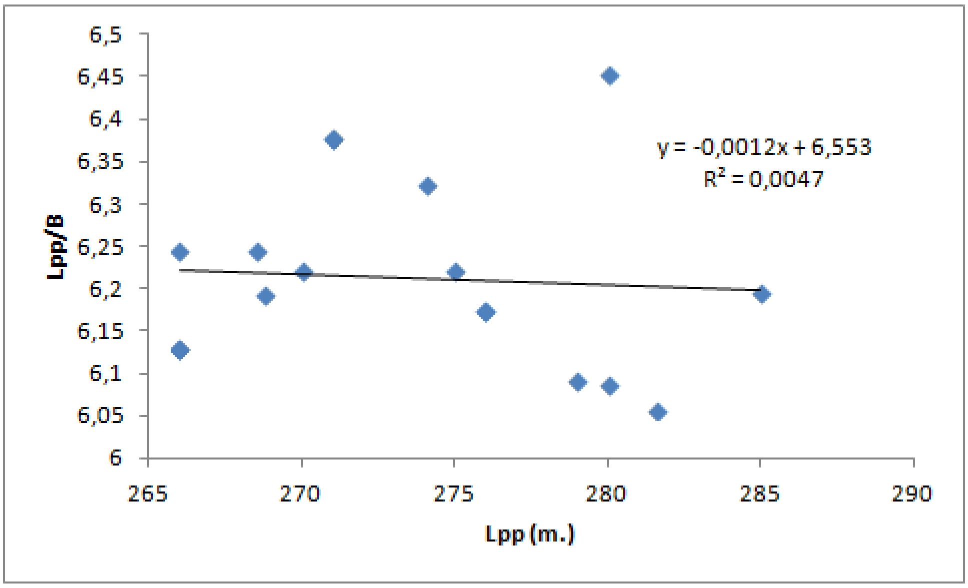
V: volumen de carga (145.000 m^3)

4-CÁLCULO DE LA MANGA (B)



$$B = 0{,}1717 \cdot Lpp - 2{,}9046$$

B = 43,33 m.



$$\frac{Lpp}{B} = -0{,}0012 \cdot Lpp + 6{,}553$$

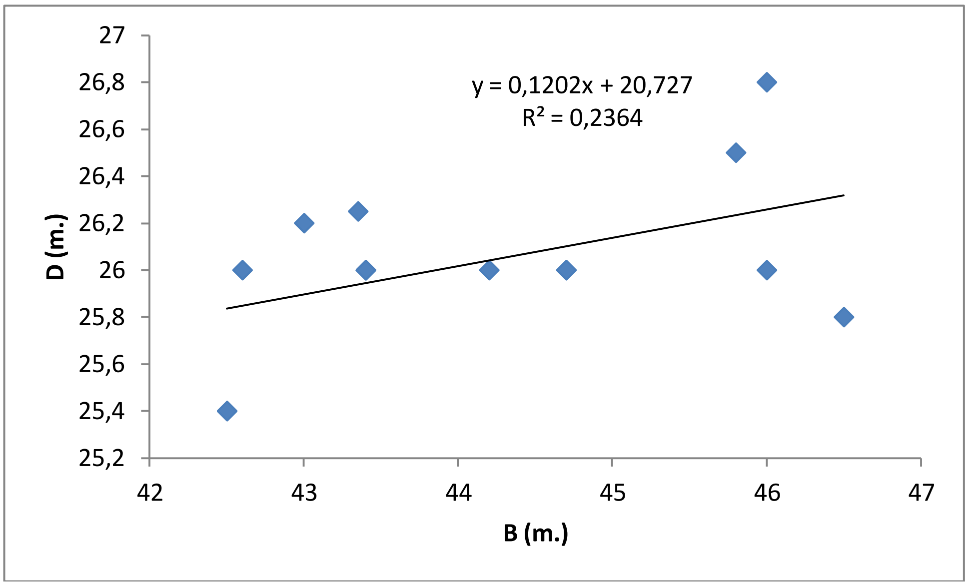
B = 43,22 m.

Ésta no es una aproximación muy buena ($R^2 = 0{,}0047$), pero haremos una media de los dos valores obtenidos.

Hacemos una media de los dos valores anteriormente obtenidos de la manga (43,33 y 43,22) y tenemos como resultado 43,27, por tanto tomaremos una manga de:

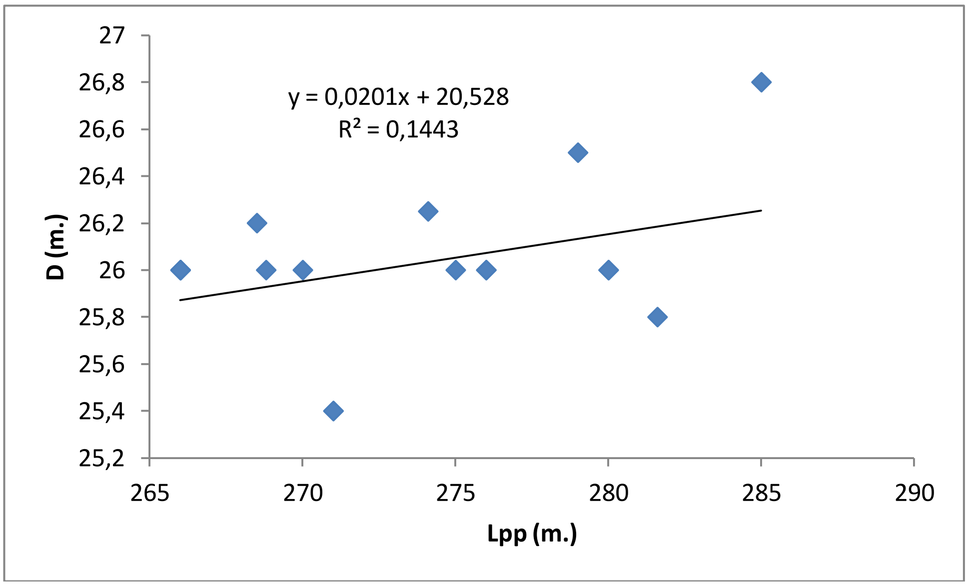
<u>B = 43,30 m.</u>

5-CÁLCULO DEL PUNTAL (D)



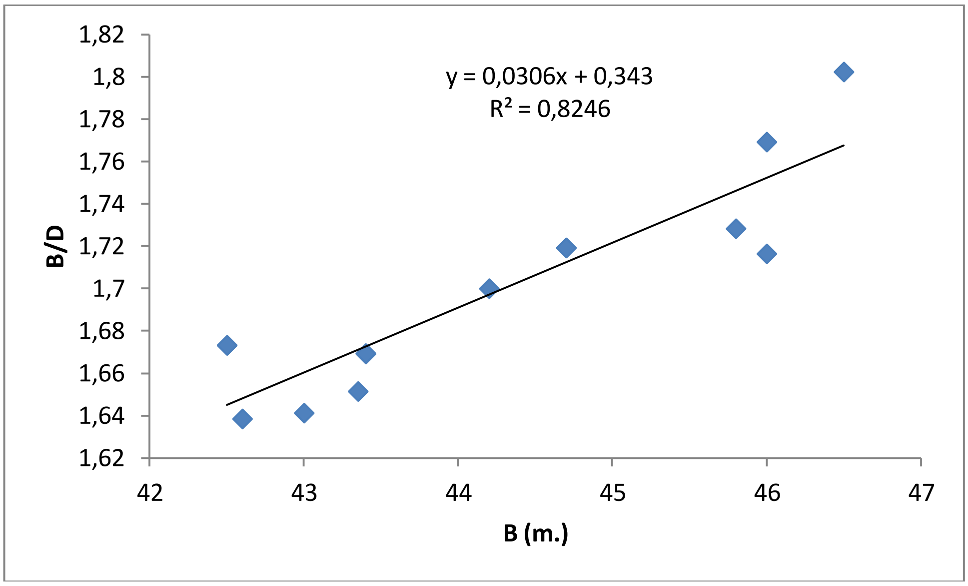
$$D = 0{,}1202 \cdot B + 20{,}727$$

D = 25,93 m.



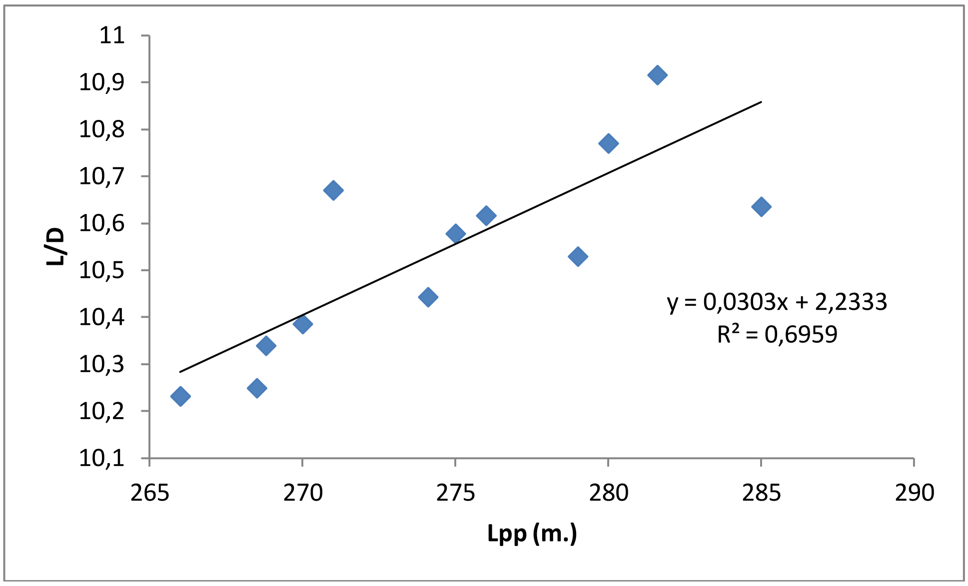
$$D = 0{,}0201 \cdot Lpp + 20{,}528$$

D = 25,94 m.



$$\frac{B}{D} = 0{,}0306 \cdot B + 0{,}343$$

D = 25,96 m.



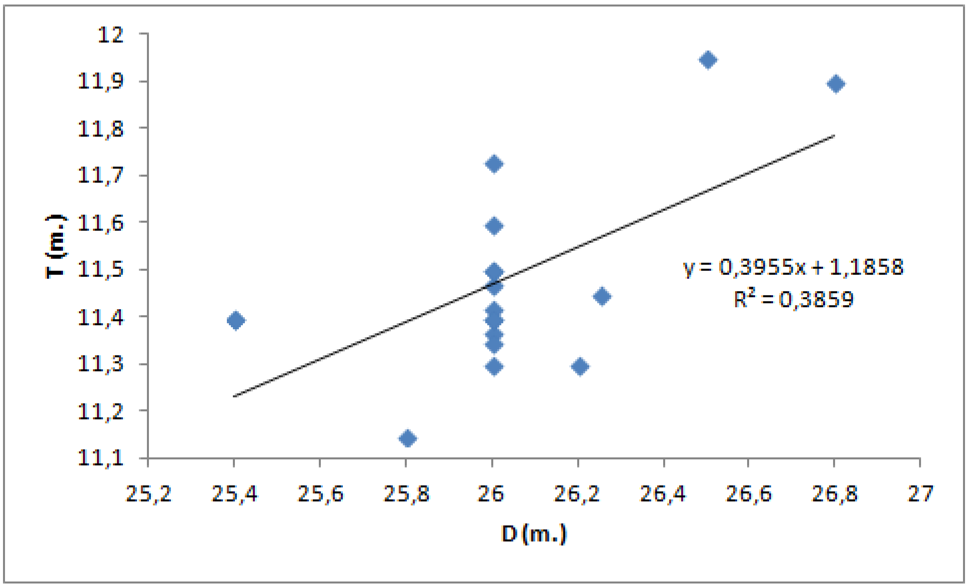
$$\frac{Lpp}{D} = 0{,}0303 \cdot Lpp + 2{,}2333$$

D = 25,91 m.

Como en el caso de la manga, hay algunas aproximaciones que no son muy buenas, pero hacemos una media de los cuatro valores anteriormente obtenidos para el puntal (25,93; 25,94; 25,96 y 25,91) y tenemos como resultado 25,93. Por tanto, tomaremos un puntal de:

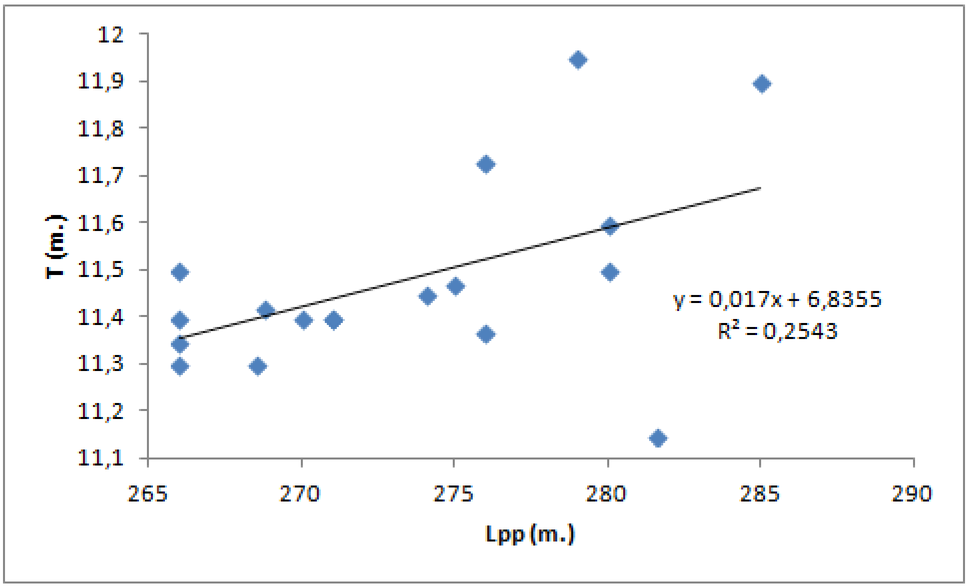
<u>D = 26 m.</u>

6-CÁLCULO DEL CALADO (T)



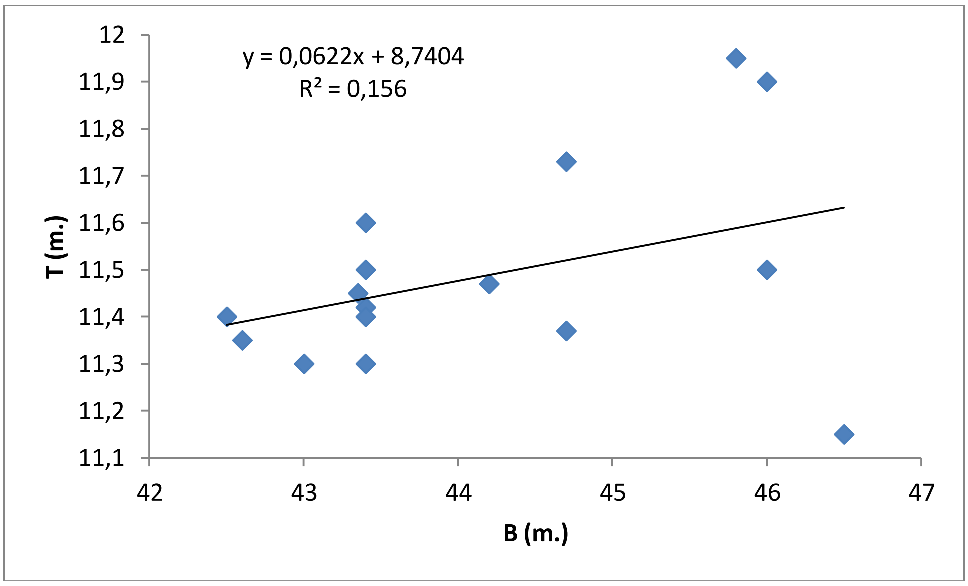
$$T = 0{,}3955 \cdot D + 1{,}1858$$

T = 11,47 m.



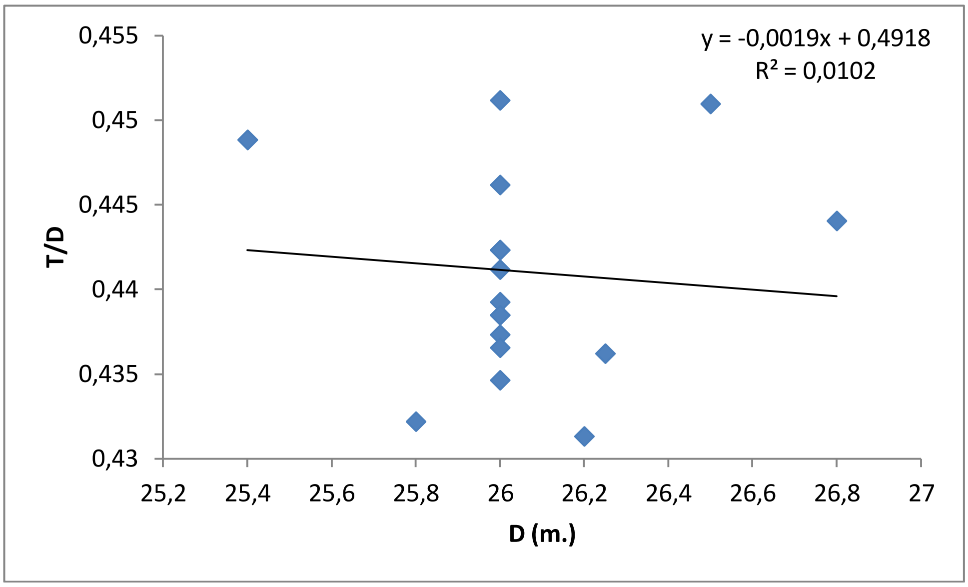
$$T = 0{,}017 \cdot Lpp + 6{,}8355$$

T = 11,41 m.



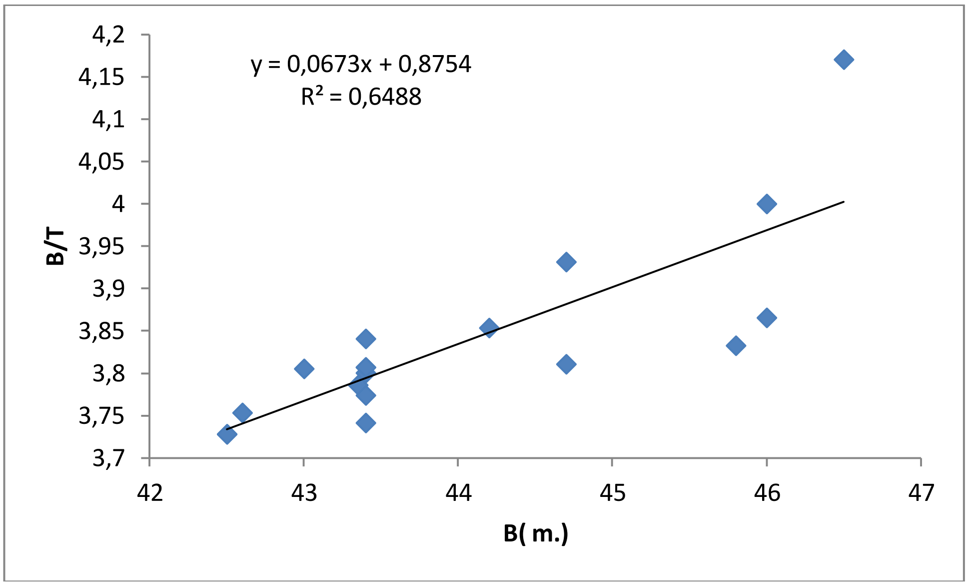
$$T = 0{,}0622 \cdot B + 8{,}7404$$

T = 11,43 m.



$$\frac{T}{D} = -0{,}0019 \cdot D + 0{,}4918$$

T = 11,50 m.



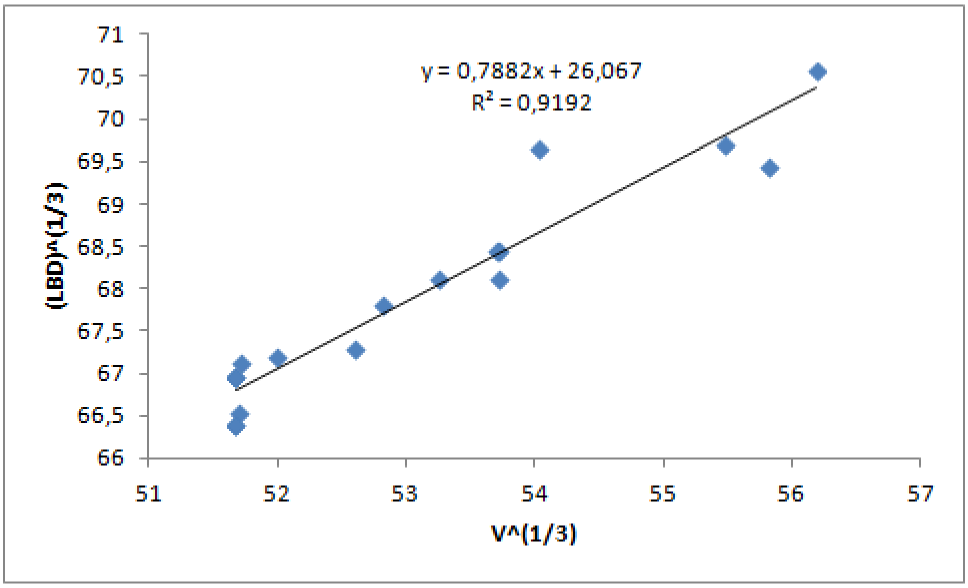
$$\frac{B}{T} = 0{,}0673 \cdot B + 0{,}8754$$

T = 11,43 m.

Como en los dos casos anteriores, hay aproximaciones que no son muy buenas, pero las tendremos en cuenta a la hora de hacer una media de los cinco valores anteriormente obtenidos para el calado (11,47; 11,41; 11,43; 11,50 y 11,43). El valor medio es 11,45 m. Tomaremos un calado de:

T = 11,50 m.

7-CÁLCULO DE LA RELACIÓN VOLUMEN/LBD



$$\sqrt[3]{LBD} = 0{,}7882 \cdot \sqrt[3]{V} + 26{,}067$$

Mediante esta fórmula calculamos nuestro $LBD_{requerido}$ para transportar los 145.000 m³, que es igual a 307.215,93, y nuestro LBD es igual a 305.654,7. No se cumple la ecuación. Pero hay que tener en cuenta que en muchas de las gráficas estamos utilizando valores de R^2 de 0,50 o 0,60, por lo que hay un error de cálculo.

8-RESULTADOS DEL PRIMER DIMENSIONAMIENTO

L (m.)	B (m.)	D (m.)	T (m.)	LBD (m³)
271,5	43,3	26	11,5	30721 5,93

9-CÁLCULO DE COEFICIENTES

Por tratarse de un barco de volumen utilizaremos las siguientes expresiones para la determinación de V_h (volumen del casco):

$$V_h = C_{BD} \cdot L \cdot B \cdot D$$

V_h = 265.675,06 m³

$$C_{BD} = C_B + C \cdot \frac{D-T}{T}(1-C_B)$$

C_{BD} = 0,8692

Donde:

C = 0,3, para formas en U

Número de Froude

$$Fn = \frac{V}{\sqrt{g \cdot L}}$$

F_n = 0,1943

Donde:

V: velocidad de servicio (19,5 knot ≈ 10,03 m/s)

g: aceleración de la gravedad (9,81 m/s²)

Lpp: eslora entre perpendiculares (271,5 m.)

Coeficiente de la maestra

$$C_m = 1 - 2 \cdot Fn^4$$

C_m = 0,9971

Coeficiente prismático

$$C_p = 1.2 - 2.1 \cdot Fn$$

C_p = 0,7920

Coeficiente de bloque

$$C_B = C_m \cdot C_p$$

C_B = 0,7897

A continuación vamos utilizar otra serie de fórmulas para calcular el coeficiente de bloque

Alexander:

$$C_B = 1.08 - 1.68 \cdot Fn$$

C_B = 0,7535

Van Lameren:

$$C_B = 1.137 - 2.02 \cdot Fn$$

C_B = 0,7445

Ayre:

$$C_B = 1.05 - 1.68 \cdot Fn$$

C_B = 0,7235

Minorsky:

$$C_B = 1.22 - 2.38 \cdot Fn$$

C_B = 0,7575

Katsoulis:

$$C_B = 0.8217 \cdot f \cdot L^{0.42} \cdot B^{-0.3072} \cdot D^{0.1721} \cdot V^{-0.6135}$$

C_B =0,7999

Donde:

f: es un factor de corrección por tipo de buque. En el caso de un gasero toma el valor de 1,04.

Para finalizar, vamos a coger dos barcos de la base de datos de los que conocemos su desplamiento. A partir de este valor podremos conocer su coeficiente de bloque y determinar las constantes a y b de la siguiente expresión:

$$C_B = a - b \cdot Fn$$

Tomamos como referencia los buques *Dapeng Sun* y *Maersk Qatar*.

C_B (Dapeng Sun) = 0,8191 y un desplazamiento de 114.789 t.

C_B (Maersk Qatar) = 0,7413 y un desplazamiento de 102.000 t.

Con el resto de datos de ambos buques sustituímos en las ecuaciones anteriores y obtenemos unos valores de *a* y *b* de:

a= 2,023

b = 6,224

Por tanto, para nuestro caso tendremos un C_B = 0,8136

Haciendo una media de todos los valores obtenidos para el coeficiente de bloque: C_B = 0,7688. Y por tanto, como primera aproximación:

$$\Delta = C_B \cdot \rho \cdot L \cdot B \cdot T = 106.535{,}12 \approx 106.536\ t.$$

Donde:

C_B = 0,7688

ρ: densidad del agua salada (1,025 t/m³)

L → Lpp: eslora entre perpendiculares (271,5 m.)

B: manga de trazado (43,3 m.)

T: calado de diseño (11,5 m.)

Con los datos obtenidos anteriormente podemos hacer una nueva estimación de la eslora:

$$L = \left(\frac{V_h (L/B)^2 \cdot (B/D)}{C_{BD}} \right)^{1/3}$$

Donde:

V_h: Volumen del casco (265.675,06 m³)

L→Lpp: eslora entre perpendiculares (271,5 m.)

B: manga de trazado (43,3 m.)

D: puntal a la cubierta principal (26 m.)

C_{BD}: coeficiente de bloque al 85%D (0,8692)

Tenemos como resultado L = 271,49 m., prácticamente el mismo valor que el obtenido por regresión lineal.

Las relaciones entre dimensiones de nuestra base de datos son:

Buque	L/B	B/D	B/T	L/D	T/D
Abdelkader	6,1957	1,7164	3,8655	10,6343	0,4440
Castillo de Santisteban	6,0870	1,7692	4,0000	10,7692	0,4423
Barcelona Knutsen	6,0917	1,7283	3,8326	10,5283	0,4509
Seri Balhaf	6,0559	1,8023	4,1704	10,9147	0,4322
British Emerald	6,2217	1,7000	3,8535	10,5769	0,4412
Trinity Arrow	6,1745	1,7192	3,9314	10,6154	0,4373
GDF Suez Point Fortin	6,1745	1,7192	3,8107	10,6154	0,4512

Express	6,4516	1,6692	3,7414	10,7692	0,4462
Dapeng Sung	6,3230	1,6514	3,7860	10,4419	0,4362
Maersk Qatar	6,2212	1,6692	3,8070	10,3846	0,4385
Fernando Tapias	6,1935	1,6692	3,8004	10,3385	0,4392
Hanjin Muscat	6,2442	1,6412	3,8053	10,2481	0,4313
British Trader	6,2441	1,6385	3,7533	10,2308	0,4365
Excelsior	6,1290	1,6692	3,7739	10,2308	0,4423
Berge Everett	6,1290	1,6692	3,8070	10,2308	0,4385
SK Summit	6,1290	1,6692	3,8407	10,2308	0,4346
Sestao Knutsen	6,3765	1,6732	3,7281	10,6693	0,4488
Iñigo Tapias	6,3765	1,6732	3,7281	10,6693	0,4488

A continuación se muestran los valores medios de estas relaciones y los intervalos máximo y mínimo en los que nos vamos a mover, que nos pueden ser de utilidad.

	L/B	**B/D**	**B/T**	**L/D**	**T/D**
MÁXIMO	6,4516	1,8023	4,1704	10,9147	0,4512
MÍNIMO	6,0559	1,6385	3,7281	10,2308	0,4313
VALOR MEDIO	6,2121	1,6915	3,8353	10,5055	0,4411

10-ELECCIÓN DE LA CIFRA DE MÉRITO

Los criterios usados con más frecuencia son los siguientes:

-Coste de construcción mínimo

-Inversión total mínima

-Coste del ciclo de vida mínimo

-Flete requerido mínimo

-Tasa de recuperación de capital propio máxima

-Tasa de rentabilidad interna máxima

En este caso, se utilizará el criterio de coste de construcción mínimo, ya que es el empleado por los astilleros para establecer las características a definir de un buque ya contratado con un valor de oferta mínimo.

Primero debemos calcular el peso en rosca y optimizar resultados

11-CÁLCULO DEL PESO EN ROSCA

El cálculo del peso en rosca lo vamos a dividir en tres partes:

-Acero

-Equipo y habilitación

-Maquinaria

Cálculo del peso de acero

Esta expresión nos permite realizar un cálculo rápido y aproximado del peso de acero del buque.

$$W_{ST} = K \cdot L \cdot B \cdot D \cdot \left(\frac{L}{D}\right)^{1/2} = 29.631{,}3\ t.$$

Peso del equipo y la habilitación

$$W_{OA} = K_e \cdot Lpp \cdot B = 2.540{,}46\ t.$$

Donde:

K_e : para buques gaseros:

$$K_e = 0{,}36 - 0{,}53 \cdot 10^{-3} \cdot Lpp = 0{,}2161$$

Lpp: eslora entre perpendiculares (271,5 m.)

B: manga de trazado (43,3 m.)

Peso de maquinaria

$$\text{Total peso maquinaria} \rightarrow \mathrm{W_Q} = \mathrm{W_{PM}} + \mathrm{W_{QR}} + \mathrm{W_{QE}} = 3.090{,}05\ \mathrm{t.}$$

<u>Peso de la maquinaria principal (motor y resto de la maquinaria propulsora)</u>

$$W_{PM} =\cdot a \cdot \left(\frac{BHP}{rpm}\right)^{b} + c \cdot BHP^{d} = 2353\ t.$$

Donde:

BHP: potencia necesaria

Para calcularla utilizaremos la fórmula de Watson:

$$BHP = \frac{0{,}889 \cdot \Delta^{2/3} \cdot (40 - \frac{L_{PP}}{61} + 400 \cdot (K-1)^2 - 12CB)}{15.000 - 1{,}81 \cdot N \cdot \sqrt{L_{PP}}} V^3 = 36.036{,}3\ \mathrm{HP}$$

$$BKW = 36.036{,}3 \cdot 0{,}746 = 26.883{,}1 \approx 26.884\ kW$$

Donde:

-N: número de revoluciones del motor, tomaremos como referencia 90 de una estimación media de los buques de la base de datos.

-K: constante de la fórmula de Alexander

$$\mathrm{CB} = \mathrm{K} - \frac{0{,}5 \cdot \mathrm{V}}{\sqrt{3{,}28 \cdot \mathrm{L_{PP}}}} \rightarrow \mathrm{K} = 1{,}0955$$

Donde:

-CB: coeficiente de bloque (0,7688).

-V: velocidad de servicio (19,5 knots).

-Lpp: eslora entre perpendiculares (271,5 m.).

-Δ: desplazamiento de nuestro buque (al calado de diseño) = 106.536 t.

-rpm: revoluciones por minuto del motor (90 rpm)

-a, b, c y d: constantes → a = 9,38, b = 0,84, c = 0,59 y d = 0,70

Peso de la maquinaria y el equipo restante

$$W_{QR} = 0{,}03 \cdot V_{MQ} = 623{,}62 \text{ t.}$$

Donde:

-V_{MQ}: volumen de la cámara de máquinas, que podemos calcular de manera aproximada mediante la siguiente fórmula:

$$V_{MQ} = \frac{L}{5} \cdot B \cdot T \cdot C_B = 20.787{,}34 \text{ m}^3$$

Donde:

-L: eslora entre perpendiculares (271,5 m.)

-T: calado de diseño (11,50 m.)

-B: manga máxima (43,3 m.).

-D: puntal a la cubierta principal (26 m.).

Peso de línea de ejes fuera de la cámara de máquinas

$$W_{QE} = K_{ne} \cdot l_{eje}(5 + 0{,}0164 \cdot L_{PP}) = 113{,}43 \text{ t.}$$

Donde:

-K_{ne}: 2 en buques de dos líneas de ejes.

-l_{eje}: longitud en metros de la línea de ejes fuera de la cámara de máquinas (tomaremos como referencia 6 m.).

-Lpp: eslora entre perpendiculares (271,5 m.).

Por tanto, tendremos que el peso en rosca (LWT) es:

$$LWT = W_{ST} + W_{OA} + W_Q = 35.261{,}81 \approx 35.262 \text{ t.}$$

Como ya hemos visto, los valores se han redondeado hacia arriba.

Utilizando el valor del desplazamiento calculado anteriormente:

$$DWT = \Delta - LWT = 71.274t.$$

12-COSTES

A la hora de realizar la evaluación económica del buque, nos centraremos en el coste de construcción. Emplearemos como guía las fórmulas y nomenclatura del libro “El Proyecto Básico del Buque Mercante”. En muchos de los coeficientes se realizará una aproximación o se tomará un valor medio dentro del determinado rango.

El cálculo del coste de construcción se desglosará en las siguientes partidas:

-Coste del material a granel (CMg)

-Coste de los equipos (Ceq) y su montaje (CmE)

-Coste de la mano de obra (Cmo)

-Costes varios aplicados (Cva)

Coste del material a granel

$$CMg = cmg \cdot W_{ST} = ccs \cdot cas \cdot cem \cdot ps \cdot W_{ST} = 32.307.261{,}22\text{ €}$$

Donde:

ccs: coeficiente de coste ponderado de las chapas y perfiles de las distintas calidades de acero del buque (1,07).

Cas: coeficiente de aprovechamiento del acero (1,11).

Cem: coeficiente de incremento por equipo metálico incluido en la estructura tales como tecle, registros, escotillas, etc. (1,08)

ps: precio unitario del acero (850 €/t)

W_{ST}: peso del acero (29.631,3 t)

Coste de los equipos (Ceq) y su montaje (CmE)

$$CEq + CmE = CEc + CEp + CHf + CEr = 18.162.463{,}42\text{€}$$

Donde:

Cec: coste de los equipos de manipulación y contención de la carga. Es una partida de difícil sistematización y se debe estudiar pormenorizadamente para cada tipo de buque.

CEp: coste de los equipos de propulsión y sus auxiliares, montaje incluido

$$CEp = cep \cdot PB = 10.753.600\text{ €}$$

Donde:

cep: coeficiente de coste unitario (400 €/Kw)

PB: potencia propulsora (26.884 Kw)

CHf: coste, montada, de la habilitación y fonda

$$CHf = chf \cdot nch \cdot NT = 1.270.500\text{ €}$$

Donde:

chf: coeficiente de coste unitario de la habilitación por tripulante (aprox. 33.000 €/tripulante)

nch: nivel de calidad de la habilitación (1,10)

NT: número de tripulantes (35)

Cer: coste del equipo restante instalado

$$CEr = cer \cdot WEr = 6.138.363,42\ €$$

Donde:

Ccer: coeficiente de coste unitario por peso

$$cer = pst \cdot cpe = ccs \cdot cas \cdot cem \cdot ps + chm \cdot csh = 2.590,3$$

Donde:

chm: costo horario medio del astillero (30 €/h).

csh: coeficiente de horas por unidad de peso (50 h/t). Está relacionado con la capacidad productiva del astillero.

Wer: peso del equipo restante

$$WEr = K \cdot L^{1,3} \cdot B^{0,8} \cdot D^{0,3} = 2.369,75\ t.$$

Donde:

K: coeficiente (0,03)

Coste de la mano de obra (Cmo)

$$CMo = CmM + CmE$$

En este apartado incluiremos solamente el coste de montaje de material (CmM), puesto que el coste de montaje de equipos (CmE) ya lo hemos incluido en el apartado de “Coste de equipos y su montaje”.

$$CmM = chm \cdot csh \cdot W_{ST} = 44.446.950\ €$$

Costes varios aplicados (Cva)

Este apartado representa los costes para el astillero de todo aquello que sin intervenir directamente en el proceso de construcción del buque, tiene un coste directo. Estos pueden ser: Sociedades de Clasificación, ensayos en canal, representación…

$$CVa = cva \cdot CC = cva \cdot (CMg + CEq + CmE + CMo) = 6.644.167,23\ €$$

Donde:

cva: representa el coeficiente de los costes varios del astillero referidos al costo de construcción del buque (0,07).

Por tanto, tendremos que el coste de construcción del buque (CC) es:

$$CC = CMg + CEq + CmE + CMo + CVa \approx 101.560.845\ €$$

13-ALTERNATIVA MÁS FAVORABLE

Para encontrar la alternativa más favorable vamos a minimizar el coste de construcción utilizando la herramienta “Solver” del programa informático Microsoft Excel. Adjuntamos las hojas de resultados como anexo.

Para ello añadiremos una serie de restricciones a nuestras variables L, B, D y T y a algunas de las relaciones entre ellas.

Restricciones de la base de datos

Utilizando los valores de las dimensiones que aparecen en nuestra vamos de datos vamos a restringir el cálculo.

	L/B	B/D	B/T	L/D	T/D	L/T
MÁXIMO	6,4516	1,8023	4,1704	10,9147	0,4512	23,9496
MÍNIMO	6,0559	1,6385	3,7281	10,2308	0,4313	23,1304
VALOR MEDIO	6,2121	1,6915	3,8353	10,5055	0,4411	23,8179

Restricciones de las dimensiones principales

Vamos a darle un margen de variación de un 5% a nuestras dimensiones originales principales, de manera que obtendremos un valor máximo y otro mínimo para cada una de nuestras dimensiones. Entre estos dos valores estarán los definitivos a calcular.

Restricción de volumen

Tomamos la restricción de volumen de las RPA del buque (145.000 m³). Por tanto, haremos variar el volumen en un 1 %, tomando como valor mínimo el de nuestras RPA.

En la siguiente tabla se muestran los valores originales y los valores finales de nuestro buque.

	CONF. INICIAL	**CONF. FINAL**	
L	271,5	269,7	m
B	43,3	43,2	m
D	26	26,3	m
T	11,5	11,5	m
Volumen	145.000	145.000	m³
Δ	106.536	105.379	t.
V	19,5	19,5	knot
Fn	0,1943	0,1950	-
Cb	0,7688	0,7673	-
Cm	0,9971	0,9971	-
Cp	0,792	0,7905	-
COSTE	101.560.845	101.099.769	€

Como podemos ver, se cumplen nuestras restricciones, incluida la del volumen (145.000 m³) al tiempo que se minimiza el coste de construcción.

Señalar que el cálculo de los nuevos coeficientes se detalla en el siguiente apartado. Como se puede observar y era de prever, apenas varían de una configuración a otra.

Con las nuevas dimensiones tendríamos un ahorro de 461.076 €.

14-NUEVO CÁLCULO DE COEFICIENTES

Por tratarse de un barco de volumen utilizaremos las siguientes expresiones para la determinación de V_h (volumen del casco):

$$V_h = C_{BD} \cdot L \cdot B \cdot D$$

V_h = 262.634,6 m³

$$C_{BD} = C_B + C \cdot \frac{D-T}{T}(1-C_B)$$

C_{BD} = 0,8571

Donde:

C = 0,3, para formas en U

C_B : coeficiente de bloque (0,7673), calculado un par de líneas más abajo.

Número de Froude

$$Fn = \frac{V}{\sqrt{g \cdot L}}$$

F_n = 0,1950

Donde:

V: velocidad de servicio (19,5 knot ≈ 10,03 m/s)

g: aceleración de la gravedad (9,81 m/s²)

Lpp: eslora entre perpendiculares (269,7 m.)

Coeficiente de la maestra

$$C_m = 1 - 2 \cdot Fn^4$$

C_m = 0,9971

Coeficiente prismático

$$C_p = 1.2 - 2.1 \cdot Fn$$

C_p = 0,7905

Coeficiente de bloque

$$C_B = C_m \cdot C_p$$

$C_B = 0,7882$

A continuación vamos utilizar otra serie de fórmulas para calcular el coeficiente de bloque

Alexander:

$$C_B = 1.08 - 1.68 \cdot Fn$$

$C_B = 0,7524$

Van Lameren:

$$C_B = 1.137 - 2.02 \cdot Fn$$

$C_B = 0,7431$

Ayre:

$$C_B = 1.05 - 1.68 \cdot Fn$$

$C_B = 0,7224$

Minorsky:

$$C_B = 1.22 - 2.38 \cdot Fn$$

$C_B = 0,7559$

Katsoulis:

$$C_B = 0.8217 \cdot f \cdot L^{0.42} \cdot B^{-0.3072} \cdot D^{0.1721} \cdot V^{-0.6135}$$

$C_B = 0,8002$

Donde:

f: es un factor de corrección por tipo de buque. En el caso de un gasero toma el valor de 1,04.

$$C_B = a - b \cdot Fn$$

Del punto 9, ya tenemos los valres de a y b, que son:

a= 2,023

b = 6,224

Por tanto, para nuestro caso tendremos un $C_B = 0,8093$

Haciendo una media de todos los valores obtenidos para el coeficiente de bloque: $C_B = 0,7673$. Y por tanto, como primera aproximación:

$$\Delta = C_B \cdot \rho \cdot L \cdot B \cdot T = 105.378{,}4 \approx 105.379\ t.$$

Donde:

$C_B = 0,7673$

ρ: densidad del agua salada (1,025 t/m³)

L → Lpp: eslora entre perpendiculares (269,7 m.)

B: manga de trazado (43,2 m.)

T: calado de diseño (11,5 m.)

15-ESTIMACIÓN DE POTENCIA

Estimación mediante fórmula de Watson

Para calcularla utilizaremos la fórmula de Watson:

$$BHP = \frac{0{,}889 \cdot \Delta^{2/3} \cdot (40 - \frac{L_{PP}}{61} + 400 \cdot (K-1)^2 - 12CB)}{15.000 - 1{,}81 \cdot N \cdot \sqrt{L_{PP}}} V^3 = 35.783{,}9 \text{ HP}$$

$$BKW = 35.783{,}9 \cdot 0{,}746 = 26.694{,}8 \approx 26.695\ kW$$

Donde:

-N: número de revoluciones del motor, tomaremos como referencia 90 de una estimación media de los buques de la base de datos.

-K: constante de la fórmula de Alexander

$$\mathrm{CB} = \mathrm{K} - \frac{0{,}5 \cdot \mathrm{V}}{\sqrt{3{,}28 \cdot \mathrm{L_{PP}}}} \rightarrow \mathrm{K} = 1{,}0951$$

Donde:

-CB: coeficiente de bloque (0,7673).

-V: velocidad de servicio (19,5 knots).

-Lpp: eslora entre perpendiculares (269,7 m.).

-Δ: desplazamiento de nuestro buque (al calado de diseño) = 105.379 t.

Estimación mediante NAVCAD

Eslora en la flotación

No tenemos todavía este dato. Por tanto, tomaremos como aproximación:

L_{WL} = 1,04·Lpp = 280,5 m.

Bulbo de proa

No tenemos todavía estos dato. Por tanto, tomaremos como aproximación los del buque de la base de datos “Express”, que tiene unas dimensiones parecidas. (Se adjutan características y plano en los anexos).

Altura (h)

$$h = 4{,}30\ m.$$

Protuberancia (x)

$$x = 6{,}55\ m.$$

Coeficiente de área de la flotación

$$C_F = \frac{1 + 2 \cdot C_B}{3} = 0{,}8448$$

Área del plano de la flotación

$$Waterplane\ Area = L \cdot B \cdot C_F = 9.842{,}799\ m^2$$

Coeficiente de área de la maestra

$$C_m = 0{,}9971$$

Área de la sección máxima (maestra)

$$Max.Section\ Area = B \cdot T \cdot C_m = 495{,}359\ m^2$$

Superficie mojada

$$S = L_{WL}(2T + B){C_m}^{0,5}\left(0{,}453 + 0{,}4425C_B - 0{,}2862C_m - 0{,}003467 \cdot \frac{B}{T} + 0{,}3696C_F\right) + 2{,}38\frac{ABT}{C_B} = 14.983{,}25\ m^2$$

Donde:

ABT: área transversal del bulbo en la perpendicular de proa. Lo calculamos a partir de una tabla del libro “El Proyecto Básico del Buque Mercante”.

Interpolando en esta tabla con los valores de L/B = 6,2430 y Cb = 0,7673, tenemos que:

ABT = 10,1 m²

Otros datos que introducimos en NAVCAD son:

Densidad del agua = 1,025 t/m^3

Viscosidad cinemática = 1,18830 ·10^{-6} m²/s

Margen de diseño: 15 %

Con todos estos datos obtenemos los siguientes resultados:

	RESISTANCE AND EFFECTIVE POWER								
SPEED [kt]	RBARE [kN]	RAPP [kN]	RWIND [kN]	RSEAS [kN]	RCHAN [kN]	RMARGIN [kN]	RTOTAL [kN]	PEBARE [kW]	PETOTAL [kW]
17,50	1658,96	82,95	0,00	0,00	0,00	248,84	1990,75	14935,3	17922,3
18,00	1760,55	88,03	0,00	0,00	0,00	264,08	2112,66	16302,7	19563,3
18,50	1867,55	93,38	0,00	0,00	0,00	280,13	2241,06	17773,9	21328,7
19,00	1980,36	99,02	0,00	0,00	0,00	297,05	2376,43	19356,9	23228,3
+ 19,50 +	2099,41	104,97	0,00	0,00	0,00	314,91	2519,30	21060,6	25272,8
20,00	2225,23	111,26	0,00	0,00	0,00	333,78	2670,27	22895,1	27474,1
20,00	2225,23	111,26	0,00	0,00	0,00	333,78	2670,27	22895,1	27474,1
20,50	2358,17	117,91	0,00	0,00	0,00	353,73	2829,81	24869,5	29843,4
21,00	2498,40	124,92	0,00	0,00	0,00	374,76	2998,08	26991,1	32389,3
21,50	2646,08	132,30	0,00	0,00	0,00	396,91	3175,29	29267,1	35120,5

Vemos que para nuestra velocidad de servicio (19,5 knot) necesitamos una potencia de 25.272,8 kW. Pero debemos destacar que esta potencia corresponde a la EHP (potencia efectiva o de arrastre). Habría que que tener en cuenta el rendimiento del conjunto de la propulsión (algo que haremos en el cuaderno 6). Teniendo en cuenta esto, vemos que difiere un tanto de la calculada por la fórmula de Watson, pero para una primera aproximación es válida.

Para los cálculos en que sea necesaria la potencia en el presente cuaderno, utilizaremos la calculada por la fórmula de Watson, puesto que ésta sí se refiere a la BHP (potencia al freno).

16-NUEVO CÁLCULO DEL PESO EN ROSCA, PESO MUERTO, DESPLAZAMIENTO Y CONSUMOS

Con los valores optimizados de nuestras dimensiones, vamos a calcular de nuevo los pesos.

PESO EN ROSCA

El cálculo del peso en rosca lo vamos a dividir en tres partes:

-Acero

-Equipo y habilitación

-Maquinaria

Cálculo del peso de acero

Esta expresión nos permite realizar un cálculo rápido y aproximado del peso de acero del buque.

$$W_{ST} = K \cdot L \cdot B \cdot D \cdot \left(\frac{L}{D}\right)^{1/2} = 29.437,72\ t.$$

Donde:

K = 0,03

Peso del equipo y la habilitación

$$W_{OA} = K_e \cdot Lpp \cdot B = 2.528,28\ t.$$

Donde:

K_e : para buques gaseros:

$$K_e = 0,36 - 0,53 \cdot 10^{-3} \cdot Lpp = 0,21,70$$

Lpp: eslora entre perpendiculares (269,7 m.)

B: manga de trazado (43,2 m.)

Peso de maquinaria

Total peso maquinaria → $\mathrm{W_Q = W_{PM} + W_{QR} + W_{QE} = 3.013,49}$ t.

Peso de la maquinaria principal (motor y resto de la maquinaria propulsora)

$$W_{PM} =\cdot a \cdot \left(\frac{BHP}{rpm}\right)^{b} + c \cdot BHP^{d} = 2.340,1\ t.$$

Donde:

-BHP: potencia necesaria (35.784 HP)

-rpm: revoluciones por minuto del motor (90 rpm)

-a, b, c y d: constantes → a = 9,38, b = 0,84, c = 0,59 y d = 0,70

Peso de la maquinaria y el equipo restante

$$\mathrm{W_{QR} = 0,03 \cdot V_{MQ} = 616,85\ t.}$$

Donde:

-V_{MQ}: volumen de la cámara de máquinas, que podemos calcular de manera aproximada mediante la siguiente fórmula:

$$V_{MQ} = \frac{L}{5} \cdot B \cdot T \cdot C_B = 20.561{,}64\ m^3$$

Donde:

-L: eslora entre perpendiculares (269,7 m.)

-T: calado de diseño (11,50 m.)

-B: manga máxima (43,2 m.).

Peso de línea de ejes fuera de la cámara de máquinas

$$W_{QE} = K_{ne} \cdot l_{eje}(5 + 0{,}0164 \cdot L_{PP}) = 56{,}54\ t.$$

Donde:

-K_{ne}: 2 en buques de dos líneas de ejes.

-l_{eje}: longitud en metros de la línea de ejes fuera de la cámara de máquinas (tomaremos como referencia 6 m.).

-Lpp: eslora entre perpendiculares (269,7 m.).

Por tanto, tendremos que el peso en rosca (LWT) es:

$$LWT = W_{ST} + W_{OA} + W_Q = 34.979{,}49 \approx 34.980\ t.$$

Como ya hemos visto, todos los valores se han redondeado hacia arriba.

DESPLAZAMIENTO

Nuestro nuevo desplazamiento será:

$$\Delta = 1{,}025 \cdot L \cdot B \cdot T \cdot C_B \approx 105.379\ t.$$

PESO MUERTO

Utilizando el valor del desplazamiento calculado anteriormente:

$$DWT = \Delta - LWT = 70.399\ t.$$

El peso muerto es la suma de la carga útil y los consumos

Carga útil

$$145.000\ m^3 \cdot 0{,}45 \frac{t}{m^3} = 65.250\ t.$$

Donde:

ρ_{LNG} = 0,45 t/m³

Consumos

En este cuaderno realiazaremos una primera aproximación a los consumos. En el cuaderno 4 se calcularán más detalladamente.

Peso del combustible

$$P_{COMB} = Autonomía(h) \cdot BHP \cdot C_e \cdot 10^{-6} = 3.741{,}22\ t.$$

Donde:

C_e: consumo específico del motor principal. Según el libro “Proyecto de Buques y Artefactos”, el consumo para motores electrógenos oscila entre 160-180 gr/BHP por hora. Por tanto, tomamos un consumo aproximado de 170 gr/BHP

BHP: potencia propulsora (35.784 Kw)

Autonomía: 12.000 millas a 19,5 knot. Señalar que un nudo (knot) es igual a una milla marina (mn) por hora.

$$t_{navegación} = \frac{Autonomía}{Velocidad} = 615{,}38 \approx 25\ días$$

Peso del agua dulce

200 litros por persona y día. 25 días de autonomía 35 personas a bordo.

$$Agua\ dulce = 200 \cdot 25 \cdot 35 \cdot 10^{-3} = 175\ t.$$

Peso del aceite

Se calcula en función del porcentaje de combustible. Se estima entre un 3-4 % del peso del combustible

$$P_{ACEITE} = 0{,}035 \cdot P_{COMB} = 130{,}94\ t.$$

Efectos y respestos: 100 t.

Tripulación y varios: 20 t.

En total tenemos: $P_{MUERTO} \approx$ 69.417,16 ≈ 69.418 t.

Margen de peso muerto: 70.399 – 69.296 = 981 t.

17-CÁLCULO DEL FRANCOBORDO

En esta primera etapa vamos a realizar un cálculo sencillo del francobordo por medio del programa Arqnaval, en el que, introduciendo solamente los datos de eslora, manga, puntal y coeficiente de bloque, nos arroja un primer resultado de nuestro francobordo y una altura mínima de proa.

Debemos señalar en el cálculo el tipo de buque que estamos proyectando, como no hay la opción de LNG, escogemos un LPG.

De acuerdo con el "Convenio internacional sobre líneas de carga de 1966", nuestro buque es tipo A. Y debemos tener:

Francobordo (FB)

$$FB = 6{,}366\ m.$$

Con lo que el buque tendría un calado en esta condición máxima de 19,961 m.

Altura mínima de proa (F_b)

$$F_b = 6{,}536\ m,.$$

En el cuaderno 9 calcularemos nuestro francobordo real de una forma mucho más detallada y precisa, esto es sólo una aproximación.

18-ESPECIFICACIÓN PRELIMINAR

En este apartado vamos a detallar la operación básica del buque así como algunos de los distintos equipos necesarios para la misma.

Partimos del buque en puerto, con los tanques en condiciones ambiente: presión, temperatura y composición. La carga del buque la constituye gas licuado, con una composición del 98% en metano, a presión ambiente y temperatura de -163ºC, que será aproximadamente la de cambio de fase líquido-gas de la carga. Como no nos interesa bajar la temperatura al no existir variaciones apreciables en la densidad de la carga, y sí encarecer el coste de enfriamiento y aislamiento.

El tipo de carga nos condiciona el buque en los siguientes aspectos:

-Los relativos a la seguridad en las maniobras de carga y descarga, debiendo evitarse la presencia de una atmósfera peligrosa en los tanques al introducir el gas.

-La temperatura de carga puede dañar el tanque por choque térmico, luego debemos acondicionarlo previamente.

-El tratamiento del "39oíl-off".

Maniobra de carga de los tanques

Preparación de la atmósfera dentro de los tanques

Esta operación se lleva a cabo después de la nueva construcción o de un viaje en seco, y antes de una operación de carga.

-Purga de aire: se hará circular por el tanque gas inerte (CO_2), para hacer una "limpieza" y eliminar así el oxígeno y la humedad presentes en el aire. Para ello se necesitará un generador de gas inerte, que podemos materializar mediante una extracción de los gases de escape de la caldera, motor principal o auxiliares o de un generador de gas inerte que funcione como generador de aire seco. El objetivo de esta operación es bajar el punto de rocío a -20ºC antes de la inertización.

-Inertización de los tanques: después de purgar el tanque de aire, se inertizará el mismo por medio del generador de gas inerte o usando el vaporizador principal produciendo GN_2 a partir de LN_2 suministrado por la terminal. El gas inerte al ser más pesado que el aire se introduce por el fondo del tanque, mientras que el GN_2 al ser más ligero se introduce por arriba. En ambos casos la operación se seguirá hasta que se alcance un contenido de oxígeno menor del 2 % y un punto de rocío más bajo de -40ºC.

-Inertización de tuberías y maquinaria: esta operación se realiza durante la inertización de los tanques. Se debe comprobar que todas las líneas que no se usen para la inertización de los tanques han sido purgadas.

Necesitaremos para este proceso de los compresores y líneas de alimentación para introducir los gases en los tanques y para su posterior evacuación, así como sendos generadores de gas inerte CO_2 y N_2.

Acondicionamiento térmico de los tanques de carga

Debido a que la carga la vamos a recibir y a transportar a una temperatura aproximada de unos –163 ºC, no es posible descargar directamente sin previamente enfriar los tanques a una temperatura cercana a ese valor, pues el choque térmico que provocaríamos dañaría los mismos permanentemente. Así mismo, las tuberías procedentes de la terminal y las del buque, deberán también estar a temperatura adecuada.

Esta problemática será analizada en el cuaderno 12.

Tratamiento del gas evaporado o "Boil off" durante la navegación

Durante la navegación normal del buque, un tanto por ciento de la carga se va evaporando, debido al calor que reciben los tanques del exterior. Podemos acometer este problema de tres maneras:

-Descargándolo a la atmósfera

-Reenviándolo a los tanques de carga, previamente re-criogenizado.

-Emplearlo para la combustión en los generadores

Nosotros lo utilizaremos para estos dos últimos procedimientos.

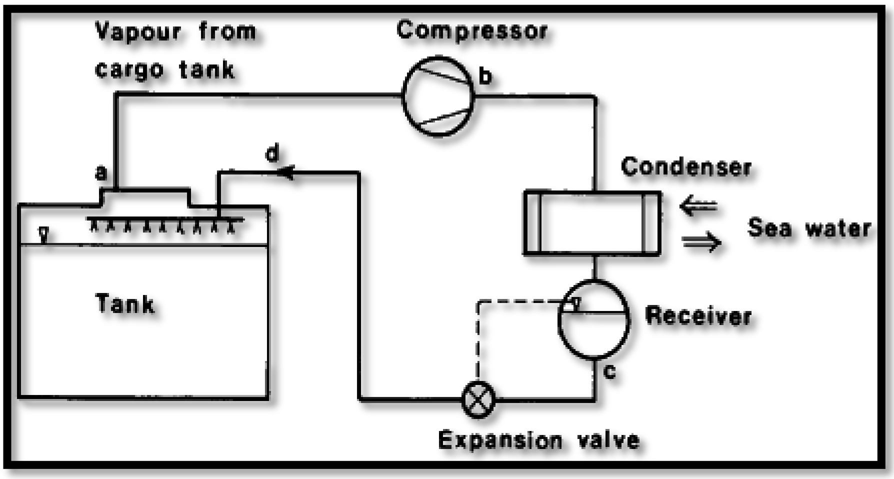
Boil off

El aislamiento de los tanques será el necesario para mantener en el viaje normal una tasa de evaporación no superior al 0.15 % del peso total.

Relicuefacción

Si queremos reenviar el gas evaporado de los tanques nuevamente a ellos, deberemos contar en el buque con una planta de relicuefacción, que sea capaz de licuar todo el gas que se evapora.

En la siguiente imagen podemos ver un esquema de lo que sería una planta de relicuefacción.



Construcción de los tanques

Los tanques y equipos de carga se diseñarán para almacenar gas licuado en cuatro tanques a presión atmosférica a una temperatura de -163 ºC.

Los tanques serán de tipo membrana TECNIGAZ GAZ-TRANSPORT.
Cada uno de los tanques consta de una barrera primaria y otra secundaria, soportadas por los aislamientos primario y secundario.

- -Aislamiento secundario: caja de conglomerado de 0.3 m de espesor, relleno de perlita y soportado por el casco.
- -Barrera secundaria: lámina de acero al níquel al 36%, que unida al aislamiento secundario forma una barrera para evitar el escape del gas.
- -Aislamiento primario: de igual construcción que el secundario, de 0.23 m de espesor y unido rígidamente al casco.
- -Barrera primaria: de la misma composición que la barrera secundaria. Contiene el gas.

Conexiones de los tanques de carga

Cada uno de los tanques de carga tiene una entrada de gas situada cerca del punto más alto del tanque.

La entrada de carga principal y el acceso al tanque se encuentra en la parte más a popa del tanque, que llamaremos entrada de gas líquido.

Los tanques tendrán las siguientes conexiones:

PARTE DE POPA (LIQUIDO)

-Entrada de la bomba principal de carga, con válvula de asiento, compartida con la bomba de emergencia.

-Dos tomas para las bombas de descarga.

-Una línea de descarga del gas de rociado.

-Sensores térmicos, de nivel.

-Línea principal.

-Medidores de nivel

-Conexiones eléctricas y de instrumentación.

PARTE SUPERIOR (GAS)

-Dos sistemas de rociado

-Conexiones de las válvulas de seguridad

Equipos para el manejo de la carga

-Bombas de carga

-Bombas de emergencia

-Compresores principales

-Compresores auxiliares

-Generador de nitrógeno

-Generador de gas inerte

Tipo de propulsión

El tipo de propulsión de nuesto buque, definida en las RPA será diesel-eléctrica. En el cuaderno 6 especificaremos los elementos que la compondrán.

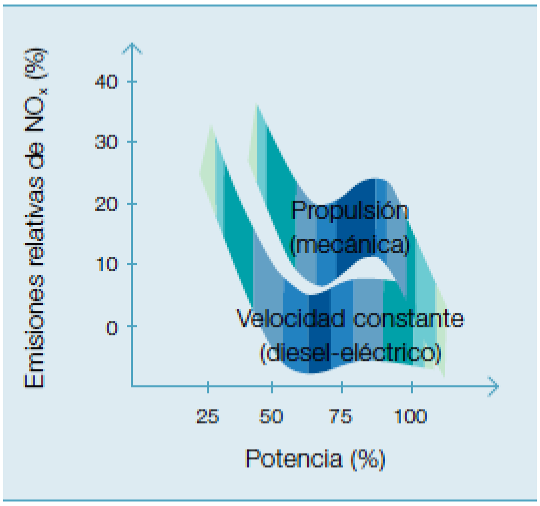
La capacidad de un motor eléctrico para proporcionar un par elevado a baja velocidad es un argumento importante a favor de la propulsión eléctrica.

La introducción de la propulsión eléctrica requiere la sustitución del eje entre el motor principal y la hélice por un sistema compuesto por generadores, cuadros de distribución, transformadores, accionamientos y motores.

Los motores diesel no tienen el mismo nivel de contaminación en todo su rango de trabajo. En el régimen óptimo de operación, el rendimiento del combustible es considerablemente mayor y la contaminación es menor que operando a baja velocidad.

En el siguiente gráfico podemos ver cómo los niveles de contaminación para distintos porcentajes de potencia. Vemos que a potencias bajas, la contaminación es similar que la de los motores mecánicos, pero a mayores potencias es sustancialmente menor.

3 Se emite menos NOx si la carga en el motor es alta (Fuente: Wärtsilä Diesel).



19-BIBLIOGRAFÍA

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-"Proyectos de Buques y Artefactos", Fernando Junco Ocampo.

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

-Diverso material web.

ANEXO I

Informe herramienta Solver

Microsoft Excel 12.0 Informe de respuestas

Hoja de cálculo: [Alternativas final.xlsx]Alternativas

Celda objetivo (Mínimo)

Celda	Nombre	Valor original	Valor final
$K$4	Coste total	101560845	101099768,4

Celdas cambiantes

Celda	Nombre	Valor original	Valor final
$C$3	L	271,5	269,7359458
$C$4	B	43,3	43,19919725
$C$5	D	26	26,36508834
$C$6	T	11,5	11,5

Restricciones

Celda	Nombre	Valor de la celda	Fórmula	Estado	Divergencia
$E$14	L/B Valores de nuestro buque	6,244003662	$E$14<=$C$14	Opcional	0,207596338
$E$14	L/B Valores de nuestro buque	6,244003662	$E$14>=$D$14	Opcional	0,188103662
$E$15	B/D Valores de nuestro buque	1,6385	$E$15<=$C$15	Opcional	0,1638
$E$15	B/D Valores de nuestro buque	1,6385	$E$15>=$D$15	Obligatorio	0
$E$16	B/T Valores de nuestro buque	3,756451935	$E$16<=$C$16	Opcional	0,413948065
$E$16	B/T Valores de nuestro buque	3,756451935	$E$16>=$D$16	Opcional	0,028351935
$E$17	L/D Valores de nuestro buque	10,2308	$E$17<=$C$17	Opcional	0,6839

$E$17	L/D Valores de nuestro buque	10,2308	$E$17>=$D$17	Obligatorio	0
$E$18	T/D Valores de nuestro buque	0,436182874	$E$18<=$C$18	Opcional	0,015017126
$E$18	T/D Valores de nuestro buque	0,436182874	$E$18>=$D$18	Opcional	0,004882874
$E$19	VOL Valores de nuestro buque	145000	$E$19<=$C$19	Opcional	1450
$E$19	VOL Valores de nuestro buque	145000	$E$19>=$D$19	Obligatorio	0
$C$3	L	269,7359458	$C$3<=$D$3	Opcional	15,33905417
$C$3	L	269,7359458	$C$3>=$E$3	Opcional	11,81094583
$C$4	B	43,19919725	$C$4<=$D$4	Opcional	4,430802749
$C$4	B	43,19919725	$C$4>=$E$4	Opcional	4,229197251
$C$5	D	26,36508834	$C$5<=$D$5	Opcional	2,234911656
$C$5	D	26,36508834	$C$5>=$E$5	Opcional	2,965088344
$C$6	T	11,5	$C$6<=$D$6	Opcional	1,15
$C$6	T	11,5	$C$6>=$E$6	Opcional	1,15

Microsoft Excel 12.0 Informe de sensibilidad

Hoja de cálculo: [Alternativas final.xlsx]Alternativas

Celdas cambiantes

Celda	Nombre	Valor Igual	Gradiente reducido
$C$3	L	269,7359458	0
$	B	43,1991	0

C$4		9725	
$ C$5	D	26,3650 8834	0
$ C$6	T	11,5	0

Restricciones

Celda	Nombre	Valor Igual	Multiplicador de Lagrange
$ E$14	L/B Valores de nuestro buque	6,24400 3662	0
$ E$14	L/B Valores de nuestro buque	6,24400 3662	0
$ E$15	B/D Valores de nuestro buque	1,6385	0
$ E$15	B/D Valores de nuestro buque	1,6385	3,496203 041
$ E$16	B/T Valores de nuestro buque	3,75645 1935	0
$ E$16	B/T Valores de nuestro buque	3,75645 1935	0
$ E$17	L/D Valores de nuestro buque	10,2308	0
$ E$17	L/D Valores de nuestro buque	10,2308	4312178, 102
$ E$18	T/D Valores de nuestro buque	0,43618 2874	0
$ E$18	T/D Valores de nuestro buque	0,43618 2874	0
$ E$19	VOL Valores de nuestro buque	145000	0
$ E$19	VOL Valores de nuestro buque	145000	367,9071 414

Microsoft Excel 12.0 Informe de límites

Hoja de cálculo: [Alternativas final.xlsx]Informe de límites 1

Celda	Celda objetivo Nombre	Igual
$K$4	Coste total	101099768,4

Celda	Celdas cambiantes Nombre	Igual	Límite inferior	Celda objetivo	Límite superior	Celda objetivo
$C$3	L	269,7359458	269,7359458	101099768,4	271,3891498	101904139,6
$C$4	B	43,19919725	43,19919725	101099768,4	43,19919725	101099768,4
$	D	26,3650	26,3650	1010997	26,3650	1010997

C$5		8834	8834	68,4	8834	68,4
$ C$6	T	11,5	11,3712 626	1010997 68,4	11,5874 5777	1010997 68,4

ANEXO II

Buques de la base de datos

ABDELKADER: Tri-fuel DE LNG carrier

Shipbuilder: **Hyundai Heavy Industries Co., Ltd**
Vessel's name: ***Abdelkader***
Hull No: **1876**
Owner/operator: **Mitsui OSK Lines (MOL)**
Country: **Japan**
Designer: **Hyundai Heavy Industries Co., Ltd**
Country: **Korea**
Model test establishment used: **Hyundai Maritime Research Institute**
Flag: **Bahamas**
IMO number: **9360922**
Total number of sister ships already completed (excluding ship presented): **1**
Total number of sister ships still on order: **0**

HYUNDAI Heavy Industries Co., Ltd (HHI) delivered the vessel Abdelkader to Mitsui OSK Lines (MOL) on 27 February. The vessel is a 177,000m^3 tri-fuel diesel electric liquefied natural gas (LNG) carrier, which is capable of serving the majority of the Atlantic terminals.

Abdelkader is equipped with four membrane cargo tanks and is designed and constructed as type 2G ship specified in IGC code, suitable for carrying LNG of which vapour pressures are withion the range from atmospheric pressure to 0.25bar g.

The vessel features a continuous deck with trunk/without forecastle and has a bulbous bow, lowered mooring deck, transom stern, open water type stern frame, single propeller driven by two electric motors.

Tank insulation is of GTT Mark III system, which has a 270mm thickness to satisfy the low boil off rate of 0.15% by volume of the total cargo per day. A shore manifold is provided on each of the upper decks between No.2 liquid dome and No.3 vapour dome. A compressor room is arranged in the area in way of No.4 tank.

Cargo discharging is done by eight pumps, two located in each of the tanks that each have a capacity of 1750m^3/hr. The supplementary gas during discharging comes from shore or is produced by an onboard LNG vaporiser to maintain cargo tank pressure. An emergency cargo pump is used when a cargo pump in a tank fails.

One LD compressor and one spray pump is used when the fuel pump is running to supply fuel gas to the engine room under normal sea going conditions. *Abdelkader* has four sets of main tri-feulled engines, two have 50% reversible synchronous motors (each with a power converter and associated transformers, control and excitation system), including one reduction gear (twin input/single output) with one propulsion shaft propeller. The vessel has a redundancy, so that failure of any motor drive auxiliary system shall not result in the loss of propulsion power.

The propulsion system onboard *Abdelkader* is a tri-fuelled diesel electric, capable of burning fuel gas, such as natural boil off gas forced boil off gas (FBOG) and also marine diesel oil (MDO) and heavy fuel oil (HFO). The power generating plant utilises all available natural boil off gas (NBOG) and makes up required power by burning additional MDO, HFO or FBOG. The main diesel engines are also fitted with exhaust gas economisers as a waste heat recovery system.

A gas combustion unit is fitted for periods when the NBOG cannot be burned in the tri-fuel diesel engines or when NBOG consumption is low and the cargo tank pressure rises. The tri-fuel diesel engines are fully compliant with MARPOL Annex VI regulation 13 and the NOx technical code.

The engine control room and cargo control room contain all facilities to allow for centralised operations of plant and equipment and also allow for unattended operation of the machinery plant under all operational modes.

Abdelkaders cargo control room is located in the accommodation deck, where the centralised control of loading, discharging, ballasting and de-ballasting and constant monitoring of the cargo takes place.

TECHNICAL PARTICULARS

Length oa: 298m
Length bp: 285m
Breadth moulded: 46m
Depth moulded
- To main deck: 26.8m
- To upper deck: 26.8m
- To other decks: 34.6m

Width of double skin
- Side: 2.65m
- Bottom: 3.3m

Draught
- Scantling: 13.0m
- Design: 11.9m

Gross: 114,200gt
Deadweight
- Design: 87,100dwt
- Scantling: 99,700dwt

Speed, service: 19.6knots
Cargo capacity
- Liquid volume: 177,400m^3

Bunkers
- Heavy oil: 6800m^3
- Diesel oil: 480m^3

Water ballast: 65,000m^3
Daily fuel consumption (based on HFO)
- Main generator engine: 161tonnes/day

Classification society and notations: Bureau Veritas, BV I +HULL, +MACH, Unrestricted navigation, Liquified gas carrier, +AUT-UMS, +VERISTAR-HULL, SYS-NEQ-1, In water survey, MON-SHAFT
% high tensile steel used in construction: approx. 5%
Main engine
- Design: Tri-fuel diesel electric
- Model: 2 x 12V50DF 2 x 9L50DF
- Manufacturer: Wartsila
- Number: 4
- Type of fuel used: Fuel gas, HFO or MDO
- Output of each engine: 2 x 11,400kW 2 x 8550kW Total 39,900kW

Gearbox
- Make: Renk
- Model: NDSH-4000
- Number: 1
- Output speed: 90.6rpm

Propellers
- Material: Ni-Al-Bronze
- Designer/manufacturer: Hyundai
- Number: 1
- Fixed/controllable pitch: Fixed
- Diameter: 8.6m
- Speed: 90.6rpm

Diesel-driven alternators
- Number: 4
- Engine make/type: Wartsila
- Type of fuel: Fuel gas, HFO or MDO
- Output/speed of each set: Total 39,900kW
- Alternator make/type: Converteam/ synchronous AC generator
- Output/speed of each set: 2 x 11,000kW/514rpm 2 x 8250kW/514rpm

Boilers
- Number: 2 x auxiliary boiler 2 x exhaust gas economiser
- Type: vertical, cylindrical, automatic controlled marine boiler (aux. boiler) Vertical, forced circulating, smoke tube (exhaust gas economiser)
- Make: Kangrim
- Output, each boiler: 7500kg/h x 10kg/cm^{2}g saturated steam Exhaust gas 1800kg/h x 10kg/cm^{2}g saturated steam

Other cranes
- Number: 2 x manifold service 2 x provision handling 1 x cargo machinery room service
- Make: Oriental Precision Co., Ltd
- Type: Electro-hydraulic driven
- Performance: 5tonnes SWL for manifold and provision handling 6tonnes SWL for cargo machinery room

Mooring equipment
- Number: 11
- Make: Pusnes
- Type: Electro-hydraulic driven

Special lifesaving equipment
- Number and capacity: 2
- Make: Norsafe
- Type: Davit launching type

Cargo tanks
- Number: 4
- Grades of cargo carried: 1
- Stainless steel-structure/piping: SUS 304/SUS 304L

Cargo pumps
- Number: 8
- Type: Vertical, centrifugal submerged
- Make: Ebara
- Capacity, each: 1750m^3 x 175mlc

Cargo control system
- Make: Converteam
- Type: AVC

Bow thruster
- Make: Kawasaki
- Number: 1
- Output, each: 2200kW

Bridge control system
- Make: Converteam
- Type: Electric propulsion system
- One-man operation: Yes

Fire detection system
- Make: Consilium
- Type: Intelligent addressable type

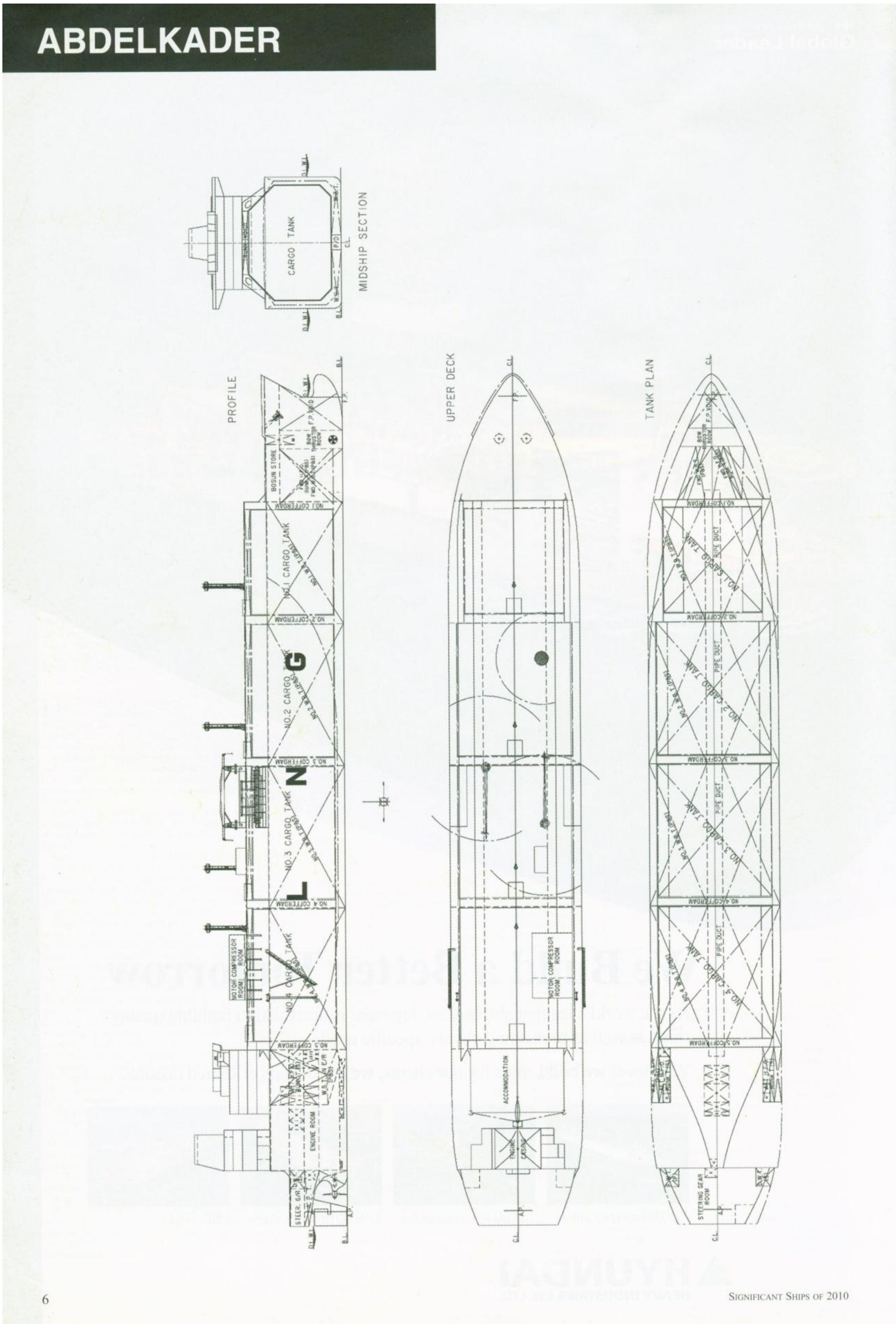
Fire extinguishing systems
- Engine room: NK/High pressure CO_2
- Cabins: Sea water + fresh water
- Public spaces: Sea water + fresh water

Radars
- Number: 3
- Make: JRC
- Models: LMA-9932-SA JMA-9922-6xA NKE-1087-6

Integrated bridge system
- Make: JRC
- Model: JAN-901M, JAN-701-CON

Waste disposal plant
- Incinerator: Kangrim KFB-73
- Sewage plant: Jongjap BIO AEROB-18

Contract date: 06 May 2006
Launch/float-out date: 10 October 2008
Delivery date: 27 February 2010


ABDELKADER
MIDSHIP SECTION
CARGO TANK
PROFILE
UPPER DECK
TANK PLAN
BOSUN STORE
NO.1 COFFERDAM
NO.1 CARGO TANK
NO.2 COFFERDAM
NO.2 CARGO TANK
NO.3 COFFERDAM
NO.3 CARGO TANK
NO.4 COFFERDAM
NO.4 CARGO TANK
NO.5 COFFERDAM
L N G
MOTOR COMPRESSOR ROOM
ENGINE ROOM
ACCOMMODATION
ENGINE CASING
STEERING GEAR ROOM
PIPE DUCT
6
SIGNIFICANT SHIPS OF 2010

BERGE EVERETT: Daewoo LNG tanker

Shipbuilder:	Daewoo Shipbuilding & Marine Engineering Co Ltd (DSME), Korea
Vessel's name:	*Berge Everett*
Hull number:	2212
Owner/operator:	Bergesen dy, ASA, Norway
Designer:	Daewoo Shipbuilding & Marine Engineering Co Ltd, Korea
Flag:	Norway
Total number of sister ships already completed:	1
Total number of sister ships still on order:	1

THE leading positions held in the LNG market by Norwegian owner Bergesen, and shipbuilder Daewoo, is demonstrated by their combined involvement in the construction of *Berge Everett*, another example of the Korean company's circa 140,000m³ capacity, specialist Type 2G gas carrier design, introduced for worldwide trading in a rapidly expanding fuel distribution network. A number of factors required consideration in the development of this class of vessel, many of which relate to parameters existing at loading and discharging terminals, where positions of mooring equipment, fenders, gangway and manifolds are of particular importance.

In addition, in order to ensure an even keel ballast arrival condition with peak tanks empty, and allowing consumables at 50% maximum capacity and three days reserve, the disposition and quantity of water ballast carried has necessitated careful study. The layout is also arranged to enable the vessel to discharge at the Everett (Boston, USA) terminal where an air draught restriction of 41.2m from the ballast waterline is enforced.

Within a double-hull structure there are four cargo tanks separated by cofferdams, and which extend above the upper deck to form a trunk. These are constructed to the Gaz Transport NO96 E-2 membrane system which uses Invar stainless steel sheet with a nickel content of 36%, for primary and secondary barriers, with perlite granules in plywood boxes inserted between them, and between the secondary barrier and the shell. This system, together with hull scantlings and cargo pumps, is suitable for the carriage of cargo of maximum specific gravity 0.50 at -163°C, and maximum boil-off rate 0.15% cargo volume. Underdeck passageways in the trunk deck space provide fore and aft access, and a duct keel in the double bottom carries pipes and cables.

Cargo handling is by means of eight Ebara, aluminium alloy, submerged, centrifugal electric pumps, each with a duty of 1700m³/h and together capable of discharging a full cargo in 12 hours. Other equipment forming part of the cargo system includes high- and low-duty compressors, main and forcing vaporisers, and boil-off/warm-up heaters. Heavy-fuel tanks are contained within the double hull and have a capacity for 13,000 nautical miles steaming at 90% MCR, allowing five days margin without the use of boil-off gas.

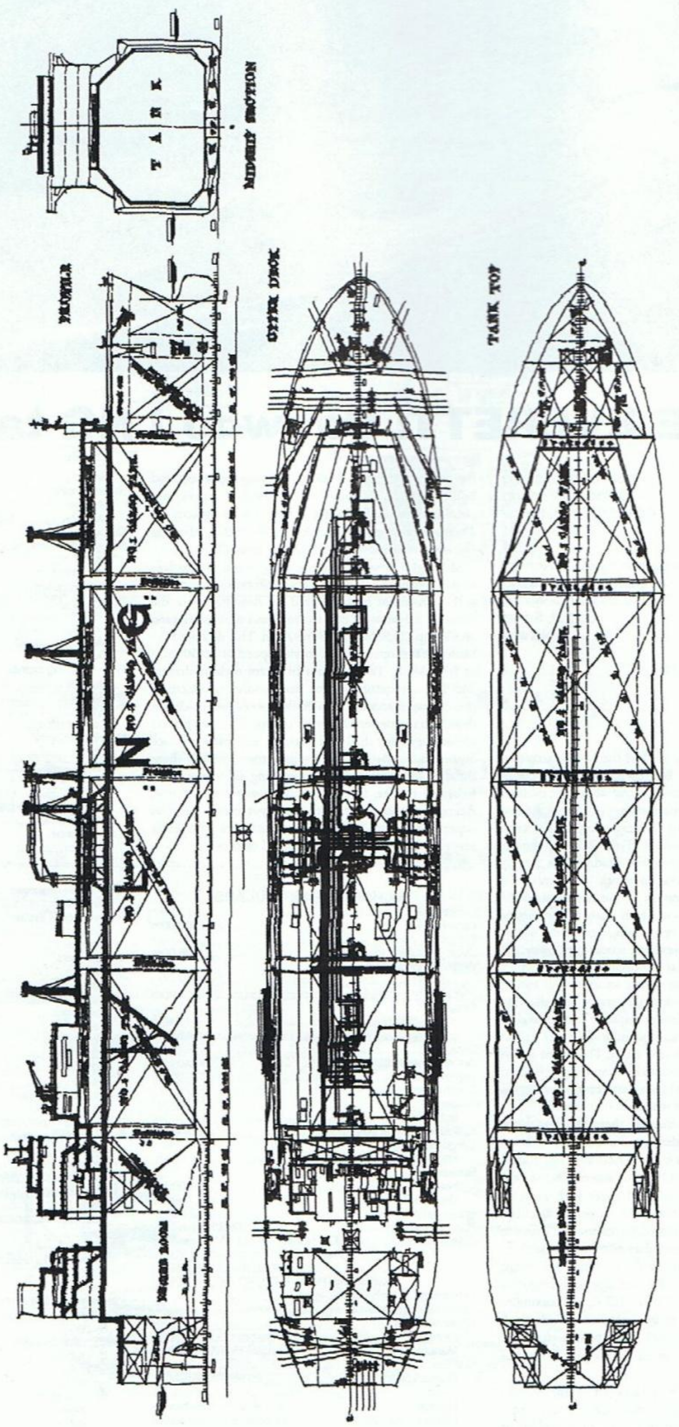
Although Daewoo is looking at the use of alternatives to the 'conventional' steam turbine propulsion system, it is this which has been adopted for *Berge Everett*, in the form of a Kawasaki cross-compound unit developing 36,690shp (26,985kW) at 88rev/min. This drives a five-bladed, FP propeller for a service speed of 19.50knots at 90% MCR. Two Mitsubishi steam-turbine-driven, 3450kW alternators are the main source of electrical power, supplemented by a Rolls-Royce/Bergen-driven diesel-alternator set of similar output. The two boilers are arranged for dual-fuel burning, and each produce 56tonnes/h. Brunvoll supplied the 1600kW bow thruster which provides manoeuvring aid to the semi-balanced rudder, fitted in an open-water sternframe. Accommodation is arranged for 43 persons in the main superstructure aft, with the living quarters completely separate from the engine and funnel casings.

TECHNICAL PARTICULARS

Length, oa	277.00m
Length, bp	266.00m
Breadth, moulded	43.40m
Depth, moulded to upper deck	26.00m
Width of double skin	
side	2.11m
bottom	3.20m
Draught	
design	11.40m
scantling	12.10m
Gross	93,844gt
Displacement	107,000tonnes
Lightweight	29,600tonnes
Deadweight	
design	70,300dwt
scantling	77,400dwt
Speed, service at 90% MCR	19.50knots
Cargo capacity	
liquid volume	138,000m³
Bunkers	
heavy oil	6000m³
diesel oil	500m³
Water ballast	52,400m³
Fuel consumption	168.80tonnes/day
Classification	Det Norske Veritas 1A1, Tanker for Liquefied Gas, Ship type 2G (-163°C, 500kg/m³, 0.25bar), NAUTICUS Newbuilding, PLUS-1, EO, W1-OC, LCS (S10)
Percentage of high-tensile steel used in construction	Nil
Steam turbines	
Design	Cross-compound impulse
Manufacturer	Kawasaki Heavy Industries
Number	1
Output/speed	26,985kW/88rev/min
Propeller	
Material	Nickel-aluminium-bronze
Designer/manufacturer	Hyundai Heavy Industries
Number	1
Pitch	Fixed
Diameter	8500mm
Speed	88rev/min
Steam-turbine-driven alternators	
Number	2
Make/type	Mitsubishi Heavy Industries/multi-stage
Output/speed	2 x 3450kW/1800rev/min
Diesel-driven alternators	
Number	1
Make/type	Rolls-Royce Bergen/-
Output/speed	3450kW/720rev/min
Boilers	
Number	2
Type	Vertical, 2-drum, water tube
Make	Mitsubishi Heavy Industries
Output	2 x 56tonnes/h
Hose-handling cranes	
Number	2
Make	Shinyong-TTS
Type	Electro-hydraulic
Performance	2 x 12tonnes swl
Mooring equipment	
Make	Rolls-Royce
Type	Electro-hydraulic
Cargo tanks	
Number	4
Grades of cargo carried	LNG
Stainless steel	Structure and piping
Cargo pumps	
Number	8
Type	Submerged electrical centrifugal
Make	Ebara
Material	Aluminium alloy
Capacity	8 x 1700m³/h
Ballast control system	
Make	Honeywell
Type	TPS (total plant solution)
Complement	
Officers	13
Crew	19
Supernumaries/spare	5
Suez crew	6
Rooms	35 x single; 1 x double; 1 x six
Bow thruster	
Make	Brunvoll
Number	1
Ouput	1600kW
Bridge control system	
Make	Kawasaki
One man operation	Yes
Fire detection system	
Make	Kongsberg
Type	BS-100 addressable
Fire extinguishing systems	
Engineroom	CO_2
Make	Unitor
Cabins/public spaces	Sea water and portable
Make	Unitor
Radars	
Number	2
Make	KMSS (Kongsberg)
Models	Autocargo 2000
Integrated bridge system	
Make	KMSS (Kongsberg)
Model	Databridge 10
Waste disposal plant	
Incinerator	
Make	Teamtec
Model	GS500C
Sewage plant	
Make	Janghap
Model	A-25
Contract date	18 December 2000
Launch/float-out date	31 August 2002
Delivery date	17 June 2003

SIGNIFICANT SHIPS OF 2003 15

BERGE EVERETT



Barcelona Knutsen: 173,400m³ LNG carrier from Daewoo

Shipbuilder: **Daewoo Shipbuilding & Marine Engineering Co., Ltd**
Vessel name: ***Barcelona Knutsen***
Hull No: **2267**
Owner/Operator: **Knutsen OAS Shipping**
Country: **Norway**
Designer: **DSME**
Country: **Norway**
Model test establishment: **HSVA**
Flag: **NIS**
IMO number: **9401295**
Total number of sister ships already completed (excluding ship presented): **0**
Total number of sister ships still on order: **3**

BARCELONA Knutsen was delivered from Daewoo Shipbuilding and Marine Engineering Co. Ltd to Knutsen OSA Shipping, Norway on 10 February. The vessel has been designed and constructed to meet the requirements of Det Norske Veritas (DNV) with the class notation +1A1 of liquefied Gas, Ship Type 2G(0.25bar -163°C, 500kg/m³), Nauticus(Newbuilding), Plus-2, E0, Naut-OC, F-A, CLEAN, Gas Fuelled, RP, TMON, BIS.

Four centre cargo tanks have a total capacity of 173,400m³ and have been designed by Gaz Transport & Technigaz (GTT) using its membrane system (GT NO 96 E-2) that will keep the liquefied natural gas (LNG) at a low temperature of -163°C with the maximum daily boil-off rate of less than 0.145% of fully loaded cargo volume.

Design fatigue life of hull structure is 40 years based on North Atlantic trading. The deck house is six tiers which is located aft of the vessel, providing accommodation for 46 persons including the Suez Crew. Care has also been taken in reducing the noise and vibration levels in this area.

The cargo handling systems onboard the *Barcelona Knutsen* have been designed to be capable of loading or discharging the LNG within 13 hours using eight cargo pumps with a capacity of 1900m³/h and four stripping/spray pumps. There is also vapour cargo handling equipment that comprises of two high duty compressors, two low duty compressors, one main vaporiser, one forcing vaporiser and one warm-up heater arranged in the cargo machinery room.

The bridge has been designed for optimum operational safety, efficiency and takes advantage of the current technology and rational navigational methods that are on the market. For one-man bridge operations the system is a modular workstation arrangement, meeting all design and equipment layout requirements in accordance with DNV's notation NAUT-OC.

TECHNICAL PARTICULARS

Length oa: 290.0m
Length bp: 279.0m
Breadth moulded: 45.8m
Depth moulded
- To upper decks: 26.5m

Width of double skin
- Side: 2.21m
- Bottom: 3.2m

Draught
- Scantling: 12.9m
- Design: 11.95m

Gross: 110,920gt
Displacement: 131,72tonnes
Lightweight: 33,79tonnes
Deadweight
- Design: 86,92dwt
- Scantling: 97,93dwt

Block co-efficient: 0.778 @ scantling draught
Speed, service: 19.5knots
Cargo capacity
- Liquid volume: 173,650m³

Bunkers
- Heavy oil: 5670m³
- Diesel oil: 530m³

Water ballast: 57,86m³
Daily fuel consumption
- Main engine only: 144.3tonnes/day

Classification: DNV, +1A1, Tanker for Liquefied Gas, Ship type 2G(0.25bar, -163°C, 500kg/m³), NAUTICUS(Newbuilding), PLUS-2, E0, NAUT-OC, F-A, CLEAN, GAS FUELLED, RP, TMON, BIS.
Main engines
- Design: Wartsila
- Model: 12V50DF x 3 sets, 9L50DF x 1 set
- Manufacturer: Wartsila
- Number: 4 sets
- Type of fuel: HFO/MDO/FUEL GAS
- Output of engine: 11,400kW x 3 sets, 8550kW x 1 set

Gearboxes
- Make: Kawasaki Heavy Industries Ltd
- Model: M1H-190/67
- Number: 2 sets
- Output speed each: 13,240kW

Propellers
- Material: Ni-Al-Bronze
- Designer/Manufacturer: DSME/Mecklenburger Metallguss GmbH
- Number: 2 sets
- Fixed/Controllable pitch: FPP
- Diameter: 7.8m
- Speed: 77.8m

Special adaptations: Manufacturing tolerance – Class S of ISO 484/1 & Surface finish – Class S of ISO 484/1
Main-engine driven alternators
- Number: 4 sets

Make/Type: Converteam/M4HXD 253-71 x 3 sets, M4HXD 253-58 x 1 set/ self excited, brushless
Output/Speed of each set: 11,000kW at 514rpm (M4HXD 253-71), 8250kW at 514rpm (M4HXD 253-58)
Boilers
- Number: 2 sets
- Type: Verical water tube
- Make: Aalborg
- Output, each boiler: 6000kg/h

Cargo cranes/cargo gear
- Number: 2
- Type: Dregen
- Type: Electro-hydraulic driven, single jib, cylinder luffing
- Performance: SWL12tonnes

Other Cranes
- Number: 2
- Make: Dregen
- Type: Electro-hydraulically driven, single jib, cylinder luffing
- Tasks: Provision and engine spare parts handling
- Performance: 12tonnes SWL

Mooring equipment
- Number: 2
- Make: Rolls-Royce Marine
- Type: Hydraulic

Special lifesaving equipment
- Number or each and capacity: 1 x 40 persons
- Make: Schat-Harding Equipment
- Type: Freefall launching type

Cargo tanks
- Number: 4

Cargo pumps
- Number: 8
- Type: Centri., vertical, submerged, single stage, direct built-in el-motor driven
- Make: Shinko Industries ltd
- Capacity: 1900m³ x 160mLC

Cargo control system
- Make: Emerson
- Type: Radar beam type for cargo tank level gauging

Ballast control system
- Make: Hanla IMS
- Type: Electro-Pneumatic

Complement
- Officers: 19
- Crew: 21
- Suez/Repair crew: 6

Fire detection system
- Make: Autronica fire and safety
- Type: Autosafe

Fire extinguishing systems
- Cargo holds: Wilhelmsen/Dry powder
- Engine room: Wilhelmsen/ High Exp. Foam system

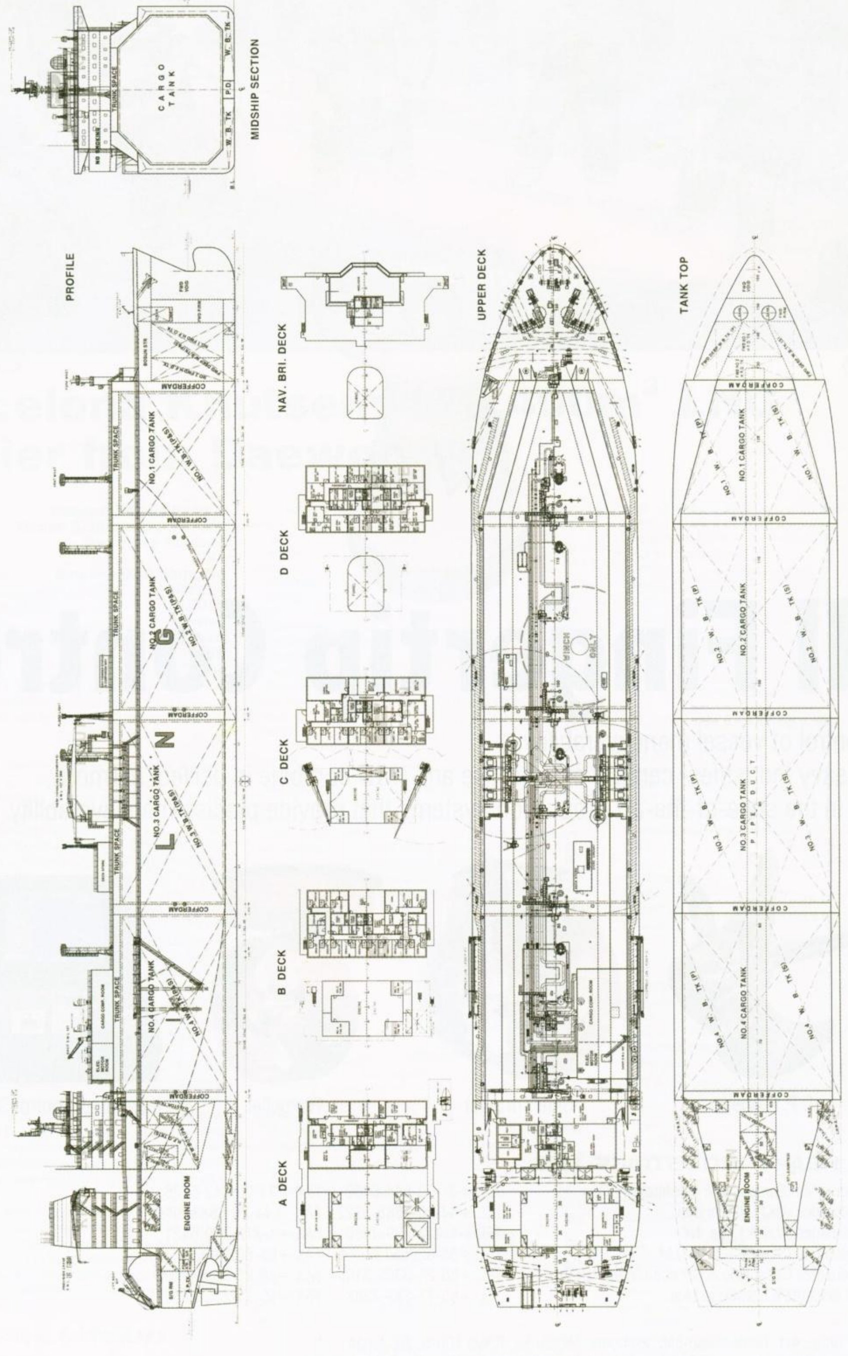
Radars
- Number: 2
- Make: JRC
- Model: JMA-9132-SA, JMA-9122-6XA

Waste disposal plant
- Incinerator: Teamtec GS500CS
- Waste compactor: Metos IMCIP400
- Sewage plant: Evac JMC-BIO AEROB-18

Contract date: 29 June 2006
Launch/float-out date: 16 May 2009
Delivery date: 10 February 2010

16 SIGNIFICANT SHIPS OF 2010

BARCELONA KNUTSEN



BRITISH EMERALD: LNG tanker with dual-fuel/diesel-electric propulsion

Shipbuilder:	Hyundai Heavy Industries Co Ltd, (HHI), Korea
Vessel's name:	*British Emerald*
Hull number:	1777
IMO number:	9333591
Owner:	BP Shipping Ltd, UK
Designer:	Hyundai Heavy Industries Co Ltd, Korea
Model test establishment used:	SSPA, Sweden
Flag:	Isle of Man
Total number of sister ships already completed:	Nil
Total number of sister ships still on order:	5

BRITISH Emerald's reign as the largest LNG carrier in the world, at 155,000m³, was short-lived (as can be seen by other entrants in this year's *Significant Ships*); nevertheless, this lead vessel of BP's new Gem class is of special interest because of its 'green' credentials, and for introducing - for this owner - an innovative propulsion system (the first dual-fuel/diesel LNG tanker was *Gaz de France Energy*, presented in our 2004 review). The use of dual-fuel marine engines is not new, but its combination here in a diesel-electric configuration (DFDE) brings a new dimension into the selection of gas-ship machinery, previously dominated by the steam turbine.

The machinery installation here is centred on four Wärtsilä type 50DF main engines: two 12-cylinder vee-type units and two with nine cylinders in line, of 11,400kW and 8550kW output, which are connected, respectively, to Converteam alternators producing 11,000kW/8250kW. These are, perhaps uniquely, each positioned directly above the propulsion motors in the two enginerooms included for redundancy purposes, and supply the ship's main electrical requirements, as well as powering two 14,860kW propulsion motors, connected via a Renk twin-input/single-output reduction gearbox to a five-bladed propeller producing a service speed of 20knots.

The main engines can operate on conventional diesel fuel or, on a loaded voyage, on boil-off gas from the cargo which is heated up and delivered as fuel gas by low duty compressors. Comparison between DFDE and similar steam-propelled gas carriers is understood to show that the latter, burning oil and gas, produced 530tonnes of CO_2 and 7tonnes SOx daily, whilst the DFDE vessel, burning only gas, emitted just 386tonnes of CO_2.

British Emerald has a flat, single-deck, with sunken mooring deck aft, and a double-skin hull containing four membrane-type cargo tanks separated by cofferdams, and constructed in accordance with the GTT Mk III containment system for carrying cargoes at cryogenic temperatures of -163°C. Tank insulation is 270mm thick to satisfy a low boil-off rate of 0.15% by volume of total cargo per day. The tanks extend above the upper deck and are enclosed in a trunk which provides access passages fore and aft.

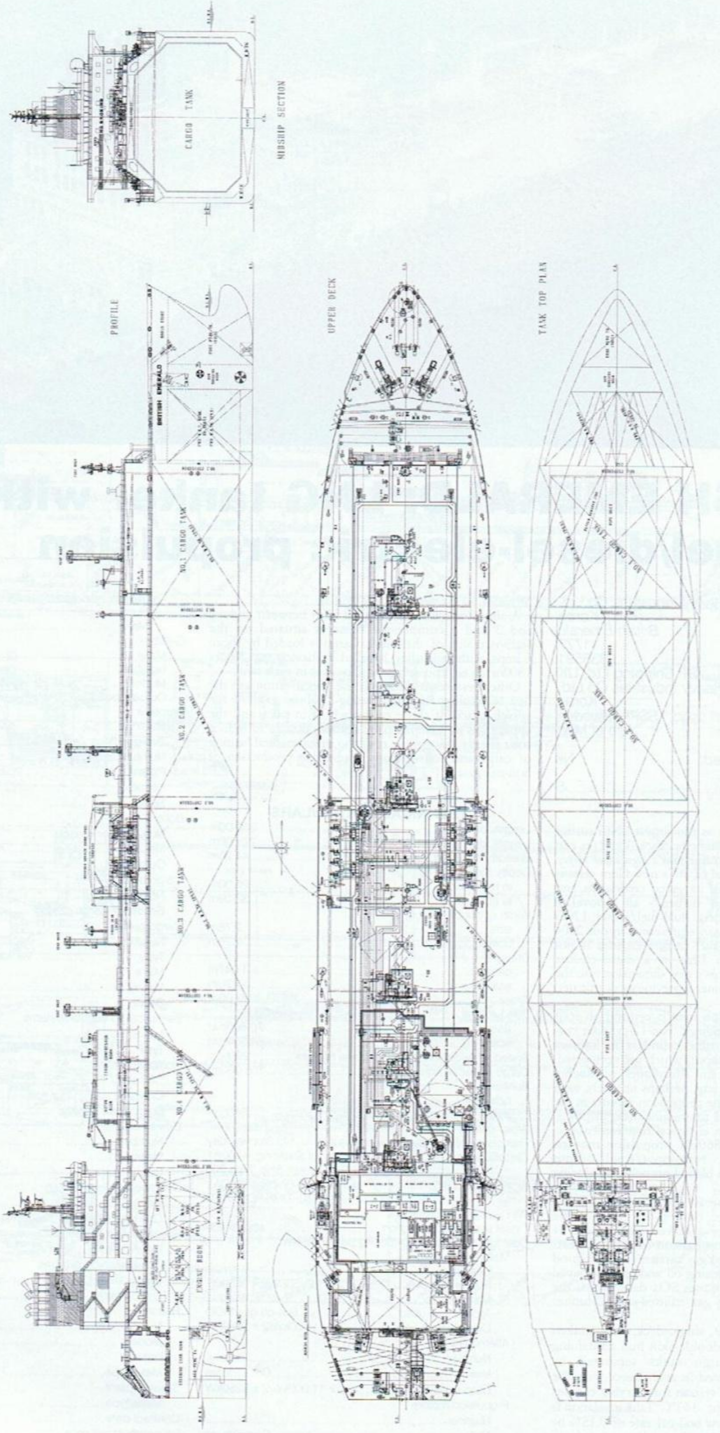
A shore manifold is arranged P&S between tanks 2 and 3 and a compressor room is situated on the starboard side of the trunk. Cargo is loaded by shore pumps, with unloading handled by having two Ebara 1800m³/h electric, submerged pumps in each tank.

Other features included in the specification are the new technology of 'cold ironing' facilities to allow the vessel to accept shore power whilst in port, and the application of external paint colours proven to reduce solar energy absorption, resulting in less natural heating of cargo and consequently minimising production of boil-off gases.

TECHNICAL PARTICULARS

Length, oa	280.00m
Length, bp	275.00m
Breadth, moulded	44.20m
Depth, moulded	
to main deck	26.00m
to trunk deck	33.09m
Width of double skin	
side	2.76m
bottom	3.20m
Draught	
design	11.47m
scantling	12.20m
Gross	102,000gt
Deadweight	
design	76,600dwt
scantling	84,300dwt
Speed, service, MCR with 15% sea margin	20knots
Cargo capacity, liquid volume	155,000m³
Bunkers	
heavy oil	nil
diesel oil	6600m³
Water ballast	59,000m³
Fuel consumption (diesel oil equivalent)	143.3tonnes/day
Classification	Lloyd's Register of Shipping, +100A1 Liquefied Gas Tanker, Ship Type 2G, SG 0.5, 0.25bar g, -163°C, *IWS ShipRight(SDA), L1, EP, +LMC, UMS, ICC, NAV
Percentage of high tensile steel used in construction	approx 2%
Dual fuel diesel electric (DFDE) power system	
Main engines	
Design	Wärtsilä
Number/models	2 x 12V50DF/2 x 9L50DF
Manufacturer	Wärtsilä
Type of fuel used	Boil-off gas/MDO
Output, each engine	2 x 11,400kW/2 x 8550kW
Alternators	
Number	4
Make	Converteam
Output, each unit	2 x 11,000kW/2 x 8250kW
Propulsion motors	
Number	2
Make	Converteam
Output, each unit	2 x 14,860kW
Frequency converters	
Number/type	2/synchronous
Make	Converteam
Gearbox	
Make	Renk
Number	1
Model	NDSH-4000 (twin input/single output)
Output speed	720 rev/min (input)/90.6rev/min (output)
Propeller	
Material	Nickel-aluminium-bronze
Designer/Manufacturer	Hyundai
Number	1
Pitch	Fixed
Diameter	8600mm
Speed	90.6rev/min
Boiler	
Number	1
Make	KangRim Heavy Industries
Output	15,000kg/h
Cargo tanks	
Number	4
Grades of cargo carried	LNG
Cargo pumps	
Number	8
Type	Vertical, submerged, centrifugal
Make	Ebara
Material	Stainless steel
Capacity	8 x 1800m³/h
Ballast/cargo control systems	
Make	Converteam
Type	Integrated automation system
Complement	
Officers	22
Crew	11
Suez/repair crew	6
Bow thruster	
Number	1
Make	Brunvoll
Output	2000kW
Bridge control system	
Make	Furuno
One man operation	Yes
Fire detection system	
Make/type	Consilium CS 3000
Fire extinguishing systems	
Cargo area	Unitor/dry powder
Engineroom	Unitor/high-pressure CO_2
Radars	
Number/make	2 x Furuno
Models	FAR-2837SW/ FAR-2827W
Incinerator	
Make/type	Hyundai/MAXI 150SL-1 WS
Sewage plant	
Make/type	Jonghap/BIO AEROB-25
Contract date	April 2004
Launch/float-out date	July 2006
Delivery date	5 July 2007

BRITISH EMERALD



BRITISH TRADER: advanced LNG tanker

Shipbuilder:	Samsung Heavy Industries Co Ltd, Korea
Vessel's name:	*British Trader*
Hull number:	1380
Owner/operator:	BP Shipping, UK
Designer:	Samsung Heavy Industries Co Ltd, Korea
Model test establishment used:	SSPA, Sweden
Flag:	Isle of Man
Total number of sister ships already completed:	Nil
Total number of sister ships still on order:	2

BRITISH TRADER has been constructed in accordance with the Gaz Transport & Technigas Mark III cargo containment system for the carriage of LNG cargoes at cryogenic temperature (-163°C) and atmospheric pressure. Within a double hull, which has been designed to last for a period of not less than 40 years, there are four cargo tanks, encased in a primary membrane of 1.2mm-thick corrugated, SUS 304L grade, stainless steel plates, and a secondary membrane of triplex glass wool. Insulation is made up of 270mm reinforced polyurethane foam, and the system allows the daily boil-off gas rate to be restricted to 0.15% of the total cargo volume.

Two 1700m^3/h cargo pumps are fitted in each tank, capable of completely discharging the cargo in 12 hours, following pre-cooling by LNG spray. Two 8000m^3/h, low-duty, and two 26,000m^3 high-duty compressors are installed, together with four spray pumps: a 550m^3/h emergency cargo pump, two warming-up heaters, an LNG vaporiser, forcing vaporiser, a 14,000Nm^3/h inert-gas generator and two 90Nm^3/h nitrogen generators.

The machinery installation is centred on a Kawasaki cross-compound steam turbine, supplied with steam from boilers which burn fuel oil or boil-off gas, or a combination of both. This drives a six-bladed propeller for a service speed of 20.10knots. Electrical power is produced by two 3450kW steam-turbine driven alternators, with a similar-sized diesel set as stand-by. A 2500kW thruster is fitted at the bow.

British Trader is equipped with a 'centralised administration and control centre', with integrated automation system (IAS) and shipboard management system (SMS), which serves as a central command station for carrying out cargo and ballasting operations, and monitoring and remotely controlling the propulsion plant. Also installed is a one-man bridge system complying with Lloyd's Register's NAV1/IBS notation, an ECDIS, a manoeuvring simulator, GMDSS console, voyage data recorder, and automatic identification system.

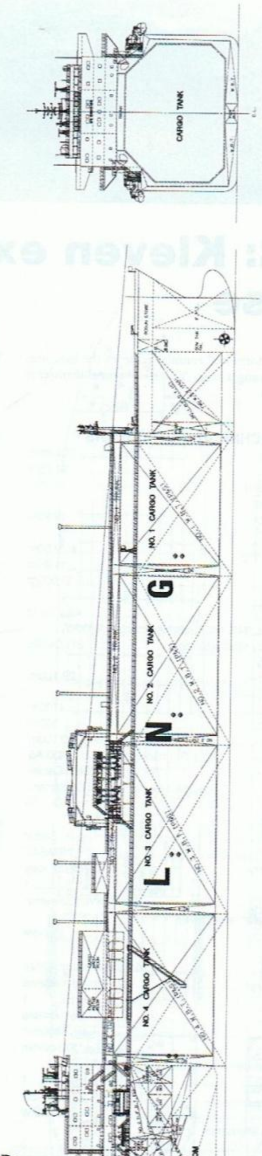
Other features of note included in the specification are a ballast water exchange system which uses sequential empty/refill procedures to complete the operation in under 30hours. The diesel-alternator engine has a low NOx emission, and there is an emergency operation for water ballast leakage, a CO_2 blowing agent for the insulation system, and all paint complies with environmental requirements.

TECHNICAL PARTICULARS

Length, oa	278.80m
Length, bp	266.00m
Breadth, moulded	42.60m
Depth, moulded	
to main deck	26.00m
to trunk deck	32.70m
Width of double skin	
side	2.30m
bottom	3.40m
Draught	
design	11.35m
scantling	12.30m
Air draught (approx)	50.00m above base
Displacement, at 12.30m	107,300tonnes
Lightweight	29,800tonnes
Deadweight	
design	68,100dwt
scantling	77,500dwt
Speed, service..	20.10knots at 85% MCR with 15% sea margin
Cargo capacity	
liquid volume	138,200m^3
Bunkers	
heavy oil	7700m^3
diesel oil	400m^3
Water ballast	54,800m^3
Fuel consumption	170.90tonnes/day
Classification	Lloyd's Register of Shipping +100A1 Liquefied Gas Tanker, Ship Type 2G, Methane (LNG) in Membrane Tanks. Maximum vapour pressure 0.25bar, minimum temperature minus 163°C/ ShipRight (SDA), IWS, L1, + LMC, UMS, CCS, ICC, NAV1, IBS, with descriptive notes ShipRight (FDA, CM, HCM, SEA(HSS-4), SEA (VDR-4), PMS(CM), SCM), Part high-tensile steel, ETA
Percentage of high-tensile steel used in construction	2.3%
Steam turbine	
Design	Cross-compound impulse turbine
Manufacturer	Kawasaki Heavy Industries
Number	1
Output	39,500shp MCR/33,580shp NCR at 85.3rev/min
Gearbox	
Make	Kawasaki Heavy Industries
Model	UA-400
Number	1
Output speed	90rev/min MCR
Propeller	
Manufacturer	Mitsubishi Heavy Industries
Number	1
Pitch	Fixed
Diameter	8250mm
Speed	90rev/min MCR
Steam-turbine driven alternators	
Number	2
Make/type	Shinko/multi-stage
Output	2 x 3450kW/1800rev/min
Diesel-driven alternator	
Number	1
Engine make	Wärtsilä
Output/speed	3600kW/720rev/min
Alternator make	ABB
Output/speed	3450kW/720rev/min
Boilers	
Number	2
Type	Water tube, forced draught
Maker	Kawasaki Heavy Industries
Output	2 x 65tonnes/h
Mooring equipment	
Make	Kocks
Type	Self-contained hydraulic
Cargo tanks	
Number	4
Stainless steel	Structure and piping
Cargo pumps	
Number	8
Type	Submerged electric
Make	Ebara International
Capacity	8 x 1700m^3
Cargo and bridge control systems	
Type	Integrated with IAS
Complement	
Officers	22
Crew	11
Suez/repair crew	6
Bow thruster	
Make	Kawasaki Heavy Industries
Number	1
Output	2500kW
Fire detection system	
Make	Consilium
Type	Analogue addressable
Fire extinguishing system	
On deck	Dry powder
Make	NK
Engineroom	CO_2
Cabins/public spaces	Sea water
Radars	
Number	2
Make	Kongsberg
Model	2 x DB10
Satellite navigation systems	
Number	2 x DGPS
Make	Leica
Model	MX412
Waste disposal systems	
Incinerator	
Make	TeamTec
Model	OGS400C
Waste compactor	
Make	Hackman Metos
Model	Orwak 5030
Waste shredder/crusher	
Make	Bin Systems
Model	F515
Contract date	20 July 2000
Launch/float-out date	9 December 2001
Delivery date	15 November 2002

12 SIGNIFICANT SHIPS OF 2002

BRITISH TRADER



SIGNIFICANT SHIPS OF 2002

13

CASTILLO DE SANTISTEBAN: STX LNG carrier with extra cargo tank capacity

Shipbuilder: **STX Offshore & Shipbuilding Co., Ltd**
Vessel name: ***Castillo De Santisteban***
Hull No: **S3008**
Owner/Operator: **Empresa Naviera Elcano SA**
Country: **Spain**
Designer: **STX Offshore & Shipbuilding Co., Ltd**
Country: **Korea**
Model test establishment used: **MOERI/SSPA**
Flag: **Malta**
IMO number: **9433717**
Total number of sister ships already completed (excluding ship presented): **0**
Total number of sister ships still on order: **0**

STX Offshore & Shipbuilding delivered its liquefied natural gas (LNG) carrier, *Castillo De Santisteban*, to Empresa Naviera Elcano SA in August. The vessel has the defining feature of having a maximum tank size that is accepted by Gaz Transport & Technigaz (GTT) with a No 93E2 membrane cargo system.

The hull of *Castillo De Santisteban* is divided into four cargo tanks by cofferdams that are built between cargo tanks and consist of five pairs of water ballast tanks in the side and bottom space.

The cargo containment, handling, control and measuring systems are designed and constructed to transport liquefied natural gas in four membrane cargo tanks at about -163°C and at the absolute pressure of 106kPa. The water ballast carried in tanks which are coated in epoxy A/C is handled by three $3300m^3$ pumps installed on the double bottom in E/R.

The additional Bureau Veritas (BV) class notation SYS-NEQ is assigned to ships which are fitted with a centralised navigation control system so arranged that the navigation and manoeuvring of the ship can be operated under normal conditions by one person, for periodical one man watch. The notation includes specific requirements for prevention of accidents.

The main propulsion consists of main dual-fuel generator engines and propulsion motors with reduction gear driving a single screw propeller through the main shafting.

The propulsion system is a dual fuel diesel electric, capable of burning a combination of natural and forced boil off gas. The power generating plant utilises all available natural boil off gas and makes up the required power by consuming additional forced boil off gas. The electric generators consist of five MAN 8L51/60DF main generators, one turbo generator, which generates electricity using waste heat gas making for a 5% fuel saving and one emergency diesel generator. *Castillo De Santisteban* also has a DF boiler and heel-out operation mode reducing gas waste and increasing the efficiency of the vessel.

TECHNICAL PARTICULARS

Length oa: 199.90m
Length bp: 288.00m
Breadth moulded: 45.80m
Depth moulded
- To main deck: 26.00m
- To upper deck: 26.00m
- To other decks: 33.55m

Width of double skin
- Side: 2.39m
- Bottom: 3.20m

Draught
- Scantling: 12.50m
- Design: 11.60m

Gross: 111,665gt
Displacement: 128,987tonnes
Deadweight
- Design: 83,515dwt
- Scantling: 93,796dwt

Block co-efficient: 0.7614
Speed, service: 20.42knots
Cargo capacity
- Liquid volume: $173,887m^3$

Bunkers
- Heavy oil: $5616m^3$
- Diesel oil: $559m^3$

Water ballast: $61,244m^3$
Daily fuel consumption
- Main engine only: 0
- Auxiliaries: 143.5tonnes/day

Classification society and notations: Bureau Veritas I +Hull, +Mach, Unrestricted Navigation, Liquefied Gas Carrier, +Veristar-Hull, DFL 40 Years, +AUT-UMS, AUT-CCS, AUT-PORT, SYS-NEQ-1, Inwatersurvey, MON-Shaft
% high-tensile steel used in construction: less than 10%
Gearbox
- Make: Kawasaki
- Model: M2H-400/85
- Number: 1
- Output speed: 84.9rpm

Propellers
- Material: Ni-Al-Bronze
- Designer/Manufacturer: Hyundai Heavy Industries
- Number: 1
- Fixed/Controllable pitch: Fixed pitch
- Diameter: 8700mm
- Speed: 84.9rpm

Diesel-driven alternators
- Number: 5
- Engine make/type: MAN Diesel/ 8L51/ 60DF
- Type of fuel: BOG, MDO, HFO
- Output/speed of each set: 8000kW x 514rpm
- Alternator make/type: ABB
- Output/speed of each: 7700kW x 514rpm

Boilers
- Number: 2
- Type: Oil fired + oil fired and gas fired
- Make: Aalborg
- Output, each boiler: 16tonnes x 8.5bar, 8tonnes x 3.5bar

Cargo cranes/cargo gear
- Number: 2
- Make: Oriental Precision & Engineering
- Type: Electro-hydraulic cylinder luffing, Single jib arm
- Performance: 15tonnes x 25m SWL

Other cranes
- Number: 2
- Make: Oriental Precision & Engineering
- Type: Electro-hydraulic, single jib arm
- Tasks: Provision crane
- Performance: 10tonnes x 10m SWL, 10tonnes x 6m SWL

Mooring equipment
- Number: 10
- Make: Rolls-Royce
- Type: Hydraulic

Special lifesaving equipment
- Number of each and capacity: 2 x 48 persons
- Make: Hyundai lifeboat
- Type: Totally enclosed type

Cargo tanks
- Number: 4
- Product range: Liquefied natural gas
- Coated tanks: Cargo containment system with invar membrane

Cargo pumps
- Number: 8
- Type: Vertical, submerged
- Make: Shinko
- Stainless steel: Al Alloy casting
- Capacity: $2050m^3/h$ at 160mlc

Cargo control system
- Make: Kongsberg
- Type: K-Chief 700

Ballast control system
- Make: Kongsberg
- Type: K-chief 700

Complement
- Officers: 21
- Crew: 17
- Suez/Repair crew: 6

Bow thrusters
- Make: Kawasaki Heavy Industries
- Number: 1
- Output: 2000kW

Bridge control system
- Make: ABB
- Type: OS800
- One-Man operation: Yes

Fire detection system
- Make: Consilium
- Type: CS4000

Fire extinguishing systems
- Cargo holds: Wilhelmsen Dry powder, sea water
- Engine room: Wilhelmsen High expansion foam
- Cabins: Samjoo Eng. Galley hood fire fighting system
- Public spaces: NK CO_2 fire extinguishing system

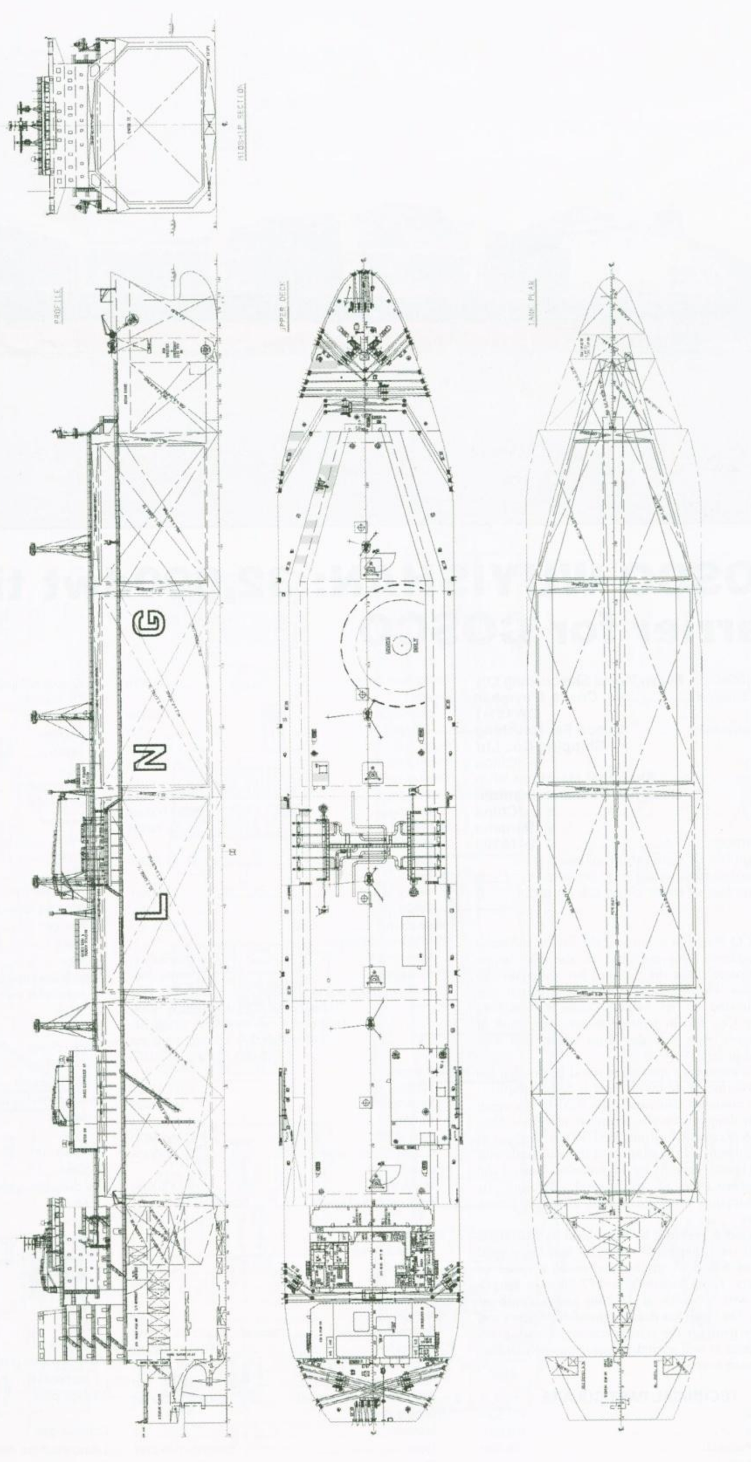
Radars
- Number: 2
- Make: Furuno
- Model: FAR-2827 (x-Band), FAR-2837S (S-Band)

Integrated bridge system
- Make: Furuno
- Model: FEA-2107

Contract date: February 2007
Launch/float-out date: April 2009
Delivery: August 2010

24 SIGNIFICANT SHIPS OF 2010

CASTILLO DE SANTISTEBAN



DAPENG SUN: first Chinese-built LNG carrier

Shipbuilder:	**Hudong-Zhonghua Shipbuilding (Group) Co Ltd (China State Shipbuilding Corp), People's Republic of China**
Vessel's name:	***Dapeng Sun***
Hull number:	**H1308A**
IMO number:	**9308479**
Owner/technical manager:	**Yue Peng LNG Shipping Co Ltd, Hong Kong/China LNG Shipping (International) Co Ltd (CLSICO), Hong Kong**
Flag:	**Hong Kong**
Total number of sister ships already completed:	**Nil**
Total number of sister ships still on order:	**4**

DAPENG SUN is another product of the burgeoning Hudong-Zhonghua Shipyard in Shanghai but this ship's most notable claim to fame is as the first LNG carrier to be built in China. It is the lead ship of a series of five, constructed in collaboration with the former Alstom Atlantique shipyard at St Nazaire (now operating as part of STX Europe), one of the pioneers of large-capacity LNG carrier construction.

Destined for operation between the North West Shelf LNG export facility at Withnell Bay, near Dampier in Western Australia, and China's first gas receiving terminal at Dapeng, Guangdong province, the vessel has entered service with a complex joint venture ownership network, involving participants in the North West Shelf project, COSCO Dalian, the Chinese LNG industry, and Hong Kong based shipowners. Shell International carried out shipyard supervision, and the technical management company (CLSICO) includes BP Shipping in its organisation.

Cargo is carried in four tanks contained within a complete double side/bottom/bulkhead structure with topside tanks, the inner line of which is carried up to form the side of a nearly full length upper deck trunk. Gas is transported at temperatures of -163°C and at near atmospheric pressure using a GTT NO96 containment system. This has primary and secondary membranes formed of Invar (36% nickel steel), in conjunction with other proven insulation materials to satisfy the required boil-off rate.

All cargo system components are subject to cryogenic temperatures, and handling is carried out using eight (two per tank) electric, stainless steel, submerged pumps each with a capacity of 1500m³/hour, and supplied from Spain by Ebara, along with four 50m³/hour spray pumps. Cargo and ballast operations are controlled by a Centrum CS3000 integrated automation system installed by the Yokogawa Electric Corp.

Dapeng Sun is fitted with a steam turbine machinery plant consisting of a UA-400 high pressure/low pressure set, including a cross compound, tandem articulated, double reduction gearbox, all supplied by Kawasaki. Mitsubishi provided two type MB-4E-KS2 water tube, internally superheated boilers, burning either HFO, low-sulphur grade HFO, or boil-off gases from the cargo to supply the turbine, which develops 27,300kW at 83rev/min. Service speed is recorded at 19.50knots at MCR, using a Mecklenburger Metallguss fixed pitch propeller.

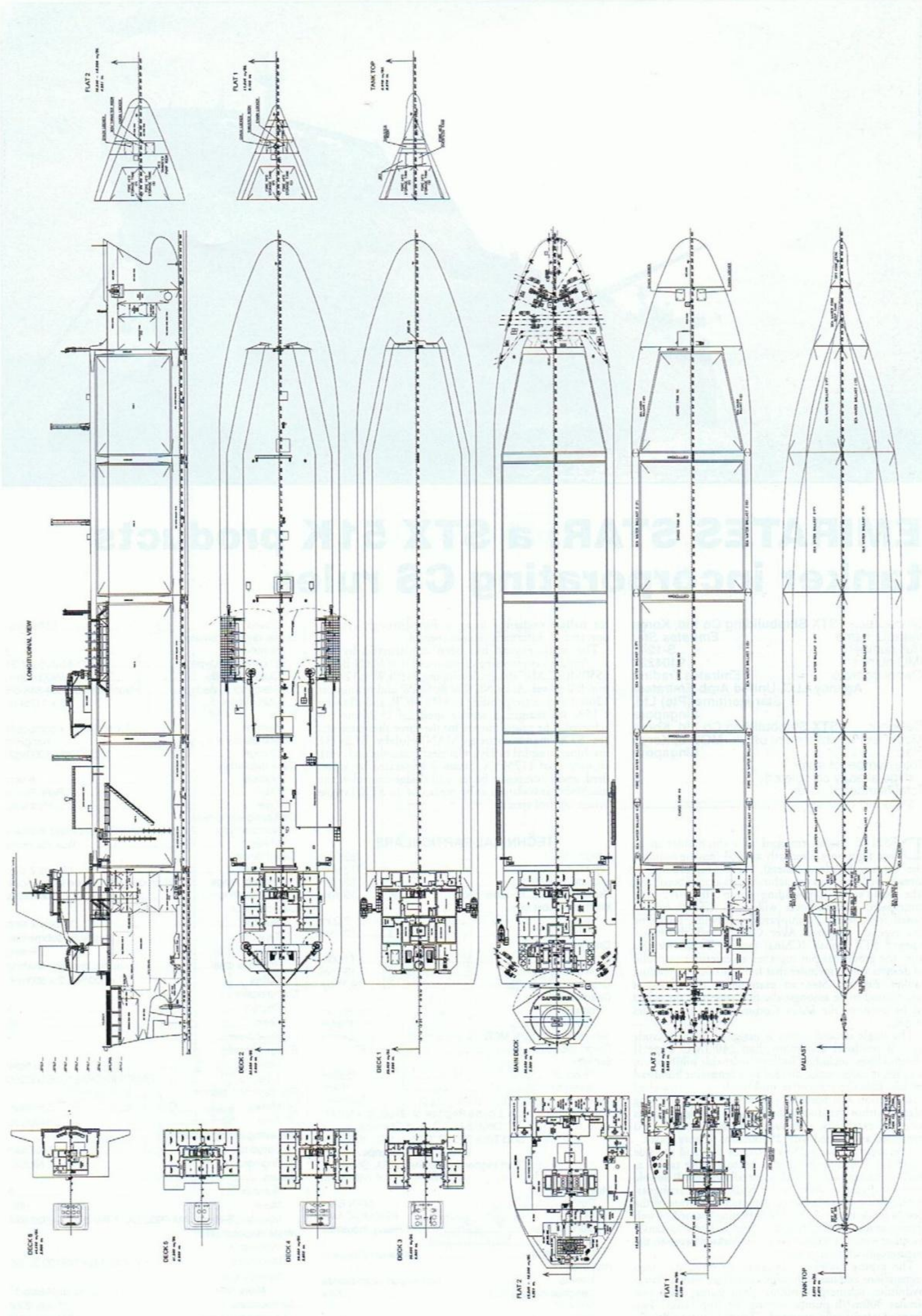
Electrical supply comes from two Mitsubishi/ABB steam turbine-driven alternator sets each producing 3200kW at 1800rev/min. Two 2000kVA ABB alternators, driven by MAN diesel engines running on MDO, are also fitted. Enhancing manoeuvrability is a Kawasaki 2000kW bow thruster.

TECHNICAL PARTICULARS

Length, oa	292.00m
Length, bp	274.10m
Breadth, moulded	43.35m
Depth, moulded	26.25m
Draught	
design	11.45m
scantling	12.33m
Gross	97,871gt
Lightweight	31,739tonnes
Deadweight	
design	83,050dwt
Speed, service, MCR	19.50knots
Cargo capacity	147,237m³ (100% full)
Bunkers	
heavy oil	5011m³
heavy oil (low sulphur)	490m³
diesel oil	323m³
Water ballast	54,762m³
Classification	American Bureau of Shipping +A1 (E), Liquefied Gas Carrier, Ship Type 2G, Membrane Type 0.25bar, -163°C, 500kg/m³, SH-DLA, SH-FL(40), SFA (40), SHCM, UWILD, +AMS, +ACCU, NBLES, HM3+R, ES & equivalent of LR LI, SCM, TCM, BWMP
Main engine	
Design	Steam turbine
Model	Kawasaki UA-400
Manufacturer	Kawasaki Heavy Industries
Number	1
Type of fuel used	HFO/LNG (boil off)
Output	27,300kW/83rev/min
Gearbox	
Make	Kawasaki
Type	Cross compound, tandem articulated, double reduction
Propeller	
Material	phosphor bronze
Manufacturer	Mecklenburger Metallguss
Number	1
Pitch	Fixed
Diameter	8800mm
Speed	83rev/min
Steam turbine-driven alternators	
Number	2
Turbine make/type	Mitsubishi/AT42CT-B
Alternator make/type	ABB/-
Output	2 x 3200kW/6600V
Diesel-driven/alternators	
Number	2
Engine make	MAN
Type of fuel used	MDO
Alternator make/type	ABB/-
Output	2 x 2000kVA/6600V
Boilers	
Number	2
Make/type	Mitsubishi/MB-4E-KS2
Output	2 x 65,000kg/h
Mooring equipment	
Number	2 x winclass; 8 x mooring winch
Make	-
Type	Electric
Cargo tanks	
Number	4
Grades of cargo	LNG
Containment system	GTT NO96 with Invar
Cargo pumps	
Number	8
Type	Electric, submerged
Make	Ebara International Corp
Stainless steel	Yes
Capacity	8 x 1500m³/h
Ballast/cargo control systems	
Make	Yokogawa Electric Corp
Type	Centrum CS3000 integrated automation system
Complement	
officers	19
crew	13
Bow thruster	
Make	Kawasaki
Number/type	1 x KT 219B
Output	2000kW/270rev/min
Bridge control system	
Make	Furuno
Type	Integrated bridge system
One man operation	Yes
Fire detection system	
Make	Autronica
Type	Release 3 interactive fire alarm
Fire extinguishing systems	
Cargo area	Unitor dry powder
Engineroom	Unitor Hi-Foam/Marioff water spray
Radars	
Number	2
Make	Furuno
Models	FAR 2827W; FAR288837SW
Waste disposal plant	
Incinerator	Deerberg Delta IRL-50
Sewage plant	Hamworthy SA4A
Contract date	11 August 2004
Launch/float-out date	28 December 2005
Delivery date	3 April 2008

42 SIGNIFICANT SHIPS OF 2008

DAPENG SUN



SIGNIFICANT SHIPS OF 2008

43

EXCELSIOR: first re-gasifying LNG carrier for the Energy Bridge concept

Shipbuilder:	Daewoo Shipbuilding & Marine Engineering Co Ltd, (DSME), Korea
Vessel's name:	*Excelsior*
Hull number:	2208
Owner/operator:	Exmar NV, Belgium
Designer:	DSME, Korea
Model test establishment used:	SSPA, Sweden
Flag:	Belgium
Total number of sister ships already completed:	Nil
Total number of sister ships still on order:	2

ENERGY BRIDGE is the name given to an innovative concept introduced by Exmar, Excellerate Energy, and DSME, which allows a tanker, having loaded an LNG cargo in the conventional way, to regasify the cargo on board and discharge the high-pressure gas, at an offshore buoy or floating terminal. Gas is then fed directly into the consumer grid system through a dedicated mooring arrangement and sub-sea pipeline, thereby by-passing the need for a costly shore terminal which would normally carry out this process.

The so-called 'LNG re-gasification (re-gas) vessel (LNG RV)' has been developed by DSME from its standard 138,000m³ capacity LNG tanker design (*Berge Everett, Significant Ships of 2003*), to which has been added regas facilities and an internal turret for sub-sea pipe connection and weather-vane mooring. That basis vessel featured a double hull containing four prismatic cargo tanks separated by cofferdams. They extended through the upper deck to form a trunk, and were constructed in accordance with the conventional GTT NO96 membrane containment system.

This has been retained, but, because the LNG RV will be operating under partially filled tank conditions involving cargo sloshing, especially when moored to a buoy, it, and the supporting structure, has been significantly reinforced in the new ship. Cargo handling in the LNG mode also remains as before, using eight submerged 1700m³/h electric pumps mounted in pump tower masts in the four tanks and capable of discharging a full liquid cargo in 12 hours: high- and low-duty compressors, main and forcing vaporisers, and boil off/warm up heaters are also included in the system.

For the LNG RV role, additional equipment has been provided, with three 620m³/h feed pumps in tanks 2, 3 and 4 supplying a re-gas process, comprising six sets of 205m³/h high-pressure pumps and vaporisers, arranged three each, port and starboard, above No 1 tank. The normal re-gasification capacity is 500mmscfd (500 million standard cubic feet per day), ensuring that a full 138,000m³ cargo can be converted to high-pressure natural gas in five-to-six days.

Discharge is effected either through P&S deck manifolds or, more particularly, in line with the Energy Bridge concept, via a submerged turret mooring and offloading (STL) system, employing a turret installed at the bow. A buoy is moored to the sea bed at the terminal and this is pulled into, and secured to, the turret's mating cone in the ship's bottom. A swivel in the turret allows the ship to weathervane without the aid of propulsion, and a quick-release feature is installed. During normal LNG transfer, the re-gas plant is depressurised, inerted, and segregated from the normal cargo piping.

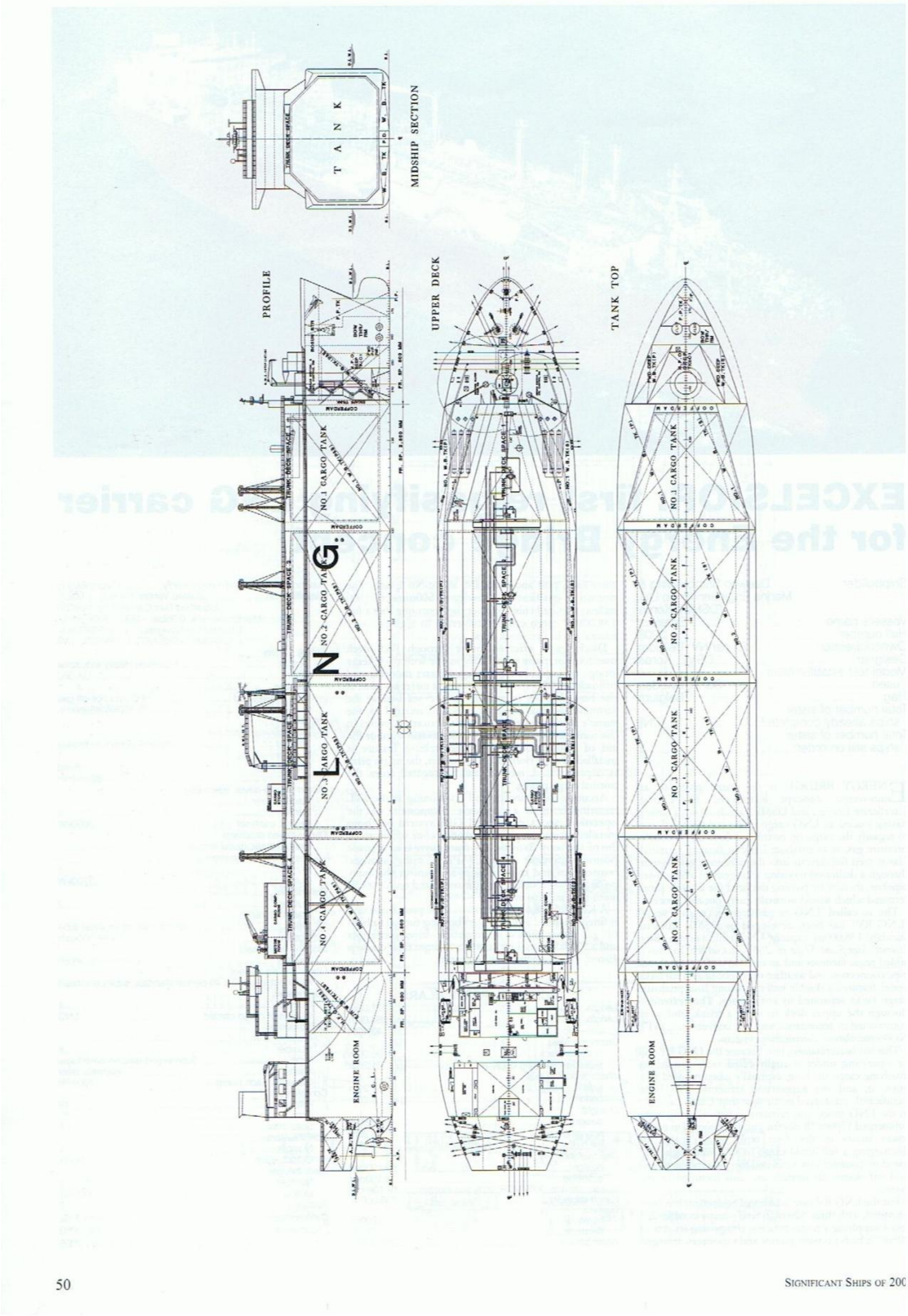
Accurate manoeuvring and positioning at the STL mooring buoy is a necessary component of the operation, and a differential GPS system has been installed which can place the mating cone within some 2m of the buoy. Assisting this manoeuvre is an acoustic position-reference system (APRS), using acoustic transceivers and transponders to monitor the buoy position. Two 1500kW bow thrusters, and one 2000kW stern unit, are also installed.

A Kawasaki 26,650kW steam turbine propulsion unit is fitted, supplied by two boilers burning fuel oil or boil-off gas. Three 3600kW steam turbine-driven generators and a 3700kW diesel set (all slightly larger than on *Berge Everett*) satisfy electrical requirements.

TECHNICAL PARTICULARS

Length, overall	277.00m
Length, bp	266.00m
Breadth, moulded	43.40m
Depth moulded	
to upper deck	26.00m
to sunken mooring deck, aft	21.26m
Width of double skin	
side	2.21m
bottom	3.20m
Draught	
design	11.50m
scantling	13.20m
Gross	93,800gt
Deadweight	
design	68,130dwt
scantling	76,130dwt
Speed, service, 90% MCR, 21% sea margin	19.10knots
Cargo capacity	138,000m³
Bunkers	
heavy oil	5700m³
diesel oil	350m³
Water ballast	51,000m³
Fuel consumption, main engine only	170tonnes/day
Classification	Bureau Veritas 1 + Hull, + Mach, Liquefied Gas Carrier, Ship type 2G (Membrane tank, 0.25bar. -163°C, 500kg/m³), Unrestricted Navigation, + VeriSTAR-Hull, + AUT-UMS, +SYS-NEQ-1, SPM/STL, IWS
Steam turbine	
Design	Kawasaki Heavy Industries
Model	UA-360
Number	1
Type of fuel used	HFO and boil-off gas
Output/speed	26,650kW/88rev/min
Propeller	
Designer/manufacturer	-
Material	Nickel-aluminium-bronze
Number	1
Pitch	Fixed
Speed	88rev/min
Steam turbine-driven alternators	
Manufacturer	-
Number	3
Output, each set	3600kW
Diesel-driven alternator	
Manufacturer, diesel engine	-
Manufacturer, alternator	-
Number	1
Output	3700kW
Boilers	
Number	2
Manufacturer	-
Type	vertical, two-drum water tube
Output	2 x 68,000kg/h
Mooring equipment	
Number	9 x mooring winch
Lifesaving equipment	
Number/type	2 x 40-person lifeboats, totally enclosed
Cargo tanks	
Number	4
Grades of cargo carried	LNG
Cargo pumps	
Manufacturer	-
Number	8
Type	Submerged electric centrifugal
Shaft	stainless steel
Capacity, each pump	1700m³/h
Complement	
Officers	19
Crew	15
Suez crew	6
Bow thrusters	
Number	2
Output, each	1500kW
Stern thruster	
Number	1
Output	2000kW
Radars	2
Contract date	13 March 2002
Launch/float-out date	15 November 2003
Delivery date	14 January 2005

EXCELSIOR


MIDSHIP SECTION
PROFILE
UPPER DECK
TANK TOP
NO.1 CARGO TANK
NO.2 CARGO TANK
NO.3 CARGO TANK
NO.4 CARGO TANK
ENGINE ROOM
L N G

EXPRESS: LNG re-gasification vessel from Daewoo

Shipbuilder: Daewoo Shipbuilding & Marine Engineering Co., Ltd
Vessel's name: *Express*
Hull No: 2263
Owner/Operator: EXMAR
Country: Belgium
Designer: Daewoo Shipbuilding & Marine Engineering Co., Ltd
Model test establishment used: SSPA
Flag: Belgium
Total number of sister ships already completed (excluding ship presented): 1
Total number of sister ships still on order: 3

Express, a 74,700dwt LNGRV (liquefied natural gas – re-gasification vessel) was delivered by Daewoo Shipbuilding & Marine Engineering Co. Ltd. (DSME) to EXMAR Marine NV of Belgium on May 11, 2009. *Express* is jointly owned by EXMAR and US company Excelerate Energy and is on a 25-year charter to Excelerate Energy. At the time of delivery *Express* was the fourth LNGRV in EXMAR's fleet.

LGNRVs are independent of shore-based re-gasification facilities, being capable of re-gasifying LNG onboard and delivering it directly into the distribution system. *Express* can discharge re-gasified liquid natural gas through a high pressure shore manifold connection or to a subsea pipeline through an internal turret arrangement connected to an offshore mooring buoy. The vessel can also operate as a conventional LNG vessel discharging to a shore-based re-gasification facility.

Express has a continuous upper deck with aft sunken deck, a raked stem with bulbous bow and a submerged turret unloading system, a transom stern with open water type stern frame, a semi balanced rudder and a fixed pitch propeller driven by a cross compound type marine steam turbine. The cargo area is of the double-hull type with a double bottom. Cofferdams are located at forward and after part of cargo area and between cargo tanks. Cargo is carried in four centre cargo tanks with the Gaz Transport & Technigaz membrane containment system ("GT NO 96 E-2").

The re-gasification plant, consisting of a number of high pressure pumps, vaporisers, heaters and other equipment is provided in way of No. 1 cargo tank. A SCR (Selective Catalytic NOx Reduction) system is provided for two main boilers and one auxiliary boiler in order to reduce the NOx level.

TECHNICAL PARTICULARS

Length oa: 291.0m
Length bp: 280.0m
Breadth moulded: 43.4m
Depth moulded
- to main deck: 26.0m
- to upper deck: 32.95m

Width of double skin
- side: 2.211m
- bottom: 3.2m

Draught
- scantling: 12.4m
- design: 11.6m

Gross: 100,300gt
Displacement: 117,300tonnes
Deadweight
- Design: 74,700dwt
- Scantling: 83,200dwt

Speed, service: 19.2knots (90% MCR with 21% sea margin)
Cargo capacity:
- Liquid volume: 151,000m³

Bunkers:
- Heavy oil: 5906m³
- Diesel oil: 480m³

Water ballast: 55,000m³
Daily fuel consumption:
- Main engine only: 170.3tonnes/day

Classification society and notations: Bureau Veritas; I +HULL +MACH, Liquefied gas carrier/LNG, Ship Type 2G (membrane tank, 0.25 bar -163C, 500kg/m3), unrestricted navigation, +VeriSTAR Hull, AUT-UMS, +SYS-NEQ-1, SPM/STL, INWATERSURVEY, MON-SHAFT.
% high tensile steel used in contrustion: 0.2%
Main engine:
- Design: Cross compound, marine steam turbine
- Model: UA 360
- Manufacturer: KHI
- Number: 1
- Output: MCR: 26,480kW/88rev/min

Gearbox:
- Make: KHI
- Number: 1

Output speed: 88rev/min
Propeller:
- Material: Ni-Al-Bronze
- Designer/Manufacturer: Hyundai
- Number: 1
- Fixed/Controllable pitch: Fixed
- Diameter: 8.5m
- Speed (NCR): 85rev/min
- Special adaptations: Class I of ISO 484/1 and class S of ISO 484/1

Turbine driven alternators:
- Number: 3

Turbine make/type: MHI/Multi-stage high efficiency turbine AT42CT
- Alternator make/type: HHI/Self-excited, brushless
- Output/speed of each set: 3700kW/1800rev/min

Diesel-driven alternators:
- Number: 1

Engine make/type: Wartsila 12V32DF / 4-stroke, dual fuel burning
- Type of fuel: MDO/Fuel gas
- Output: 4020kW

Boilers
- Number: 2
- Type: Vertical, 2-drum, water tube type
- Make: MHI
- Output, each boiler: 71,000kg/hour x 6.03MPa

Cargo cranes:
- Number: 2
- Make: TTS Marine Crane AS
- Type: Electro-hydraulically driven

Performance: 12tonnes (SWL) x 12m/min.
Other cranes
- Number: 2
- Make: TTS Marine Crane AS
- Type: Electro-hydraulically driven,

Tasks: Engine spare part & provision handling
Performance: 12tonnes (SWL) x 10m/min.
Mooring equipment
- Number: 2 windlasses + 7 mooring winches
- Make: TTS KOCKS GMBH
- Type: Electro-hydraulically driven, high pressure type

Special lifesaving equipment:
- Number of each and capacity: 2 x 40persons
- Make: UMOE Schart-Harding
- Type: Totally enclosed type (FRP)

Cargo tanks
- Number: 4
- Stainless steel: SUS 316L for cargo system

Cargo pumps
- Number: 8
- Type: Cryogenic centrifugal
- Make: Ebara
- Materials: Aluminium alloy casing and impeller
- Capacity (each): 1700m³/h

Cargo control system
- Make: Honeywell
- Type: Central computerised system

Ballast control system
- Make: Honeywell
- Type: Central computerised system

Complement
- Officers: 18
- Crew: 15

Bow thrusters:
- Make: Brunvoll As
- Number: 2
- Output (each): 1500kW

Stern thrusters:
- Make: Brunvoll As
- Number: 1
- Output: 2000kW

Submerged Turret Unloading (STL)
- Make: Advanced Production & Loading AS
- Number: 1
- Capacity: Approx. 500 MMSCFD

Bridge control system
- Make: KHI
- Type: UA 360

Is bridge fitted for one-man operation? Yes
Fire detection system
- Make: Consilium
- Type: Addressable

Fire extinguishing systems
- Cargo holds: None
- Engine room: High expansion foam system / Kashiwa
- Cabins: Portable fire extinguishing system
- Public spaces: Portable fire extinguishing system

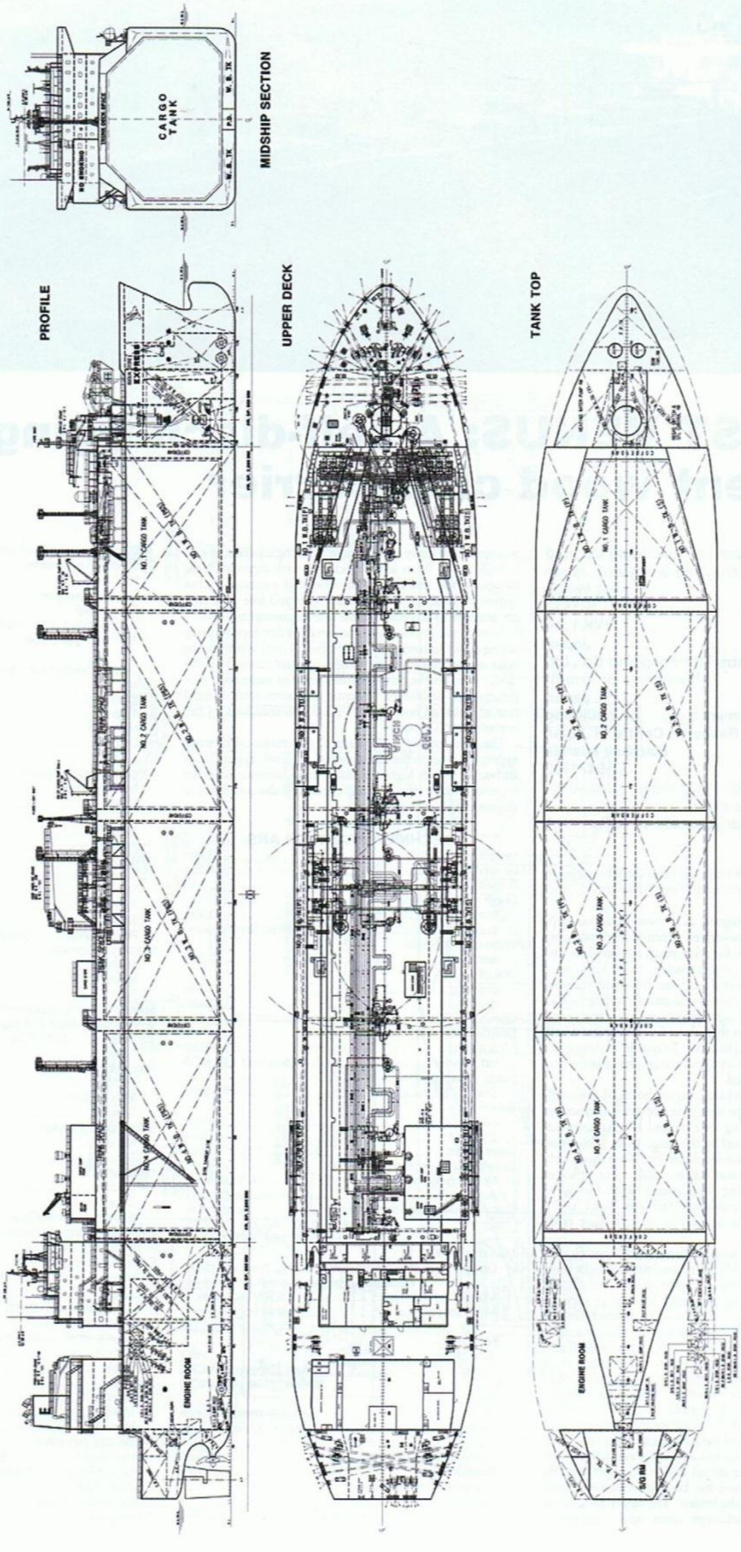
Radars
- Number: X-band(one set) & S-band(one set)
- Make: SAM Electronics
- Model(s): Chart radar 1100

Integrated bridge system:
- Make: SAM Electronics
- Model: Chart pilot 1100

Waste disposal plant
- Incinerator: Kangrim KEI-70SDA
- Sewage plant: Jonghap AER0B-18

Contract date: 10 January 2006
Launch/float-out date: 21 June 2008
Delivery date: 11 May 2009

EXPRESS


MIDSHIP SECTION
CARGO TANK
PROFILE
UPPER DECK
TANK TOP
ENGINE ROOM

FERNANDO TAPIAS: Daewoo-built LNG tanker for Spanish owner

Shipbuilder:.......Daewoo Shipbuilding & Marine Engineering Co Ltd, Korea
Vessel's name:........................*Fernando Tapias*
Hull number:.. 2205
Owner/operator:...... Naviera F Tapias Gas SA, Spain
Designer:..........Daewoo Shipbuilding & Marine Engineering Co Ltd, Korea
Flag: .... Spain
Total number of sister ships already completed:....................................Nil
Total number of sister ships still on order:...1

FERNANDO TAPIAS has been built for the transportation of liquefied natural gas (LNG), and special attention has been paid in her design to the facilities at loading and discharging berths worldwide, to ensure compatibility of mooring arrangements, fender contact areas, gangway and manifold positions, and other aspects. Laid out with a continuous single deck, and a sunken aft deck, the vessel has four cargo tanks, constructed on the Gaz Transport membrane system (GT No 96 E-2), positioned in a double-hull configuration which is extended above the deck to form a trunk.

Gas is maintained at a temperature of -163°C with a maximum boil-off rate of less than 0.15% fully loaded cargo volume. Primary/secondary barriers of 36% nickel-steel (Invar) alloy are fitted in the cargo tanks, with plywood boxes filled with expanded pearlite forming primary/secondary insulation. Underdeck passageways in the trunk deck space provide fore and aft access, and a duct keel in the double bottom serves as a pipe and cable passage.

The cargo handling systems are designed to load/discharge cargo within 12hours, using two sets of 1700m³/h pumps and one stripping/spray pump in each tank, forming a complete assembly within a 'tripod mast' construction with Saab radar beam-type level gauges, and all fittings and pipes. Vapour handling equipment such as two high-duty compressors, two low-duty compressors, one main and one forcing vaporiser, and two boil-off/warm-up heaters, are arranged in the cargo machinery room.

The main propulsion unit is a Kawasaki UA-360 cross-compound steam turbine, developing 36,000shp at 88rev/min (behind the gearbox). The unit has high- and low-pressure turbines, double-reduction gearing, main condenser, and astern turbine. Two dual-fuel boilers supply steam for the main turbine, steam auxiliaries, and turbo-generators. Two of the latter are installed for electrical power together with one diesel-powered set. Each develops a similar output of 3450kW. Current is transmitted to three switchboards (main, cargo, and emergency) located in separate rooms. An integrated automation system is fitted, and control and monitoring is carried out from the cargo and engine control rooms.

Accommodation and navigation spaces are arranged right aft, with the latter designed for optimum operational safety around a modular workstation, fitted for one-man operation, and meeting all design and layout requirements of the BV notation +SYS-NEQ-1.

TECHNICAL PARTICULARS

Length, oa	298.00m
Length, bp	268.80m
Breadth, moulded	43.40m
Depth, moulded	
to main deck	26.00m
to trunk deck	32.75m
Width of double skin	
side	2.21m
bottom	3.20m
Gross	94,822gt
Deadweight	
design	72,367dwt
scantling	79,364dwt
Draught	
design	11.42m
scantling	12.12m
Speed, service (90% MCR: 21% sea margin)	19.50 knots
Cargo capacity	
liquid volume	140,627m³
Bunkers	
heavy fuel	6004m³
diesel oil	502m³
Water ballast	53,108m³
Fuel consumption	
main engine only	165.60tonnes/day
Classification	Bureau Veritas, I + Hull, + MACH, Liquefied Natural Gas Carrier, Ship Type 2G, (membrane tank, 0.25bar, -163°C, 500kg/m³), unrestricted navigation, + VeriSTAR-HULL, AUT-IMS, AUT-PORT, +SYS-NEQ-1, In Water Survey, MON-SHAFT
Percentage of high-tensile steel used in construction	Nil
Steam turbine	
Design	Cross-compound impulse turbine
Manufacturer	Kawasaki Heavy Industries
Model	UA-360
Number	1
Output	MCR: 36,000shp/88rev/min NCR: 32,400shp/85rev/min
Propeller	
Material	Cunial
Manufacturer	Lips
Number	1
Pitch	Fixed
Diameter	8500mm
Speed	88rev/min (MCR)
Steam-turbine driven alternators	
Number	2
Turbine make	Mitsubishi Heavy Industries
Type	Multi-stage
Alternator make	Hyundai Heavy Industries
Output	2 x 3450kW/1800rev/min
Diesel-driven alternator	
Number	1
Engine make	Ssangyong Heavy Industries
Alternator make	Hyundai Heavy Industries
Output	1 x 3450kW/720rev/min
Boilers	
Number	2 plus 1 low-pressure steam generator
Type	2 x vertical two-drum 1 x horizontal tubular
Makers	Mitsubishi Heavy Industries and Donghwa Entec
Output	2 x 56tonnes/h; 1 x 6.5tonnes/h
Hose-handling cranes	
Number	2
Make/type	Hydralift/electro-hydraulic
Capacity	2 x 12tonnes
Mooring equipment	
Number	2 x mooring winch/windlass, 7 x mooring winch
Make	Kocks
Type	High-pressure hydraulic
Cargo tanks	
Number	4
Product range	LNG
Coated tanks	No
Stainless steel	No
Cargo pumps	
Number	8
Type	Submerged electrical
Make	Ebara International
Capacity	8 x 1700m³/h
Cargo control system	
Type	Integrated automation system
Make	Honeywell Korea
Ballast pumps	
Make	Shinko
Type	Electric vertical centrifugal
Complement	
Officers	21
Crew	16
Repair/Suez crew	6
Bow thruster	
Make	Brunvoll
Number	1
Output	1 x 1600kW
Bridge control system	
Make	STN Atlas
One man operation	Yes
Fire detection systems	
Make	Consilium
Type	25 heat detectors; 6 flame detectors; 235 smoke detectors
Fire extinguishing systems	
Cargo spaces	Dry powder, water spray, nitrogen
Make	NK Fire Protection
Engineroom	High-expansion foam
Make	Kashiwa
Waste disposal plant	
Incinerator	
Make	Hyundai-Atlas
Model	Maxi T150 SL W/S
Waste compactor	
Make	Metos Marine
Model	Uson UP-10
Sewage plant	
Make	Jong-Hap
Model	AEROB-18
Contract date	31 March 2000
Launch/float-out date	3 November 2001
Delivery date	30 September 2002

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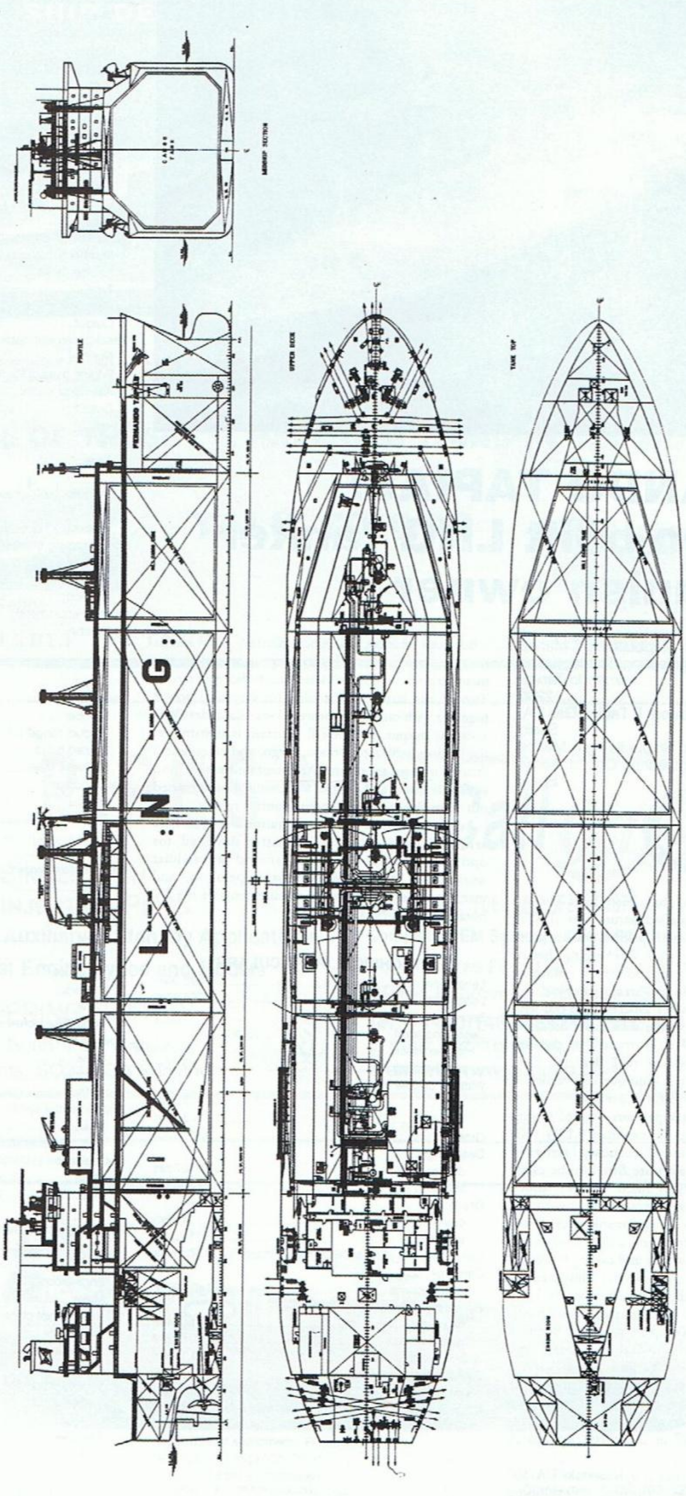
FERNANDO TAPIAS



GDF Suez Point Fortin: 154,900m^3 type LNG carrier from Japan

Shipbuilder: **Koyo Dockyard co., Ltd. Of Imabari Group**
Vessels name: ***GDF Suez Point Fortin***
Hull No: **2263**
Owner/operator: **Los Halillos Shippping co., SA**
Country: **Panama**
Model test establishment used: **Shipbuilding research centre of Japan**
Flag: **Panama**
IMO number: **9375721**
Total number of sister ships already completed (excluding ships presented): **2**
Total number of sister ships still on order: **0**

IMABARI has opened up further avenues for the group to expand into with the delivery of *GDF Suez Point Fortin*. The vessel was delivered to its owner GDF Suez on 16 February. The vessel is owned by a consortium led by Mitsui OSK Lines and will be operated by Los Halillos Shipping.

GDF Suez Point Fortin's main feature is that its No 1 tank is of a horizontally trapezoid shape, making it the first of its kind, in order to use maximum tank capacity despite the compact hull to ensure longitudinal hull structure. It is one of only three vessels with this type of tank capacity.

The hull structure of the vessel was designed and developed under Lloyd's Register's (LR) notation ShipRight (SDA, FDAplus, CM). SDA and FDAplus analysis were carried out in close cooperation with LR London. *GDF Suez Point Fortin* has been designed with a fatigue life set at 40 years.

Reinforced Polyurethane foam (R-PUF) has been used as thermal insulation for the cargo tanks and cargo piping. Formerly, Hydro-Chloro-Fluoro-Carbon (HCFC) was employed as a gas in micro bubbles of R-PUF. In comparison the HCFC, ODP and GWP has less CO_2 than the old method. Imabari has used a new material onboard *GDF Suez Point Fortin* that has been developed from a Japanese manufacturer that still uses the micro bubble technology with CO_2 that still keeps the same thermal conductivity as the previous material.

GDF Suez Point Fortin is 289.93m in length overall, 44.70m wide and has a 26m depth with a design draught of 11.73m and a deadweight of 72,354dwt. It is powered by a Kawasaki UA – 400 type cross compound impulse steam turbine with double reduction gear that can run on either heavy fuel oil (HFO) or liquefied natural gas (LNG) and is capable of 19.5knots at 80.4MCR.

TECHNICAL PARTICULARS

Length oa: 289.93m
Length bp: 276.00m
Breadth moulded: 44.70m
Depth moulded
- To main deck: 26.00m
- To upper deck: 26.00m
- To other decks: 33.12m (trunk deck)

Width of double skin:
- Side: 2.51m
- Bottom: 3.20m

Draught:
- Scantling: 12.60m
- Design: 11.73m

Gross: 101,129gt
Deadweight:
- Design: 72,354dwt
- Scantling: 85,547dwt

Speed, service: 19.5knots (80.4%MCR output)
Cargo capacity:
- Liquid volume: 154,913m^3

Bunkers:
- Heavy oil: 6460m^3
- Diesel oil: 700m^3

Water ballast: 53,690m^3
Daily fuel consumption: 163.4tonnes/day
Classification society and notations: LR +100A1, Liquified Gas Tanker, Ship Type 2G, Methane(LNG) in membrane tanks, Maximum vapour pressure 0.25bar, Minimum temperature -163°C, ShipRight(SDA,FDA plus, CM), *IWS, L1, +LMC, UMS, NAV1, IBS, ICC

Main engines
- Design: Kawasaki Heavy Industries Ltd.
- Model: Kawasaki UA – 400 type cross compound impulse steam turbine with double reduction gear
- Manufacturer: Kawasaki Heavy Industries Ltd.
- Number: 1 set
- Type of fuel: HFO and/or LNG
- Output of each engine: MCR 29,420kW x 81rpm NCR 26,480kW x 78.2rpm

Gearboxes
Make: Kawasaki Heavy Industries Ltd. (Reduction gear is included in main turbine set.)
Model: UA420/80 – S (tandem articulated, double reduction gear)

Propeller
- Material: Ni-Al-Bronze
- Designer/manufacturer: Mitsubishi Heavy Industries Ltd.
- Number: 1 set
- Fixed/Controllable pitch: Fixed type

Diesel-driven alternators
- Number: 1 set
- Engine make/type: Yanmar co., Ltd./ 4 – cycle diesel engine
- Type of fuel: Diesel oil or Marine gas oil
- Output/speed of each set: 3604kW/720rpm
- Alternator make/type: Nishishiba electric co., Ltd/ Totally enclosed, brushless
- Output/speed of each set: 3250kW/720rpm

Steam turbine-driven alternators
Turbine make/type: Shinko Industries Ltd/ Super heated stem driven, multi stage condensing
Output/speed of each set: 3250kW/8145kW
Alternator make/type: Nishishiba electlic co. Ltd/ Totally enclosed brushless
Output/speed of each set: 3250kW x 1800rpm

Boilers
- Number: 2 sets
- Type: Kawasaki UME 66/53
- Make: Kawasaki Heavy Industries Ltd
- Output each boiler: Max evaporation 66,000kg/h

Other cranes
- Number: 2 sets
- Make: Sekigahara Seisakusho Ltd
- Type: Electro-hydraulic high-pressure
- Tasks: Hose handling
- Performance: Hoisting load 5tonnes/ working radius 22m~4.6m

Mooring equipment
- Number: Windlass 2 sets/ Mooring winch 8 sets
- Make: Fukushima Ltd
- Type: Electro-hydraulic Low-pressure

Special lifesaving equipment
- Number of each and capacity: 2 sets x 50 persons
- Make: Ernst Hatecke
- Type: Enclosed

Cargo tanks
- Number: 4 tanks (membrane type)
- Grades of cargo carried: Liquefied natural gas
- Product range: Max. specific gravity 0.5 at -163°C
- Stainless steel – structure/piping: Stainless steel (304L)

Cargo pumps
- Number: 8 sets
- Type: Vertical submerged
- Make: Shinko Industries Ltd
- Stainless steel: Ball bearing
- Capacity: 1700m^3 x 160m

Cargo control system
- Make: Yokogawa Electric Corp.
- Type: Integrated automation system

Ballast control system
- Make: Yokogawa Electric Corp.
- Type: Integrated automation system

Complement
- Officers: 13
- Crew: 16
- Suez/Repair crew: 6

Bow thrusters
- Make: Kawasaki Heavy Industries Ltd
- Number: 1 set
- Output: 2200kW

Bridge control system
- Make: Japan Radio co., Ltd.
- Type: Integrated navigation system
- One-man operation: Yes

Fire detection system
- Make: Nippon Hakuyo
- Type: FF – 1515 – 4

Fire extinguishing system
- On deck: Dry chemical powder fire extinguishing system
- Make/Type: Unitor
- Engine room: High expansion foam fir extinguishing system
- Make/Type: Kashiwa-teck
- Cabins: Seawater
- Public spaces: Seawater

Radars
- Number: 3 sets (X-Band:2 S-Band:1)
- Make: Japan Radio Co., Ltd
- Model: JMA – 9122 – 9XA, NKE – 1125 – 9, JMA – 9132 – SA

Waste disposal plant
- Incinerator: Sunflame co., Ltd
- Model: OSV-600SDAI
- Waste compactor: Electrolux professional AB
- Model: 41 80 10 (TT100)
- Sewage plant: Taiko Kikai Industries co., Ltd

Contract date: 21 November 2005
Launch/float-out date: 12 August 2008
Delivery date: 16 February 2010

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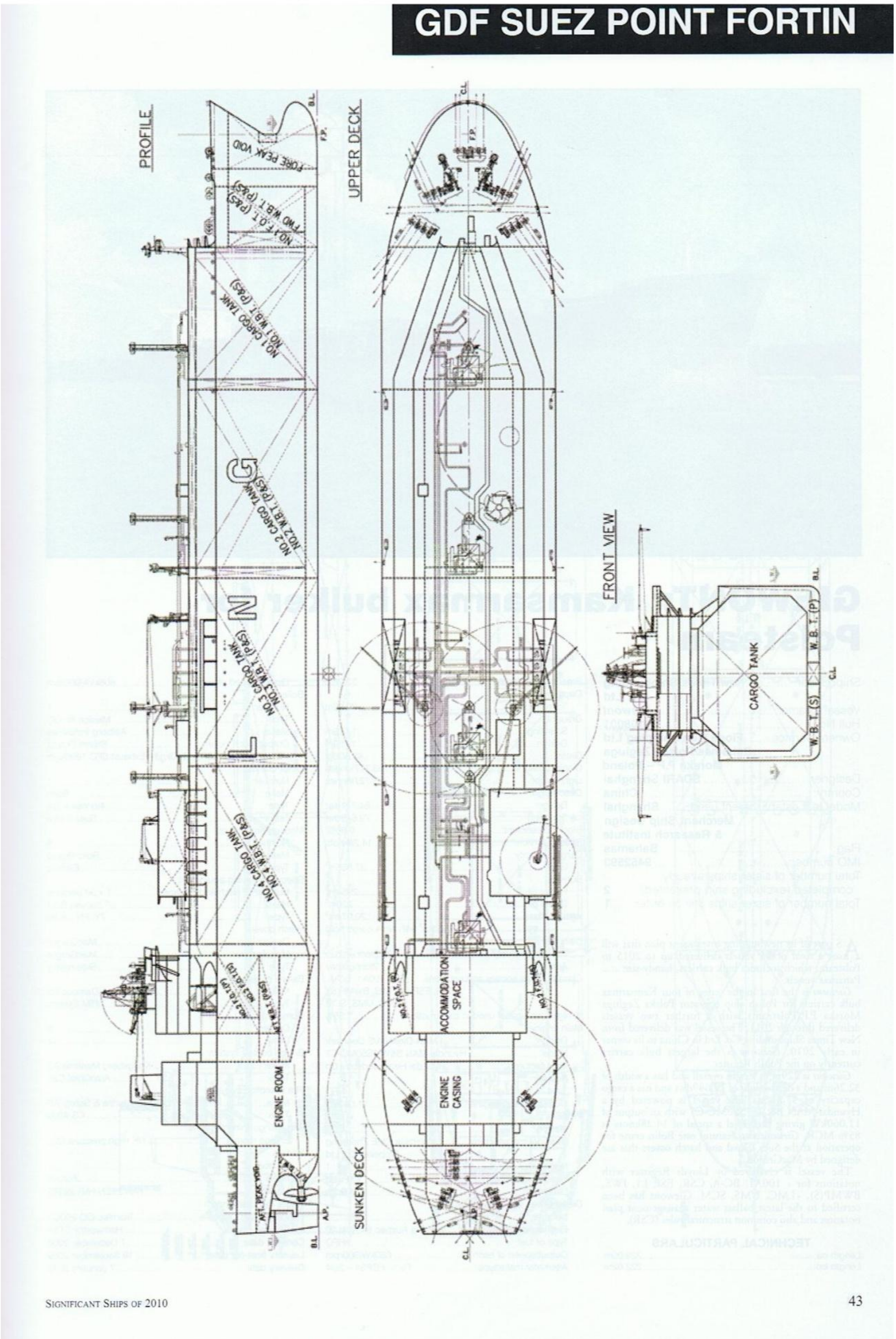

GDF SUEZ POINT FORTIN
PROFILE
UPPER DECK
FRONT VIEW
SUNKEN DECK
FORE PEAK VOID
NO.1 CARGO TANK
NO.2 CARGO TANK
NO.3 CARGO TANK
NO.4 CARGO TANK
CARGO TANK
ENGINE ROOM
ACCOMMODATION SPACE
ENGINE CASING
SIGNIFICANT SHIPS OF 2010
43

HANJIN MUSCAT: satisfying Korea's fuel requirements

Shipbuilder: ....**Hanjin Heavy Industries Co Ltd, Korea**
Vessel's name: ....***Hanjin Muscat***
Hull number **N-054**
Owner/operator: ..**Hanjin Shipping Co Ltd, Korea**
Designer: ....**Hanjin Heavy Industries Co Ltd, Korea**
Flag: ....**Panama**
Total number of sister ships already completed: ....**-**
Total number of sister ships still on order **2**

SUCH is the demand for liquefied natural gas (LNG) to satisfy the domestic demands of the Korean Gas Corp (KOGAS), that three out of the four major Korean shipbuilders who are today serious players in the world market for this type of ship, are currently involved with an extensive KOGAS newbuilding programme which will run for a number of years yet. Present contracts call for vessels of around 138,000m³ capacity, suitable for operation between Gulf ports and Korean terminals, but, as the three reports included in this review show, within these parameters, each builder/owner combination has left its own mark.

Hanjin Muscat is a larger version of *Hanjin Pyeong Taek* (*Significant Shops of 1995*), and uses the same Gaz Transport No 96-2 membrane cargo containment system, featuring a four-tank format with the tanks contained in a complete double-hull structure which includes ship's sides and bottom, transverse bulkheads, and upper deck trunk. The side and bottom spaces are sloped at top and bottom, and are divided by the duct keel to form P&S integral ballast tanks. This double structure not only protects the tanks from external damage, but insulates the outer hull against critical steelwork fractures caused by the low temperature (-163°C) and atmospheric pressure at which cargoes are carried. A considerable amount of structural analytical work was carried out for these new larger membrane designs by the Korean Register of Shipping.

Tank insulation is formed by primary and secondary membranes of 0.70mm Invar sheets (a product containing 36% nickel steel) in conjunction with expanded Perlite beads contained in plywood boxes, which are attached to the inner hull by stud bolts. This combination is able to sustain the liquid pressure and static and dynamic loads, and to limit the daily boil-off rate to 0.15% of cargo volume. A tripod mast is built within each tank, to which the filling line and two Ebara 1700m³/h electric, submersible pumps are attached. These are used for unloading purposes only, loading being carried out by shore pumps, with vapour produced in the operation returned to shore by the ship's two 32,000m³/h compressors.

The performances of the equipment mentioned are all substantially higher than those fitted on *Hanjin Pyeong Taek*, reflecting the increased capacity of the newer vessel. This continues with other items supplied, such as a 26,000kg/h main vaporiser and 7600kg/h forcing vaporiser, 13,800Nm³/h inert-gas generator, two 140Nm³/h nitrogen generators, and two 1250m³/h vacuum pumps. Four 50m³/h stripping/spray pumps, a 550m³/h emergency cargo pump and two sets of 20,000kg/h boil-off/warm-up heaters are also fitted.

Two personnel can operate and monitor the entire ship from a centralised administration and control centre on accommodation deck D, using two separate Yamatake-Honeywell TDC 3000 Basic automation systems. These serve cargo/ballast operations and machinery/electric generation, respectively, with Whessoe tank level gauges, a Foxboro custody transfer system, and a Mitsubishi total boil-off gas control system. Mitsubishi also supplied a loading calculator to assist cargo operations, together with an auto combustion control, burner management and main turbine controls. Other equipment includes an AMCO turbo feed pump control system and Kvaerner ship performance monitors for the machinery intallation.

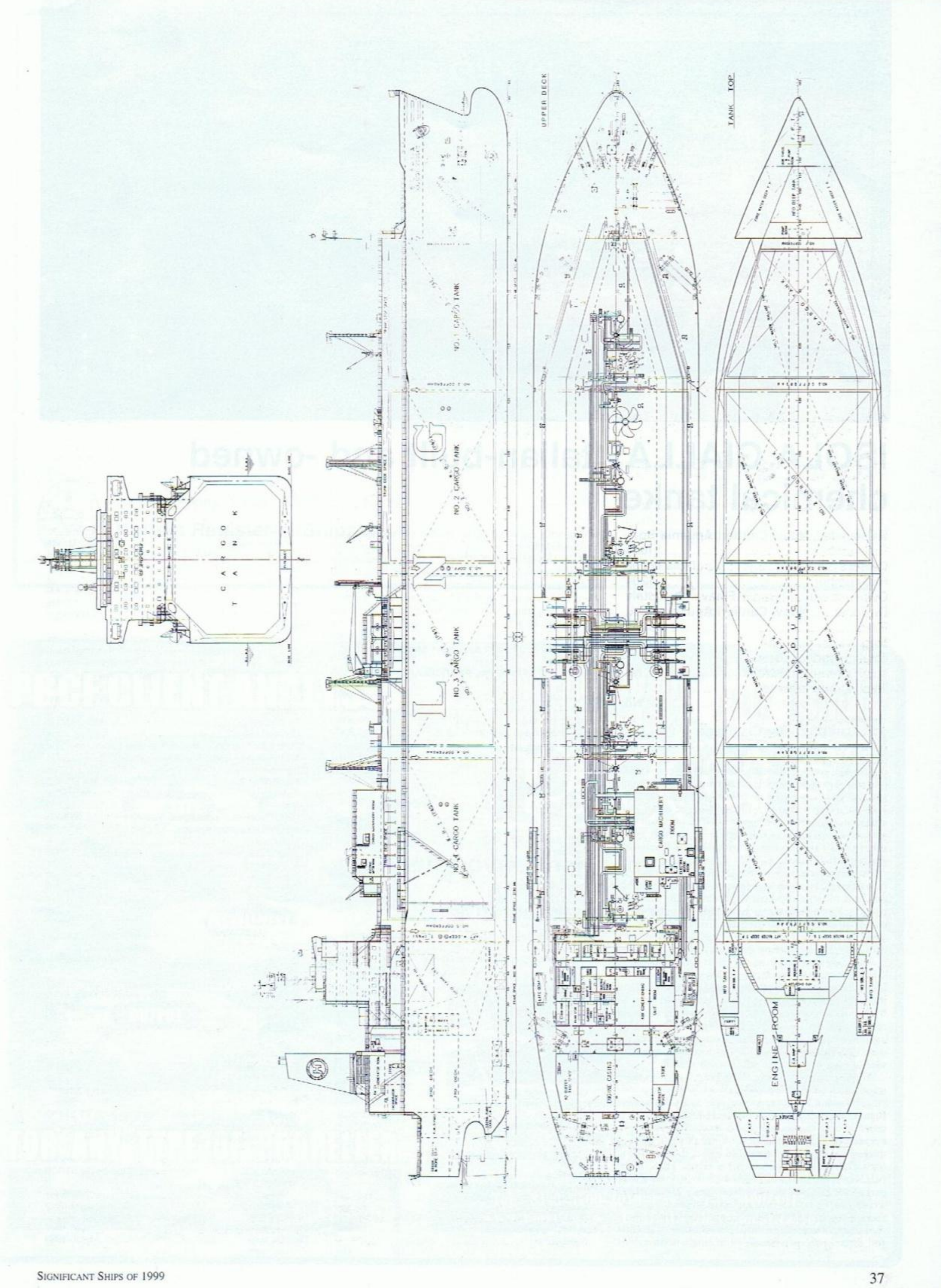
A Mitsubishi MS 40-2 cross-compound steam turbine developing 38,900shp drives a FP propeller through a double-reduction gearbox for a service speed of 20.3knots, using steam generated from two vertical, two drum watertube boilers, burning oil or boil-off gas, or a combination of both. Two 3450kW turbo-alternators and a similar sized diesel-alternator set satisfy electrical requirements. A water scoop system is provided for cooling the main condenser.

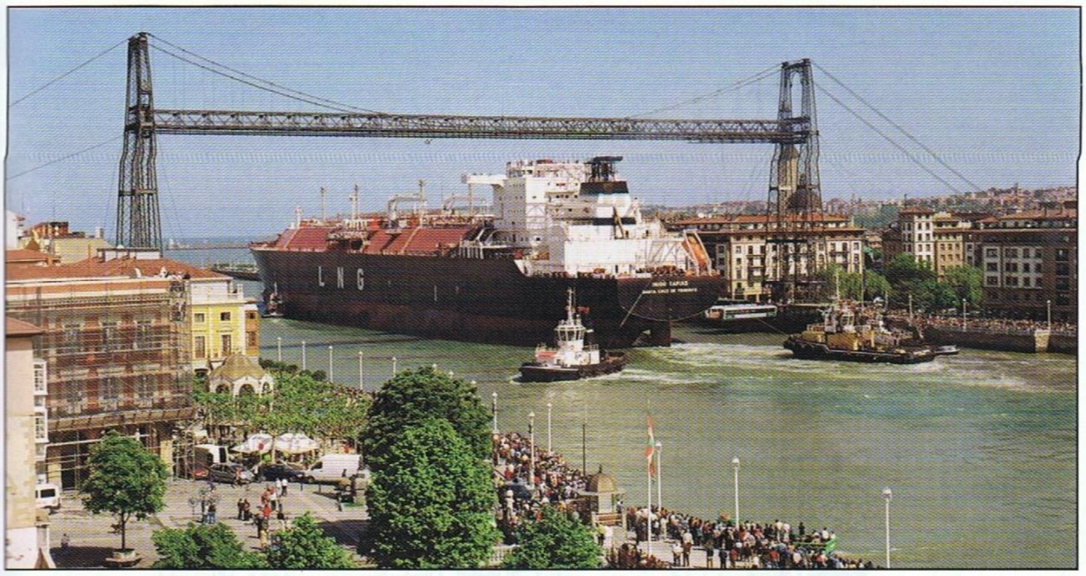
Mitsubishi also supplied one of its Total Navigation Systems, which is integrated with three radars, echosounder, doppler sonar and docking system supplied by Atlas Elektronik. Additional aids include a Tokimec chartplotter and two GPS navigators.

PRINCIPAL PARTICULARS

Length, oa	280.00m
Length, bp	268.50m
Breadth, moulded	43.00m
Depth, moulded	
to main deck	26.20m
to trunk deck	32.55m
Width of double skin	
side	2.20m
bottom	3.00m
Gross	93,765gt
Deadweight	
design	68,524dwt
scantling	75,463dwt
Draught	
design	11.30m
scantling	12.00m
Speed, service with 21% sea margin	20.30knots
Cargo capacity	
liquid volume	138,366m³
Bunkers	
heavy oil	6046m³
diesel oil	235m³
Water ballast	52,488m³
Fuel consumption	
main engine only	201tonnes/day
Classification	Korean Register of Shipping +KRS1-Liquefied Gas Carrier, +KRM1-UMA, 2G3M(R)/0.25bar, -163°C, 0.5SG(LGC), (LWS) *also* Bureau Veritas +I 3/3E, Liquefied Gas Carrier/LNG, Deep Sea, AUT-MS*
Percentage of high-tensile steel used in construction	Nil
Main engine	
Design	Mitsubishi Heavy Industries Ltd
Model	MS 40-2 steam turbine
Manufacturer	Mitsubishi Heavy Industries Ltd
Number	1
Output	38,900shp/83rev/min
Gearbox	
Make	Mitsubishi Heavy Industries Ltd
Type	Double-helical dual-tandem articulated
Number	1
Propeller	
Material	Nickel-aluminium-bronze
Manufacturer	Hyundai Heavy Industries Ltd
Number	1
Pitch	Fixed
Diameter	8500mm
Speed	83rev/min
Steam turbine-driven alternators	
Number	2
Turbine make	Mitsubishi
Alternator make/type	Hyundai/HFJ5 714-44E
Output	2 x 3450kW/1800rev/min
Diesel-driven alternator	
Number	1
Engine make	Hyundai/Wärtsilä
Alternator make	Hyundai
Output	3450kW/720rev/min
Boilers	
Number	2
Type	Two drum (steam and water), water tube, dual fuel
Make	Mitsubishi
Output	2 x 68,000kg/h(max)/59,000kg/h(normal)
Hose-handling cranes	
Number	2
Make/type	Dong Nam/electro-hydraulic
Capacity	2 x 10tonnes/22m
Mooring equipment	
Number	2 x windlass; 9 x mooring winch
Make	Brissonneau et Lotz(BLM)
Type	Electro-hydraulic
Cargo/ballast control systems	
Make	Mitsubishi
Type	MCS-6100A
Complement	
Officers	24
Crew	15
Travelling workers	8
Cargo tanks	
Number	4
Product range	Liquefied natural gas
Coated tanks	Gaz Transport cargo containment system with Invar membrane
Cargo pumps	
Number	8 plus 4 stripping
Type	12EC-24 submerged centrifugal
Make	Ebara
Capacity	8 x 1700m³/h
Bow thruster	
Make	Nakashima/TC-280tonne
Number	1
Fire detection system	
Make	Consilium Marine
Type	CS 300
Fire extinguishing systems	
Cargo area	Dry powder
Make	Fain
Engineroom	Fixed high-pressure CO_2
Radars	
Number	3 (2 x S-band; 1 x X-band)
Make	STN Atlas
Models	Atlas 9600
Satellite navigation system	
Make	JRC
Model	JLR-6800 DGPS
Computers on ship	
Number	8
Make	Mitsubishi
Waste disposal plant	
Incinerator	
Make	Kangrim
Model	KIN-50 SOA
Waste compactor	
Make	Metos
Model	UP-10
Sewage plant	
Make	Evac
Model	AHM 0122
Contract date	24 December 1996
Launch/float-out date	30 April 1998
Delivery date	30 July 1999

HANJIN MUSCAT





INIGO TAPIAS: satisfying Spain's increasing LNG requirements

Shipbuilder:	IZAR (Astillero Sestao, Bilbao), Spain
Vessel's name:	*Inigo Tapias*
Hull number:	319
Owner/operator:	Naviera F Tapias SA, Spain
Designer:	IZAR
Model test establishment used:	MARIN, The Netherlands
Flag:	Spain
Total number of sister ships already completed:	Nil
Total number of sister ships still on order:	4 (*contract shared with IZAR (Puerto Real)*)

A PROJECTED 50% increase in Spain's consumption of gas has initiated this contract, for vessels equalling in capacity the largest yet built, which re-introduces construction of LNG tankers into the country's shipyards after a lapse of more than 30 years. Although designed to load/unload at all the world's current terminals, *Inigo Tapias* will normally be employed transporting gas from Trinidad and Tobago to Spain, with hull form, propulsion and power systems, developed for maximum energy economy on what is virtually a liner service. To this end, Schneekluth wake-equalising ducts have been fitted at the stern, in front of a five-bladed FP propeller, in an arrangement claimed to reduce power requirements by 1.50%.

The proven reliability of steam turbine propulsion, along with the ability of that system to burn boil-off gases in the boilers, is demonstrated by the fitting of a conventional (for this type of vessel) machinery installation centred upon a Kawasaki package, comprising a main propulsion turbine developing 28,000kW at 83rev/min, two 3150kW turbo-generators, main feed pump turbines, and reversible double-reduction gearing, all assembled at the shipbuilder's Ferrol works. A 3150kW diesel-alternator set is installed and an 1800kW electric bow thruster is fitted. The two Mitsubishi boilers each have an output of 65,000kg/h and are arranged to burn heavy oil, boil-off gas, or a combination of both.

Inigo Tapias is a single-deck vessel with sunken aft deck, and all accommodation and navigating spaces aft, built with principal dimensions which differ slightly from those of other, similar sized vessels (see *Significant Ships of 2002*), resulting in a slightly longer, narrower hull form. This is in order to meet a beam restriction on the building berth at the Sestao yard. The machinery casings and accommodation are not integrated, in order to minimise vibration transmission, and the design satisfies the requirements of a Type 2G tanker suitable for the carriage of liquid natural gas of SG 0.46 at -163°C. Maximum boil off rate is 0.15% cargo volume.

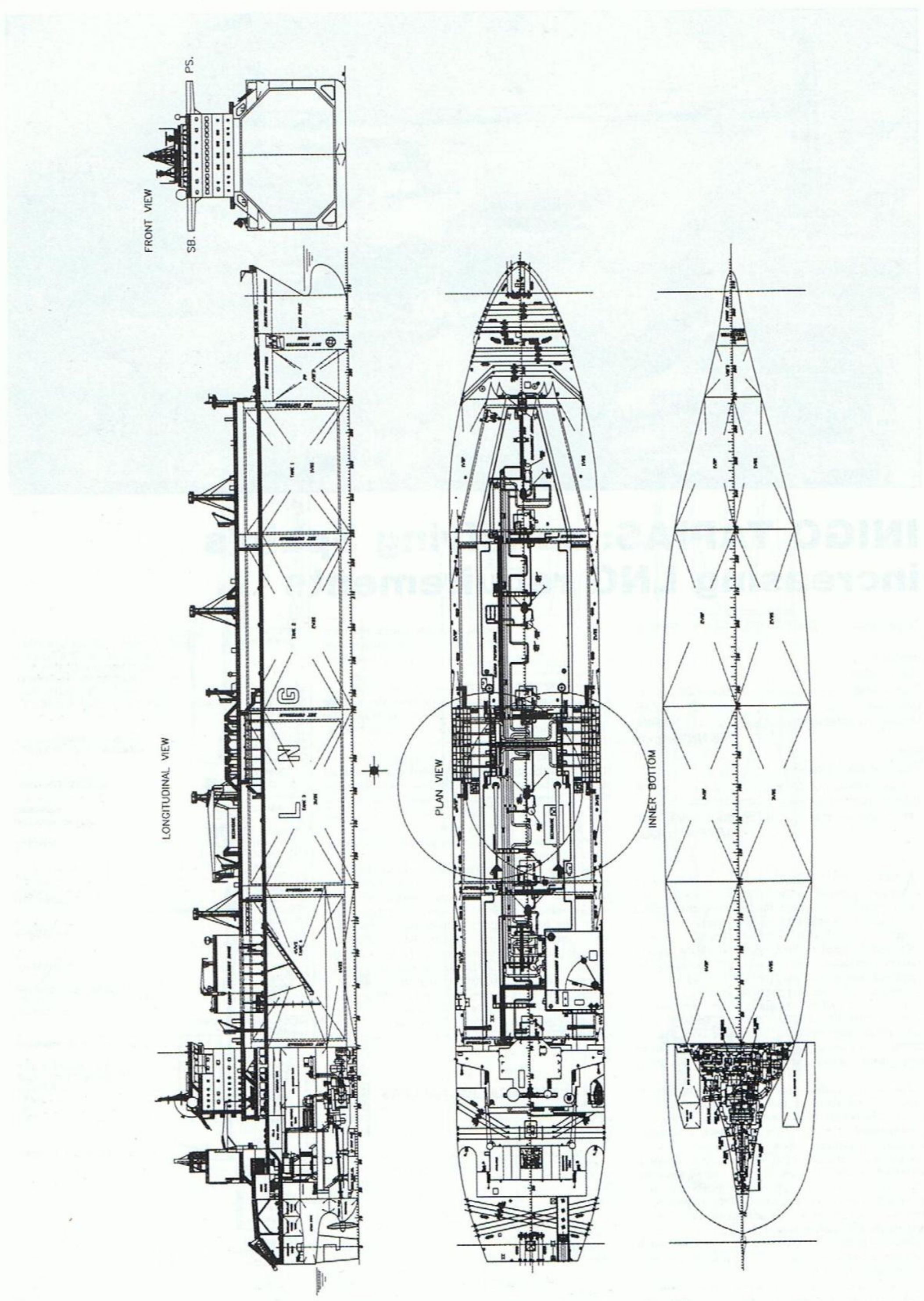
The four cargo tanks, which extend above the deck to form a trunk, are built within a complete double-hull structure with integral spaces utilised as water ballast tanks, in accordance with a Gaz Transport/Technigas NO96-E2 membrane technique, using Invar stainless steel sheet with a 36% nickel content for the primary and secondary barriers. Between these, and the secondary barrier/shell, perlite granules in plywood boxes are inserted.

The cargo handling systems can discharge the vessel in 12 hours using two 1700m³/h electric submerged pumps, and one 50m³/h stripping pump, in each tank, supplemented by a 530m³/h emergency cargo pump. Each tank has a liquid manifold; vapour manifold; stripping manifold and cooling manifold, with the liquid pipelines running to the bottom of the tanks and the vapour line connected at the top. Included in the cargo systems are 2 x 30,000m³/h high-duty, and 2 x 8000m³/h low-duty, compressors; two 23,000kg/h main heaters and 1 x 20,000kg/h LNG vaporiser. The forcing vaporiser capacity is 6950kg/h; the inert gas generator is rated at 15,000Nm³/h and the two nitrogen generators each produce 120Nm³/h.

TECHNICAL PARTICULARS

Length, oa	284.40m
Length, bp	271.00m
Breadth, moulded	42.50m
Depth, moulded	
to main deck	25.40m
to trunk deck	32.20m
Width of double skin	-
Gross	93,450gt
Draught	
design	11.40m
scantling	12.30m
Deadweight	
design	68,200dwt
Speed	
service	19.50knots
ballast trial, at 90% MCR	21.00knots
Cargo capacity	
liquid volume (100% full)	138,000m³
liquid volume (98.5% full)	135,930m³
Bunker capacity	-
Water ballast	-
Classification	Lloyd's Register of Shipping, +100A1, Liquefied Gas Tanker, Ship Type 2G, Methane in Membrane Tanks, Max. Pressure 0.25bar, Min Temperature -163°C, +LMC, UMS, PORT, SDA, IWS, SCM, LI, FDA, NAV1, IBS, ES, TCM, CCS
Main engine	
Steam turbine	
Design	Cross-compound impulse
Manufacturer	Kawasaki Heavy Industries
Model	-
Number	1
Output	28,000kW/83rev/min
Gearbox	
Make	Kawasaki
Type	Double-reduction
Propeller	
Manufacturer	Navalips
Number of blades	5
Number	1
Pitch	Fixed
Diameter	8700mm
Speed	83rev/min
Steam-turbine-driven alternators	
Number	2
Output	2 x 3150kW
Diesel-driven alternator	
Number	1
Output	1 x 3150kW
Boilers	
Number	2 x water tube, dual fuel
Make	Mitsubishi Heavy Industries
Output	2 x 65,000kg/h
Hose-handling cranes	
Number	2
Duty	2 x 12tonnes swl
Cargo tanks	
Number	4 x membrane type
Design	Gaz Transport/Technigas
Type	NO96-E2
Product range	LNG
Coated tanks	No
Stainless steel	No
Cargo pumps	
Number	8
Type	Electric submerged
Make	-
Capacity	8 x 1700m³/h 4 x 450m³/h, stripping
Ballast pumps	
Make	-
Capacity	3 x 2500m³/h; 1 x 350m³/h ejector; 1 x 200m³/h ejector
Complement	-
Stern appendage	Schneekluth wake-equalising ducts
Bow thruster	
Make	-
Number	1
Output	1 x 1800kW
Contract date	-
Launch/float-out date	-
Delivery date	1 August 2003

INIGO TAPIAS



MAERSK QATAR: 145,600m³ LNG carrier for RasGas project

Shipbuilder:	Samsung Heavy Industries Co Ltd, Korea
Vessel's name:	*Maersk Qatar*
Hull number:	1562
IMO number:	9321732
Owner/operator:	AP Möller-Maersk Group, Denmark
Designer:	Samsung Heavy Industries Co Ltd, Korea
Model test establishment used:	Samsung Ship Model Basin, Korea
Flag:	Danish International Shipping Register
Total number of sister ships already completed:	11 (different owners)
Total number of sister ships still on order:	7

THE diversity of the Möller-Maersk Group is difficult to measure, but some idea of its extent is demonstrated in this edition of *Significant Ships* where four of this leading owner's newbuildings are featured, including the largest container ship in the world, together with this vessel - one of the largest LNG tankers in service, alongside two 'baby-size' box ships. Equally, Samsung can point to its own varied output, and a rise to becoming a world leader in LNG carrier design in just seven years since delivering the first ship of this type.

Maersk Qatar is a development of Samsung's standard design, which conforms closely to what has become an industry 'norm', offering around 140,000m³ capacity. In fact, *Maersk Qatar*, with some slight 'tweaking' of length and beam over earlier ships, will load nearly 6000m³ more than that, in its operations on the RasGas project.

The design features a double-skin hull with side spaces joined with top and bottom wing tanks arranged to carry water ballast. These enclose four individual cargo tanks, separated by cofferdams, and constructed in accordance with the Gaz Transport and Technigas (GTT) Mk 3 containment system for the carriage of LNG cargoes at cryogenic temperatures (-163°C).

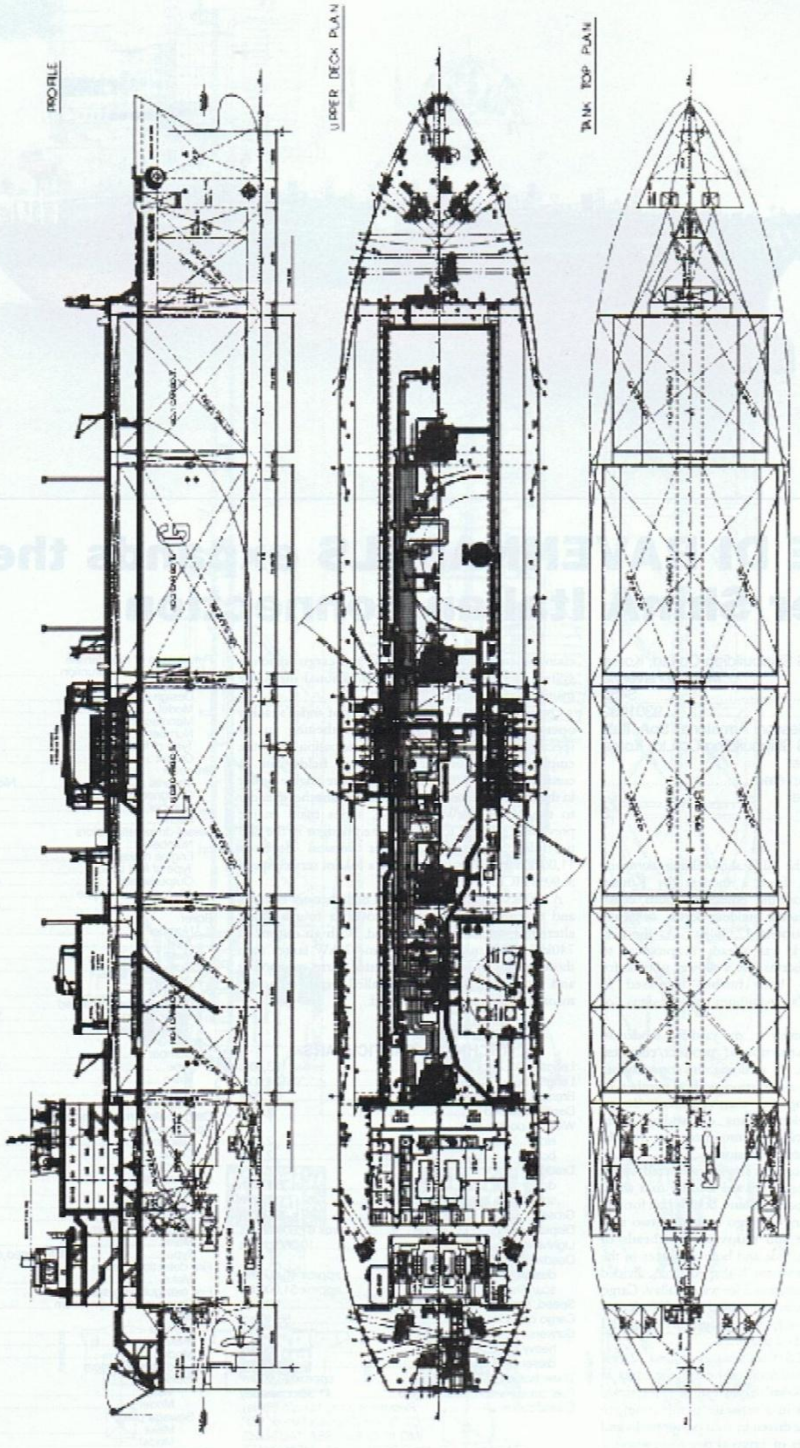
These tanks extend above the upper deck and are enclosed in a trunk which also provides access passages forward and aft. The containment system, which is designed to limit the daily boil-off rate to 0.15% cargo volume, is complemented by three Ebara 1700m³/h electric submersible pumps, capable of discharging cargo in 12 hours, following pre-cooling by LNG spray.

Despite the fact that its does hold contracts for both low-speed diesel and diesel-electric-powered LNG tankers, Samsung has retained the 'traditional' steam turbine propulsion system for *Maersk Qatar*. This makes use of a Kawasaki UA400, cross-compound, direct-reversible, impulse-type unit developing 29,050kW and driving an FP propeller at 90rev/min for a service speed of 20.6knots. A double-reduction, articulated gearbox is integrated with the main turbine. Two 3450kW steam turbine-driven alternators are installed, and there is also a diesel set with the same output. Steam is produced in two watertube boilers arranged to burn either oil fuel or boil-off gases.

TECHNICAL PARTICULARS

Length, oa	approx 283.00m
Length, bp	approx 270.00m
Breadth, moulded	43.40m
Depth, moulded	
to main (upper) deck	26.00m
to trunk deck	32.80m
Width of double skin	
side	2.53m
bottom	3.10m
Draught	
design	11.40m
summer	12.00m
scantling	12.40m
Gross	96,508gt
Displacement (design)	102,000tonnes
Lightweight	30,740tonnes
Deadweight	
design	71,450dwt
summer	77,450dwt
scantling	81,450dwt
Block coefficient (design)	0.745
Speed, service, 85% MCR, design draught	20.60knots
Cargo capacity	145,600m³
Bunkers	
heavy oil	7490m³
diesel oil	440m³
Water ballast	57,000m³
Fuel consumption, main engine	171.7/tonnes/day
Classification	American Bureau of Shipping, +A1, E, Liquefied Gas Carrier, Ship Type 2G (Membrane Tank, max pressure 25kPaG, min temp -163°C, SG 500kg/m³), SH, SH-DLA, SHCM, SFA (40) +AMS, +ACCU, UWILD, PMS including CMS, NIBS, HM3+R with Descriptive Note: 'Slam Warning, Hull Girder Stress, Full VDM'
Percentage of high-tensile steel used in construction	approx 13%
Main engine	
Design	direct reversible steam turbine
Model	UA-400
Manufacturer	Kawasaki Heavy Industries
Number	1
Output	29,050kW
Main boilers	
Number	2
Type	Water tube
Manufacturer	Kawasaki Heavy Industries
Output	2 x 66tonnes/h
Gearbox	
Make	Kawasaki Heavy Industries
Type	double-reduction, articulated
Number	1
Output speed	90rev/min
Propeller	
Material	Nickel-aluminium-bronze
Designer/manufacturer	Samsung/Nakashima
Number	1
Pitch	Fixed
Diameter	8600mm
Speed	90rev/min
Steam-turbine driven alternators	
Number	2
Make/type	Mitsubishi/AT42CT-B
Output/speed	2 x 3450kW/1800rev/min
Diesel-driven alternator	
Number	1
Engine make/type	STX-MAN/8L32/40H
Type of fuel	MDO
Output/speed	3664kW/720rev/min
Alternator type	Nishishiba
Output/speed	3450kW/720rev/min
Cargo tanks	
Number	4 x IMO Type 2 membrane (GTT Mk 3 system)
Cargo pumps	
Number	8
Type	submerged electric
Make	Ebara
Capacity	8 x 1700m³/h
Custody transfer system	Saab Rosemount
Integrated automation system	Kongsberg Maritime
Complement	41 plus 6 Suez crew
Bow thruster	
Make	Kawasaki Heavy Industries
Number	1
Output	2500kW
Bridge control system	
Make	Kawasaki
Type	part of main turbine installation
Fire detection system	
Make	Consilium Marine
Type	CS 3000
Fire extinguishing system	
Engineroom	High-pressure CO_2
Make	Unitor
Radars	
Number	2
Make	Kongsberg
Model	DB 1028
Integrated bridge system	
Make	Kongsberg
Model	SEAMAP 1021
Contract date	29 October 2003
Launch/float-out date	9 July 2005
Delivery date	15 April 2006

MAERSK QATAR



SERI BALHAF: Mitsubishi's first dual-fuel diesel-electric LNG tanker

Shipbuilder: **Mitsubishi Heavy Industries, Ltd.Nagasaki Shipyard & Machinery Works, Japan**
Vessel's name: ***Seri Balhaf***
Hull No: **2223**
Owner/Operator: **MISC Berhad**
Country: **Malaysia**
Designer: **Mitsubishi Heavy Industries, Ltd.**
Country: **Japan**
Model test establishment used: **MHI Nagasaki R&D Center, Japan**
Flag: **Malaysia**
IMO number: **9331660**
Total number of sister ships already completed (excluding ship presented): **Nil**
Total number of sister ships still on order: **1**

Seri Balhaf is the largest Japanese-built LNG Tanker to feature the Gaz Transport & Technigaz membrane cargo containment system (GTT No.96E 2F) and electric propulsion motors with a Dual Fuel Engine (DFE) system. This results in improved fuel efficiency for the main propulsion system, supplemented by the high propulsive performance achieved by using a refined hull form developed using CFD (Computational Fluid Dynamics).

The principal dimensions of the membrane tanks were optimised taking into account the requirements of LNG terminals world-wide, with particular attention given to major Japanese, Korean and Taiwanese terminals. Cargo tank dimensions were determined to minimise sloshing dynamic loads.

The water ballast tanks adjacent to No.2 & 3 cargo tanks are divided into two pairs to facilitate safe ballast water exchange by the displacement method whilst remaining within the vessel's designed longitudinal strength parameters. The ballast exchange is automated by Mitsubishi Heavy Industries' ABE (Automatic Ballast Exchange) system.

One fuel gas pump of submerged type is provided in each of No.2 & 3 cargo tanks. Where natural boil-off is inadequate for vessel needs forced boil-off gas is supplied using cargo LNG transferred by fuel gas pump or spray pump from cargo tanks.

The propulsion plant consists of two electric propulsion motors and four Wärtsilä dual fuel engines (3 x 12V50DF plus 1 x 6L50DF). These dual fuel engines can run in MDO mode, burning diesel oil only, and in gas mode, burning mainly gas with diesel oil as a pilot fuel. In the gas mode the engines can use forced boil-off gas supplied as described above or natural boil-off gas generated in the cargo tanks. The natural boil-off gas is transferred to the engine room through a low duty gas compressor installed in the cargo machinery room.

The engines are arranged in two separate machinery spaces, each with independent fuel systems, seawater cooling systems, fresh water cooling systems, ventilation systems, and fire detection devices.

Two ABB AMZ 1120MS08 LSF electric propulsion motors drive one propeller through a Renk NDSH-3920 reduction gear. Each electric propulsion motor has independent feeder circuits and is operated individually. A gas combustion unit in the engine casing burns surplus boil-off gas where the amount of natural boil-off gas exceeds vessel requirements.

A Mitsubishi Heavy Industries DCS (Distributed control system) is provided to facilitate monitoring and control of the principal machinery and the equipment in the engine and cargo handling areas from the centralised control room.

Seri Balhaf and her sister ship, *Seri Balqis*, have been chartered to lift Yemen LNG cargoes for 20 years, plus further options.

TECHNICAL PARTICULARS

Length oa: 294.6m
Length bp: 281.6m
Breadth moulded: 46.5 m
Depth moulded to upper deck: 25.8 m
Width of double skin:
- side: 2.36m approx.
- bottom: 3/1m approx.

Draught:
- scantling: 12.40m
- design: 11.15m

Gross: 107,633gt
Deadweight, scantling: 91,201dwt
Speed, service: 19.5knots at 100% MCR
Cargo capacity:
- Liquid volume: 157,720m^3 (100% at -163 degrees C)

Bunkers:
- Diesel oil: 2600m^3

Water ballast: 57,900 m^3
Daily fuel consumption:
- Main engine only: 129tonnes/day

Classification society and notations: Bureau Veritas I, +Hull, +Mach Liquefied Gas Carrier/ LNG, +Unrestricted navigation, +AUT-UMS, +VeriStar-Hull, Mon-Shaft, Inwatersurvey
Main generator engines:
- Design & manufacturer: Wärtsilä
- Model: 12V50DF and 6L50DF
- Number: 3 x 12V50DF + 1 x 6L50DF
- Type of fuel: MDO and Natural Gas
- Output of each engine: 3 x 11,400kW + 1 x 5700kW

Propulsion Electric Motor:
- Design & manufacturer: ABB
- Number & model: 2 x AMZ 1120MS08 LSF

Gearbox:
- Make: Renk
- Number & model: 1 x NDSH-3920
- Output: 24,750kW x 78.0rev/min

Propeller:
- Material: Nickel aluminum bronze
- Designer/Manufacturer: Mitsubishi Heavy Industries, Ltd.
- Fixed/Controllable pitch: 1 x Fixed
- Diameter: 9.0m
- Speed: 78.0rev/min

Exhaust-gas scrubbing equipment:
- Manufacturer: Aalborg Industries K.K.
- Type: ... Mono-pressure, forced circulation, fin tube type

Boiler:
- Number & type: 1 x Cylindrical type
- Make: Aalborg Industries K.K.
- Output, each boiler: 9000kg/h

Mooring equipment
- Number: 2 x mooring winch/windlass, 7 x Mooring winch
- Make: Friedrich Kocks GmbH
- Type: Electro-hydraulic

Special lifesaving equipment:
- Number of each and capacity: 2 x 44 persons
- Make: Hyundai Life boats Co., Ltd.
- Type: FRP enclosed type lifeboat

Cargo tanks:
- Number: 4
- Grades of cargo carried: LNG

Cargo pumps:
- Number: 8
- Type: Electric motor driven centrifugal submerged
- Make: Ebara Corporation
- Capacity (each): 1850m^3/h / 170tonnes/h

Cargo control system:
- Make: Mitsubishi Heavy Industries, Ltd.
- Type: Distributed Control System

Ballast control system:
- Make: Mitsubishi Heavy Industries, Ltd.
- Type: Automatic Ballast Exchange system

Complement:
- Officers: 12
- Crew: 19
- Supernumaries/Spare: 5
- Suez/Repair Crew: 4

Bow thrusters:
- Make: Kawasaki Heavy Industries, Ltd.
- Number & ouput: 1 x 2000kW

Fire detection system:
- Make: Autronica A/S

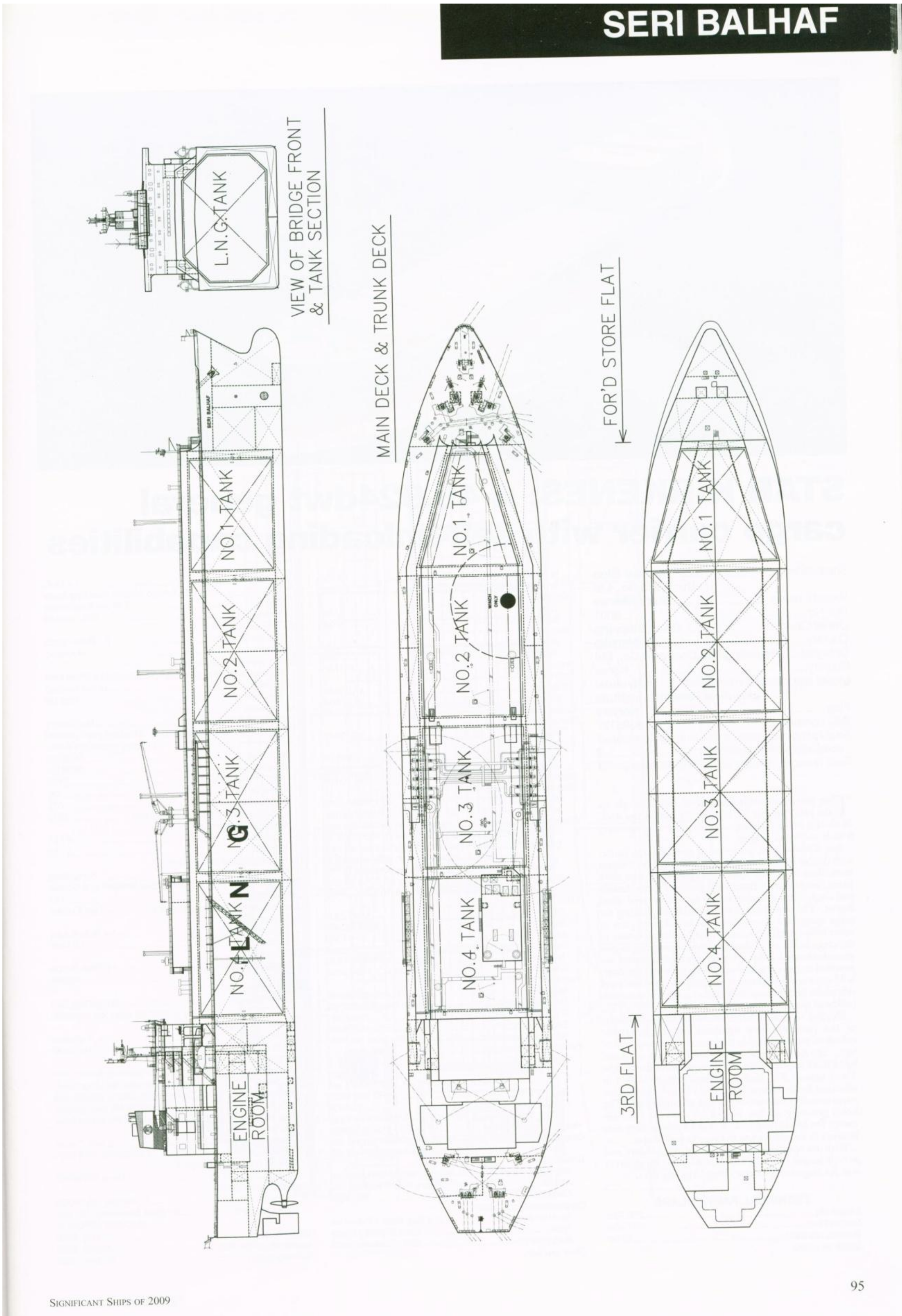
Fire extinguishing systems:
- Cargo holds: Dry powder
- Engine room: CO_2

Radars:
- Number & make: 2 x Japan Radio Co., Ltd.
- Models: 1 x X-band with ARPA, 1 x S-band with ARPA

Integrated bridge:
- Make: Japan Radio Co., Ltd.

Waste disposal plant
- Incinerator: Sunflame Co., Ltd.
- Sewage plant: Taiko Kikai Industries Co., Ltd

Contract date: 23 July 2004
Launch/float-out date: 16 February 2008
Delivery date: 1 January 2009


SERI BALHAF
VIEW OF BRIDGE FRONT & TANK SECTION
L.N.G. TANK
MAIN DECK & TRUNK DECK
FOR'D STORE FLAT
3RD FLAT
NO.1 TANK
NO.2 TANK
NO.3 TANK
NO.4 TANK
ENGINE ROOM
LNG
SIGNIFICANT SHIPS OF 2009
95

GENERALIDADES

El buque ha sido proyectado para transportar en sus cuatro tanques, convenientemente aislados, de doble membrana, 138.000 m³ de LNG a –163° C, con un peso específico de 0,46, y suficientes consumos para unas 20.000 millas navegando a 19,5 nudos al 90% de la PMC del equipo propulsor.

Ha sido diseñado, en principio, para efectuar tareas de carga en la s terminales especializadas de Ras Laffan (Qatar), DAS Island (EAU), Port Fortin (Trinidad y Tobago), Bethonia (Argelia), Bonny (Nigeria), y West Shelf (Australia), y descargar en las terminales de Huelva (España) y Boston (USA). Está preparado asimismo para cumplir los requisitos presentes y futuros de las terminales de descarga en Barcelona, Bilbao y Cartagena, así como en la terminal de Peñuelas, en Puerto Rico. El tiempo de descarga de todo su cargamento de LNG es de unas 12 horas.

Las formas del casco, así como todo el sistema de propulsión y los sistemas de generación eléctrica, han sido diseñados para una máxima eficiencia energética.

CARACTERÍSTICAS PRINCIPALES
MAIN PARTICULARS

Eslora total / *Lenght o.a.*	284,4 m.
Eslora entre pp / *Length b.p.*	271,0 m.
Manga de trazado *Moulded Breadth*	42,5 m.
Puntal a Cbta. Principal *Depth to Main Deck*	25,4 m
Puntal a Cbta. Tronco *Depth to Trunk Deck*	32,2 m
Calado de diseño *Design Draught*	11,4 m
Calado de escantillonado *Scantling Draught*	12,3 m.
Peso muerto *Deadweight*	68.200 t
Capacidad de carga (100%) *Cargo Capacity (100%)*	138.000 m³
Sistema de contención de carga *Cargo Containment system*	Membrana NO96 ® GTT
Capacidad de lastre *Ballast capacity*	49.600 m³
Potencia propulsora *Propulsion Power*	28.000 kW a 83 rpm
Velocidad de servicio *Service Speed*	19,5 nudos *knots*
Autonomía / *Range*	20.000 m.n.
Tripulación / *Crew*	34 personas
Clasificación *Classification*	Lloyd's Register of Shipping ✠100 A1, Liquefied Gas Tanker, Ship type 2G*, Methane in Membrane tanks, Max. pressure 0,25 bar, Min. temperature -163° C, Shipright (SDA), *IWS, LI, ✠ LMC, UMS, CCS, PORT, NAV 1, IBS. With the Descriptive Notes: Shipright FDA, TCM, CM, SCM, ES (✠2)*

GENERAL

The Sestao Knutsen *is, as mentioned earlier, specially designed to carry, in four membrane tanks, 138,000 m³ (total capacity, excluding the dome, internal structure and fittings) of liquefied natural gas of a specific gravity of 0.46, at –163° C, with sufficient fuel capacity for a 20,000-mile range navigating at 19.5 knots at 90% of MCR of the propulsion engine.*

The ship is arranged with a flush deck, raked stern and bulbous bow without a forecastle. The accommodation, including the bridge and propulsion machinery are located aft. The General Arrangement can be seen in the drawing that accompanies this description.

The propulsion power is provided by a steam turbine driving a single shaftline, fitted with a fixed-pitch propeller. The main particulars, capacities, class and additional notations are indicated in the box on this page.

It is designed initially to load at the dedicated terminals of Ras Laffan (Qatar), Das Island (United Arab Emirates), Port Fortin (Trinidad y Tobago), Bethonia (Algeria), Bonny (Nigeria) and West Shelf (Australia),

SK SUMMIT: Daewoo's KOGAS contribution

Shipbuilder:	**Daewoo Heavy Industries Ltd, Korea**
Vessel's name:	***SK Summit***
Hull number:	**2202**
Owner/operator:	**Omnia Enterprises SA, Panama/SK Shipping Co Ltd, Korea**
Designer:	**Daewoo Heavy Industries Ltd, Korea**
Flag:	**Panama**
Total number of sister ships already delivered:	**-**
Total number of sister ships still on order:	**2**

SK Summit is another vessel built for KOGAS (Korea Gas Corp) charter and represents Daewoo's interpretation of that company's requirements. The yard has produced a design with principal dimensions only marginally different from *Hanjin Muscat* (qv), and which is similarly powered by steam turbines; these, despite their high fuel consumption, have proved to be a successful prime mover for LNG carriers. This is because of their ability to use boil-off gases from the cargo in their boilers, as well as fuel oil. However, Daewoo has selected Kawasaki, rather than Mitsubishi, to supply the UA-400 type, slightly higher powered and faster running (40,000shp/96rev/min) turbine set for its vessel.

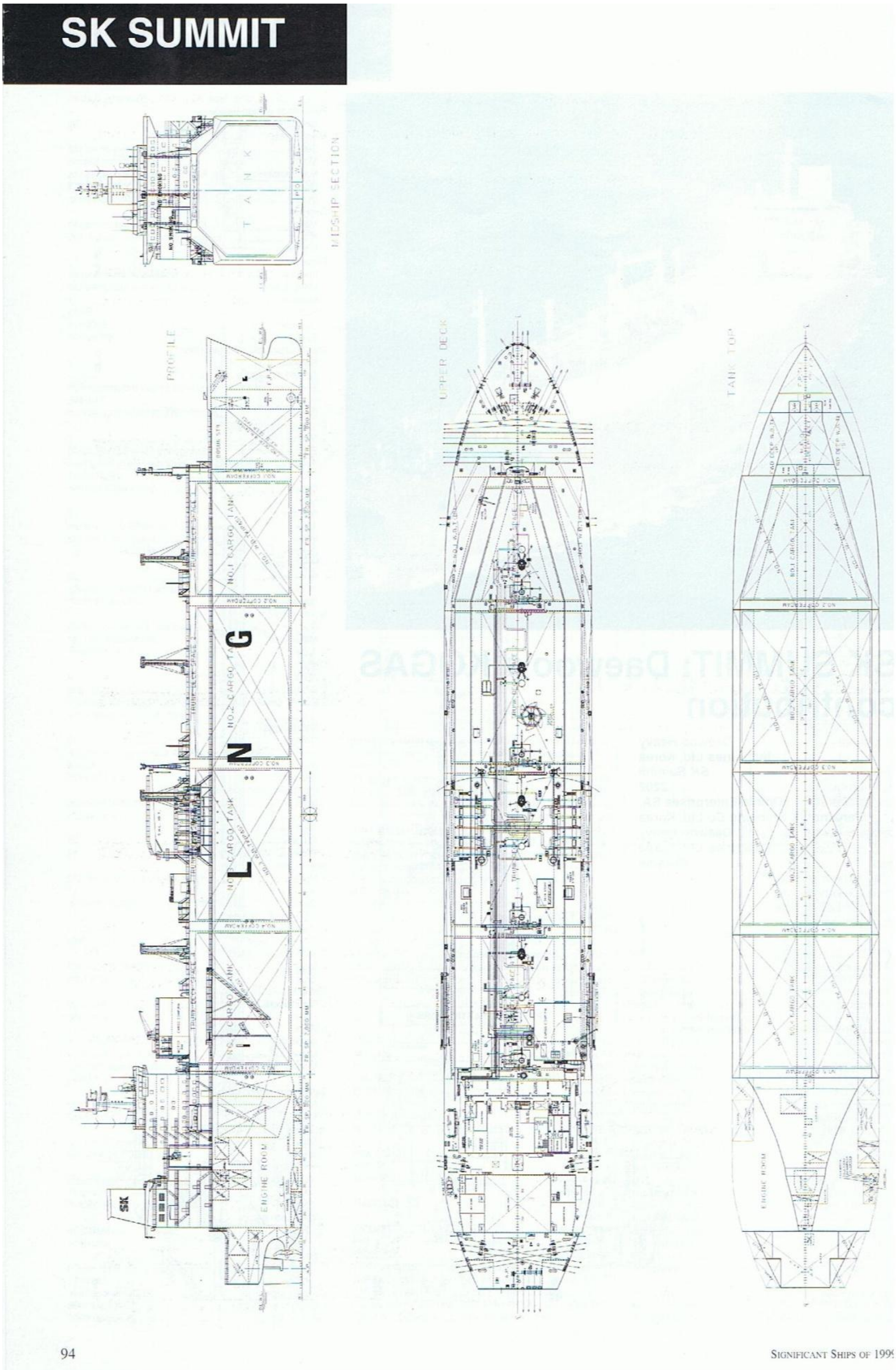
With a supply of steam readily available, two 3450kW turbo-alternators are the main source of electrical power, supplemented by a supply from a similar sized diesel-driven set. The demand for more economic and safer seaborne transportation of LNG has resulted in the development of integrated automation systems for both cargo and engineroom machinery in most vessels of this type. That fitted to *SK Summit* has been designed and programmed by Yamatake-Honeywell using the TDC 3000 LCN system, with control and monitoring carried out from a centralised administration and control centre (CACC) located in the accommodation block.

Daewoo's commitment to the building of LNG carriers is evidenced by its involvement at all stages of the construction process and high level of quality control, required for the insulation boxes, cargo pipes and pump towers, and the Invar sheets used in the tank insulation. Over 125km of welding was needed to join this nickel-alloy steel, which has a very small thermal shrinkage co-efficient at very low temperatures, and Daewoo developed its own technology, plus an automatic welding machine, to carry out this work.

The company also built three, state-of-the-art fabrication shops at Okpo Shipyard, especially to manufacture the many components of an LNG installation, and developed the first LNG carrier simulator, which allows designers and operators the opportunity to carry out realistic ship operations by computer. The cargo containment system adopted for *SK Summit* is a No 96 E-2 design from Gaz Transport & Technigaz (GTT), which uses the same principles as the 96-2 membrane system adopted for *Hanjin Muscat*, namely primary and secondary membranes of 0.70mm Invar sheets in conjunction with expanded perlite beads contained in plywood boxes, to give a total thickness of 530mm.

PRINCIPAL PARTICULARS

Length, oa	277.00m
Length, bp	266.00m
Breadth, moulded	43.40m
Depth, moulded to main deck	26.00m
Gross	95,400gt
Deadweight,	
design	69,000dwt
scantling	76,000dwt
Draught	
design	11.30m
scantling	12.00m
Speed, service, with 21% sea margin	20.30knots
Cargo capacity	
100% at -163°C	138,000m³
Bunkers	
heavy fuel	6000m³
diesel oil	470m³
Water ballast	52,000m³
Fuel consumption, main engine only	203tonnes/day
Classification	Korean Register of Shipping +KRS1 Liquefied Natural Gas Carrier, 2G3M(R), -163°C, 0.5SG(1GC), +KRM1-UMA 1WS, *and* Det Norske Veritas, 1A1, Tanker for LNG, EO, LCS(SID), W1-OC, Ship Type 2G (-163°C, 500kg/np, 0.2bar)
Percentage of high-tensile steel used in construction	Nil
Main engine	
Design	Kawasaki Heavy Industries Ltd
Model	UA-400 steam turbine
Manufacturer	Kawasaki Heavy Industries Ltd
Number	1
Output	40,000shp/96rev/min
Gearbox	
Make	Kawasaki Heavy Industries Ltd
Model	UA-400
Number	1
Propeller	
Material	Nickel-aluminium-bronze
Manufacturer	Hyundai Heavy Industries Ltd
Number	1
Pitch	Fixed
Diameter	8200mm
Speed	96rev/min
Steam turbine-driven alternators	
Number	2
Turbine make/type	-
Alternator make/type	Hyundai Heavy Industries/HFJ5 714-44E
Output	2 x 3450kW/1800rev/min
Diesel-driven alternator	
Number	1
Engine make/type	Ssangyong-MAN B&W/8L32/40
Alternator make/type	Hyundai Heavy Industries/ HFJ5 804-1
Output	3450kW/720rev/min
Boilers	
Number	2
Type	UME 68/59 double-drum
Make	Kawasaki Heavy Industries Ltd
Output	2 x 68,000(max),58,000(min)kg/h
Hose-handling cranes	
Number	2
Make/type	Nor-Marine/MCV1800-10-24Ex
Capacity/speed	10tonne/24m/min
Mooring equipment	
Number	2 x windlass: 8 x mooring winch
Make	Brissonneau et Lotz
Type	Electro-hydraulic
Cargo tanks	
Number	4
Product range	Liquefied natural gas
Coated tanks	Gaz Transport cargo containment system with Invar membrane
Cargo pumps	
Number	8
Type	8 x 12EC-24 submerged centrifugal
Make	Ebara
Capacity	8 x 1700m³/h
Cargo/ballast control system	
Make	Yamatake Industrial Systems
Type	TDCS-3000LCN
Complement	
Officers	26
Crew	14
Bow thruster	
Make	Kawasaki Heavy Industries Ltd
Number	1
Output	2000kW/210rev/min
Bridge control system	
Make	-
One man operation	Yes
Fire detection system	
Make	Nittan System AB
Type	NSAC-1 addressable type
Fire extinguishing system	
Engineroom	Fixed CO_2
Make	Namyang
Radars	
Number	3
Make	Kongsberg Norcontrol
Models	Databridge 2000BL: 2 x S-band; 1 x X-band
Satellite navigation system	
Make	Trimble
Model	NT 200D
Integrated navigation system	
Make	Kongsberg Norcontrol
Model	DB2000BL/AP2000
Waste disposal plant	
Incinerator	
Make	Kangrim
Model	UW1-350MP
Waste compactor	
Make	Metos Co
Model	Uson 8251
Sewage plant	
Make	Jonghap Machine Co
Model	Aerob-25
Contract date	23 December 1996
Launch/float-out date	4 April 1998
Delivery date	3 August 1999


SK SUMMIT
MIDSHIP SECTION
PROFILE
UPPER DECK
TANK TOP
L N G
ENGINE ROOM
94
SIGNIFICANT SHIPS OF 199

TRINITY ARROW: Imabari Group delivers its first LNG carrier

Shipbuilder: ....**Imabari Shipbuilding Co Ltd (Koyo Dockyard), Japan**
Vessel's name: ....***Trinity Arrow***
Hull number: **2258**
IMO number: **9319404**
Owner/operator: ....**Cypress Maritime (Panama SA, Panama/K Line LNG Shipping UK Ltd, UK**
Designer: ....**Imabari Group (Koyo Dockyard), Japan**
Model test establishment used:.... **Shipbuilding Research Centre of Japan, Japan**
Flag: ....**Panama**
Total number of sister ships already completed: ....**Nil**
Total number of sister ships still on order: **2**

IMABARI Shipbuilding Group's first LNG tanker is understood to be the largest capacity vessel of this type yet built in Japan. Although conforming to the traditional 'membrane-type' gas tanker layout with four cargo spaces, each containing an independent trapezoidal cargo tank which extends into a trunk above the upper deck, the design is unusual: in a departure from the norm, No 1 tank is of horizontally trapezoidal shape. It is claimed that this is the first time the arrangement has been used, and that it brings benefits of increased cargo capacity and, by virtue of its shape, allows an improved hull form to be developed, leading to better propulsive performance and reduced fuel consumption.

Because *Trinity Arrow* is intended for worldwide trading rather than long term operation on a specific route, Imabari sought to ensure compatability with most major LNG terminals in its design. This features a complete double-hull structure with cargo tank divisional bulkheads forming cofferdams heated by circulating glycol water to keep the temperature above +5°C, to suit the physical properties of the steel, in accordance with the IGC code.

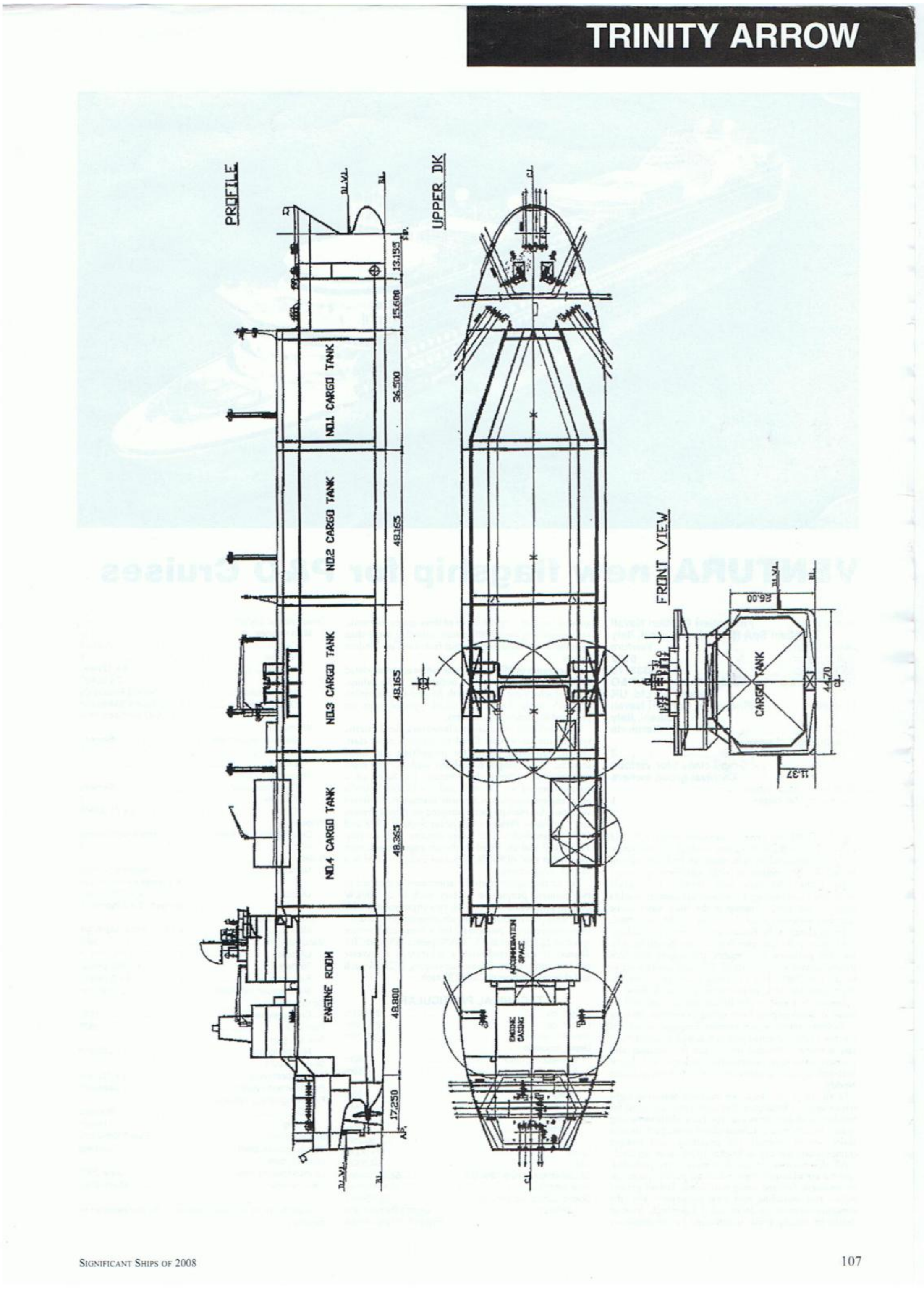
A GTT Mk III cargo containment system has been adopted. This has a primary barrier of 1.2mm SUS membrane with orthogonal corrugations, and a secondary barrier of Triplex membrane, sandwiched between first and second glass fibre reinforced polyurethane foam layers. The insulation has a total thickness of 270mm, which allows an LNG boil off less than 0.15% each day to be maintained during a voyage.

Each cargo tank is fitted with two 1700m³/h Shinko submerged cargo pumps, and one 50m³/h cargo stripping/spray pump. A further cargo pump of 550m³/h is provided for emergency use. Cargo control is carried out from the bridge, allowing full observation and monitoring of all operations, which are handled through port and starboard, midship manifolds. An automatic ballast exchange system is installed for use at sea, taking into consideration the strength, stability and safety aspects of the procedure, in accordance with IMO requirement A868(20). As is the current trend, separate bunker tanks are provided for holding low-sulphur fuel, for use in sulphur emission control areas (SECAs).

Trinity Arrow is fitted with a Kawasaki UA-400 turbine, supplied with steam from two water tube boilers arranged to burn heavy oil and boil-off gas. This installation develops a maximum continuous rating of 29,420kW at 81rev/min, and drives a fixed pitch propeller through a double-reduction, tandem articulated gearbox integrated with the main turbine, for a service speed of 19.50knots when running at 80% full power. Three Nishishiba 3250kW alternators are fitted, two driven by Shinko steam turbine prime movers, and one connected to a Yanmar diesel engine, to satisfy electrical requirements.

TECHNICAL PARTICULARS

Length, oa	289.00m
Length, bp	276.00m
Breadth, moulded	44.70m
Depth, moulded	
to trunk deck	33.12m
to upper deck	26.00m
Width of double skin	
side	2.51m
bottom	3.20m
Draught	
design	11.37m
scantling	12.60m
Gross	101,080gt
Deadweight	
design	72,318dwt
scantling	85,511dwt
Speed, service at 80% MCR	19.50knots
Cargo capacity, liquid volume	154,982m³
Bunkers	
heavy oil	6460m³
diesel oil	700m³
Water ballast	56,780m³
Fuel consumption	161tonnes/day
Classification	Lloyd's Register +100A1, Liquefied Gas Tanker, Ship Type 2G, Membrane (LNG) in Membrane Tanks, Max Vapour Pressure 0.25bar, Minimum Temperature -163°C, ShipRight (SDA, FDA plus CM), *IWS, L1, +LMC, UMS, NAV 1, IBS, ICC
Percentage of high tensile steel used in construction	10.30%
Percentage of stainless steel used	0.10%
Main engine	
Design	Direct reversible steam turbine
Manufacturer	Kawasaki Heavy Industries
Model	UA-400
Number	'1
Output, MCR	29,420kW/81rev/min
Output, NCR	26,480kW/78.2rev/min
Main boilers	
Number	2
Manufacturer	Kawasaki Heavy Industries
Type	UME LL153 watertube
Output, max	2 x 66,000kg/h
Gearbox	
Type	Tandem, articulated, double reduction, integrated with main turbine
Propeller	
Material	Nickel-aluminium-bronze
Designer/manufacturer	Mitsubishi Heavy Industries
Number	1
Pitch	Fixed
Diameter	8800mm
Steam turbine-driven alternators	
Number	2
Turbine manufacturer	Shinko
Alternator make	Nishishiba
Output/speed	2 x 3250kW/1800rev/min
Diesel-driven alternator	
Number	1
Engine make	Yanmar
Type of fuel used	Diesel/marine gas oil
Output/speed	3404kW/720rev/min
Alternator make	Nishishiba
Output/speed	3250kW/720rev/min
Cargo tanks	
Number	4 x IMO type 2G membrane type: GTT Mk III system
Cargo pumps	
Number	8
Type	vertical submerged
Make	Shinko
Capacity	8 x 1700m³/h
Ballast/cargo control systems	
Make	Kokogawa
Type	Integrated automation system
Complement	
Officers	11
Crew	18
Supernumaries	6
Suez crew	6
Bow thruster	
Make	Kawasaki Heavy Industries
Number	1
Output	2200kW
Bridge control system	
Make	Japan Radio Co
Type	Integrated automation system
One man operation	Yes
Fire detection system	
Make	Nippon Nahuyo
Type	FF-1515-4
Fire extinguishing system	
Cargo area (deck)	Unitor, dry powder
Engineroom	Kashiwa, high expansion foam
Radars	
Number	2
Types	1 x JMA-922M9XA, LX-band; 1 x JMA-932MSA, S-band
Make	Japan Radio Co
Integrated bridge system	
Make	Japan Radio Co
Waste disposal plant	
Incinerator	Sunflame DSV 600 SA1
Waste compactor	Electrolux
Sewage plant	Taiko Kikai SBT-65
Contract date	3 August 2004
Launch/float-out date	17 August 2006
Delivery date	31 March 2008


TRINITY ARROW
PROFILE
UPPER DK
FRONT VIEW
NO.1 CARGO TANK
NO.2 CARGO TANK
NO.3 CARGO TANK
NO.4 CARGO TANK
ENGINE ROOM
CARGO TANK
SIGNIFICANT SHIPS OF 2008
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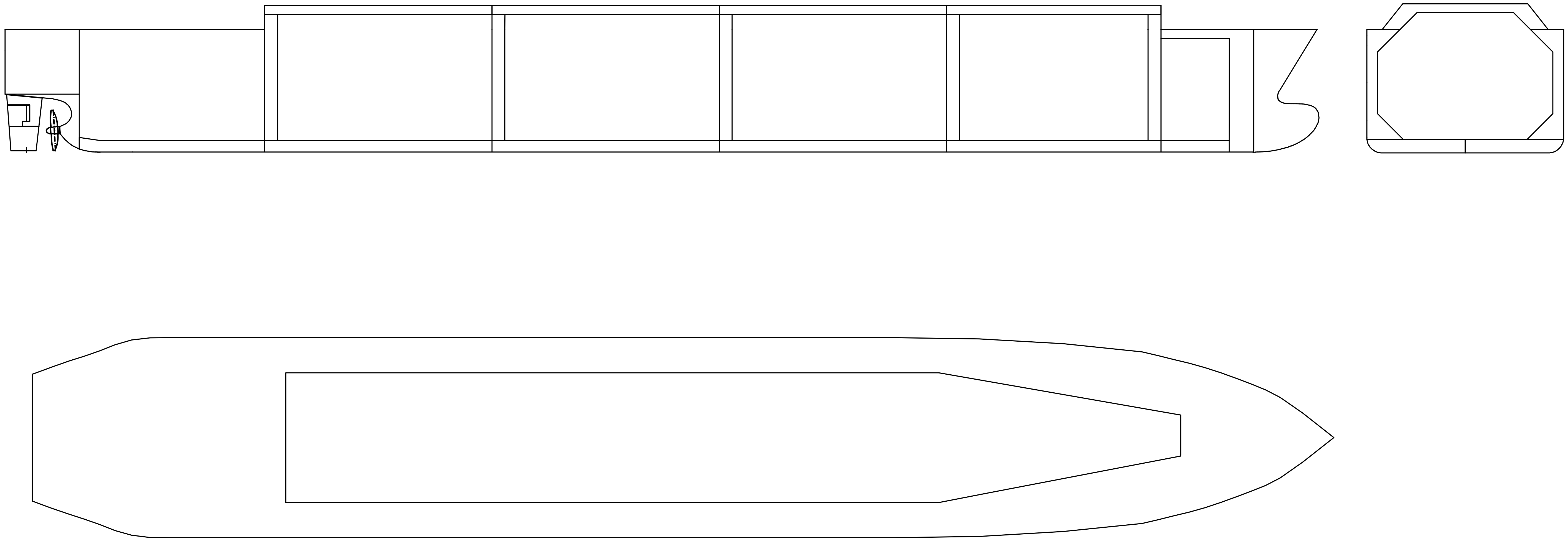
ANEXO III

Croquis conceptual buque proyecto



UNIVERSIDADE DA CORUÑA

ESCOLA POLITÉCNICA SUPERIOR

PROYECTO:
15 105 P

CROQUIS DISPOSICIÓN GENERAL

AUTOR: ISMAEL GRANDAL MOURIZ

ESCALA 1:900

PRODUCIDO POR UN PRODUCTO EDUCATIVO DE AUTODESK