UNIVERSIDADE DA CORUÑA

Escola Politécnica Superior

Trabajo Fin de Grado/Máster
CURSO 2019/20

REMOLCADOR ROMPEHIELOS DE 90 TPF

Grado en Ingeniería Naval y Oceánica

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FECHA

DICIEMBRE 2020

Escola Politécnica Superior

UNIVERSIDADE DA CORUÑA

GRADO EN INGENIERÍA NAVAL Y OCEÁNICA

TRABAJO FIN DE GRADO

CURSO 2019-2020

PROYECTO NÚMERO

TIPO DE BUQUE: BUQUE REMOLCADOR ROMPEHIELOS 90 TPF, PARA OPERACIONES DE PUERTO Y OPERACIONES ROMPEHIELOS

CLASIFICACIÓN, COTA Y REGLAMENTOS DE APLICACIÓN: BUREAU VERITAS, MARPOL, SOLAS Y REGLAMENTOS STANDARD PARA ESTE TIPO DE BUQUE.

CARACTERÍSTICAS DE LA CARGA: 90 TPF

VELOCIDAD Y AUTONOMÍA: 12 NUDOS EN CONDICIONES DE SERVICIO, 85% MCR + 15% MM

SISTEMAS Y EQUIPOS DE CARGA / DESCARGA: LO HABITUAL EN ESTE TIPO DE BUQUES

PROPULSIÓN: DIÉSEL ELÉCTRICA MDO CON DOS HÉLICES AZIPODS

TRIPULACIÓN Y PASAJE: 6 TRIPULANTES

OTROS EQUIPOS E INSTALACIONES: LOS HABITUALES EN ESTE TIPO DE BUQUES.

Ferrol, 10 Setiembre 2019

ALUMNO/A: **D. MIGUEL BURGOS TORRES**

Escola Politécnica Superior

TRABAJO FIN DE GRADO/MÁSTER

CURSO 2019/20

REMOLCADOR ROMPEHIELOS DE 90 TPF

Grado en Ingeniería Naval y Oceánica

Cuaderno 1

ELECCIÓN DE LA CIFRA DE MÉRITO, DEFINICIÓN DE LA ALTERNATIVA Y SELECCIÓN DE LA MÁS FAVORABLE

Índice:

1. INTRODUCCIÓN:

Este proyecto se basa en el diseño de un remolcador rompehielos de 90 TPF, destinado principalmente a operaciones de remolque en puerto y operaciones rompehielos en puerto.

Este buque contará con un sistema de propulsión diésel eléctrica con MDO, cuyo funcionamiento se basa en dos motores eléctricos encargados de suministrar el movimiento a la hélice, los cuales son alimentados por varios generadores con su correspondiente alternador.

El buque contará con 6 tripulantes y tendrá una velocidad de servicio de 12 nudos, el resto de equipos e instalaciones serán los habituales en este tipo de buques.

En este cuaderno se realizará un dimensionamiento básico del buque proyecto mediante una base de datos en la que se recopilan buques similares al buque proyecto, dicho dimensionamiento se realizará mediante el uso de regresiones lineales y formulación.

También se hará un estudio de alternativas basándose en las dimensiones obtenidas a partir de la base de datos, de las cuales se elegirá la alternativa más favorable en función de la cifra de mérito.

Posteriormente se realizará una estimación de la potencia necesaria para el buque proyecto mediante el programa “*NavCad”*.

También se realizará una comprobación del francobordo del buque proyecto donde se explicarán todas las reglas utilizadas y la corrección aplicada en cada una de ellas.

Y, por último, se hará un estudio preliminar de los pesos; peso de acero, peso en rosca, peso muerto, carga, consumos, etc.

2. BASE DE DATOS

Para comenzar el cuaderno, se realizará una base de datos con buques semejantes al buque a proyectar según los requerimientos impuestos en la RPA, en concreto remolcadores que realizan operaciones en puerto.

Los buques seleccionados para la base de datos son del año 2009 en adelante con un TPF entre 68 y 118 toneladas. Como se puede observar los buques de la base de datos no siguen unas dimensiones lineales en relación con el bollard pull, por lo tanto, será un dato a tener en cuenta al obtener las dimensiones principales a partir de las rectas de regresión.

NOMBRE	AÑO	FUENTE	BOLLARD PULL (TPF)	L (m)	LPP (m)	B (m)	D (Depth)(m)	T (Draught)(m)
DUX	2017	Significant small ships	100	40,2	38,5	16	6,1	-
Vortex	2010	Significant small ships	73	38,7	34,6	14	5,9	-
Sigrid dunlap	2018	Significant small ships	81,7	37,03	35,32	11,58	5,5	4,81
Luisa Neri	2016	Significant small ships	80,8	32,7	30,54	12,82	5,35	-
Zeycan Y	2013	Significant small ships	75	24,2	23,45	11,25	4,38	-
RT Emotion	2015	Significant small ships	86	31,95	29,84	12,6	4,82	3,73
Ocean Tundra	2013	Significant small ships	110,3	36	34,04	13	6,85	5,49
Mojaweb	2011	Significant small ships	68	39,1	35,37	13,5	6,11	5,05
Lamnalco sana´a	2009	Significant small ships	118	35,8	32,93	14,5	6,03	4,75
Svitzer Kilroom	2010	Significant small ships	113	39	36,43	14,7	6,11	-

VELOCIDAD SERVICIO (nudos)	DWT (t)	A (t)	LIGHTWEIGHT (t)	Tripulación	Max. velocidad	POTENCIA KW	DWT^1/3
-	241,6	1545,9	-	8	15	6000	6,23
12	528	1638	1110	10	14,5	5300	8,08
10	551	1163	602	6	14,5	7980	8,20
-	-	815	-	10	14,3	10100	-
-	100	500	400	6	12	3530	4,64
-	-	598	-	3	13,1	5295	-
11	300	1250	950	10	14	6000	6,69
12	364,4	1221,8	857,4	14	13,1	3892	7,14
-	390	1355	963	10	15	6120	7,31
-	516	1448	932	10	15,7	6100	8,02

La información de los respectivos buques se encontrará en el ANEXO I de este mismo documento.

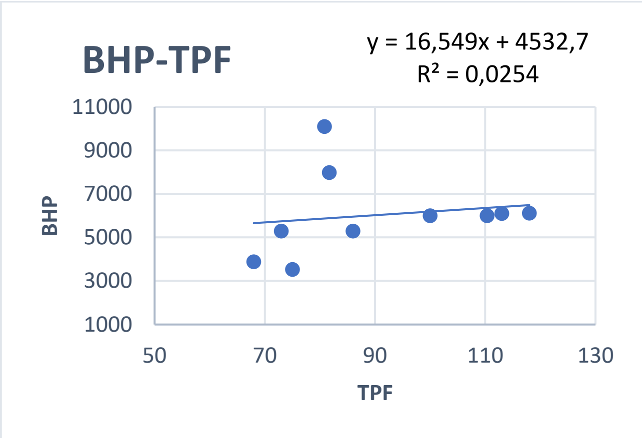
3. DIMENSIONAMIENTO BÁSICO

A partir de los datos de los buques de la base de datos se calculan las dimensiones básicas del buque proyecto, entre ellas la eslora, la manga, el puntal, el calado, los TPF y el coeficiente de bloque, mediante diversas regresiones lineales.

Cálculo de eslora entre perpendiculares

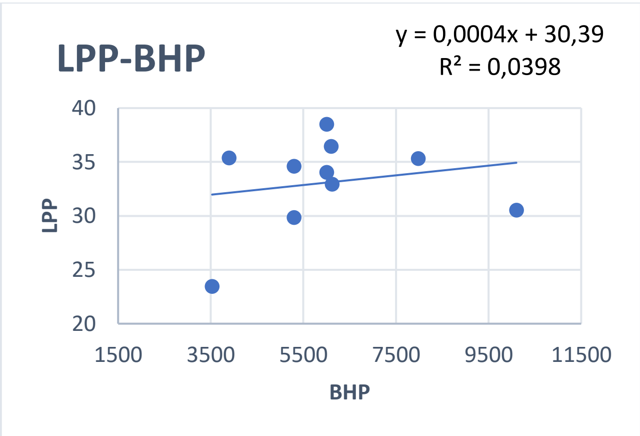
El cálculo de la eslora entre perpendiculares del buque proyecto se obtiene a través de rectas de regresión enfrentándola con la potencia obtenida y los TPF, ya que no se puede enfrentar a ninguna dimensión básica debido a que no se tienen dichas dimensiones.

Los TPF ya los tenemos definidos en la RPA, por lo tanto, únicamente falta por obtener la potencia necesaria para conseguir el tiro exigido. Para ello se obtiene un valor estimado de la potencia a través de una recta de regresión entre la potencia y los TPF de los buques de la base de datos.

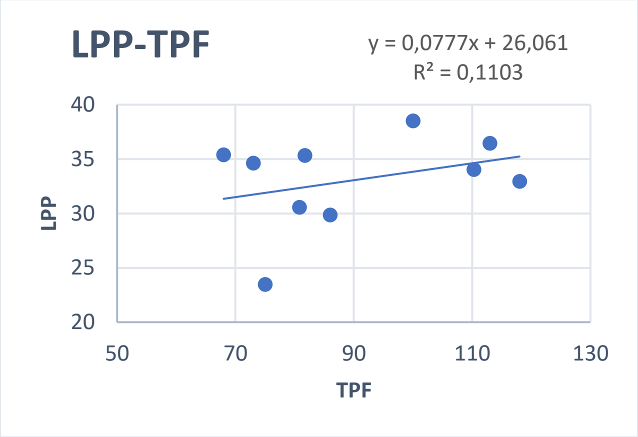


$$BHP = 16{,}549 * TPF + 0{,}0254 = 6022{,}11\ Kw$$

Una vez obtenidos los TPF y la potencia necesaria, se utilizan para obtener la eslora entre perpendiculares del buque proyecto.



$$LPP = 0{,}0004 * BHP + 30{,}39 = 32{,}8\ m$$



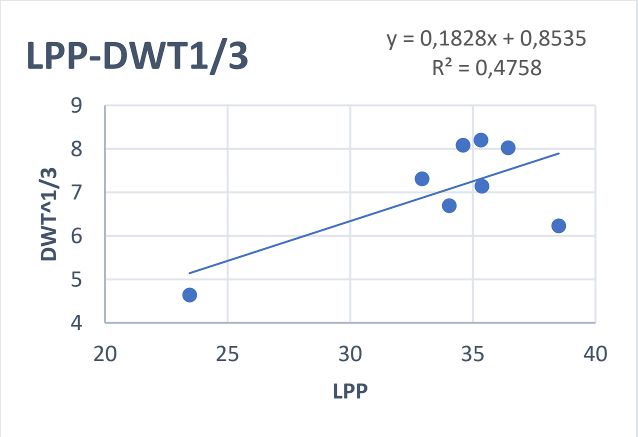
$$LPP = 0{,}0777 * TPF + 26{,}061 = 33{,}05\ m$$

Se obtienen dos valores de la eslora entre perpendiculares mediante dichas regresiones, por lo tanto, para elegir un valor se realiza una media entre ambos.

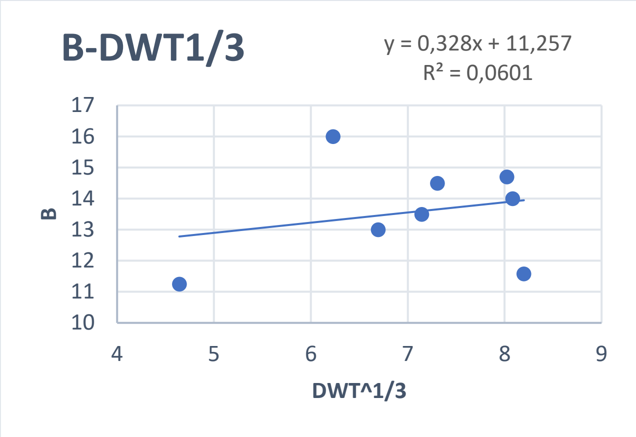
$$\boldsymbol{LPP = 32,93\ m}$$

Cálculo de la manga

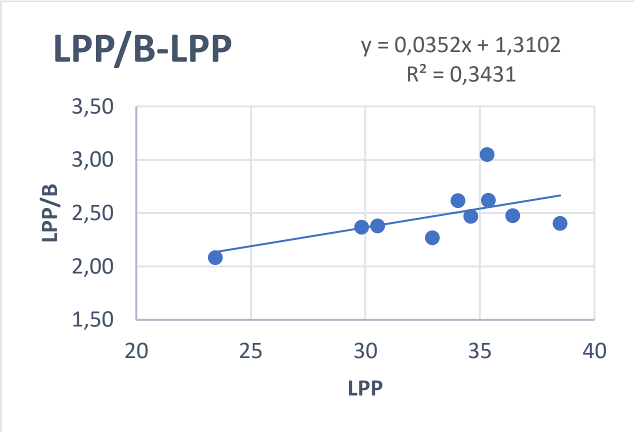
Una vez obtenida la eslora entre perpendiculares, se obtiene la manga con una relación entre manga y eslora y también entre manga y peso muerto.



$$DWT^{\frac{1}{3}} = 324{,}59\ t$$



$$B = 0{,}328 * DWT^{\frac{1}{3}} + 11{,}257 = 13{,}51\ m$$



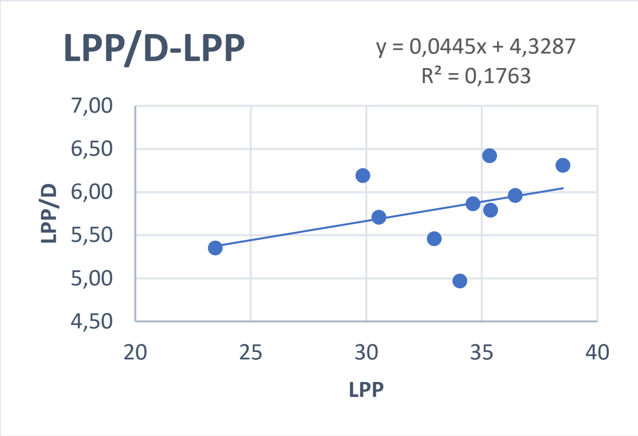
$$B = \frac{LPP}{0{,}0352 * LPP + 1{,}3102} = 13{,}33m$$

Una vez obtenidos los dos valores de la manga, el valor final será una media entre ambos valores.

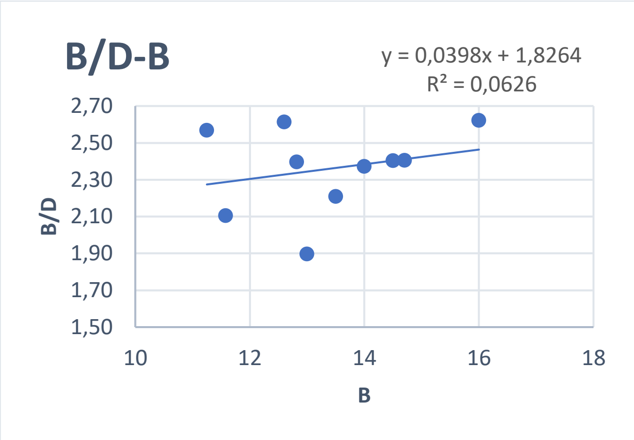
$$\boldsymbol{B = 13,42\ m}$$

Cálculo del puntal

En cuanto al cálculo del puntal del buque se obtiene con las siguientes regresiones. Una de ellas enfrentándola con la eslora entre perpendiculares, y la otra enfrentándola con la manga.



$$D = \frac{LPP}{0{,}0455 * LPP + 4{,}3287} = 5{,}65\ m$$



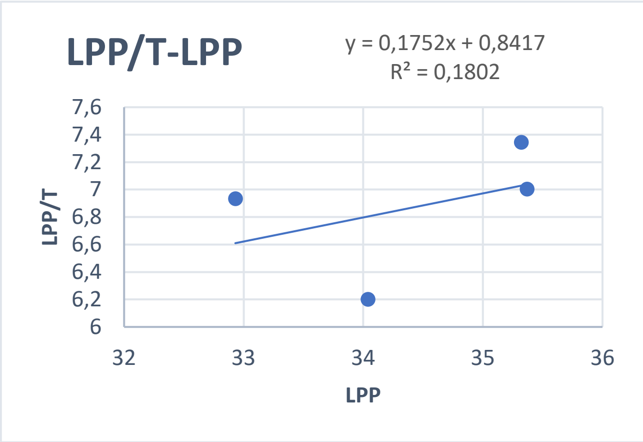
$$D = \frac{B}{0{,}0398 * B + 1{,}8264} = 5{,}69\ m$$

Una vez obtenidos ambos valores del puntal se realiza una media de ambos para obtener el valor final del puntal.

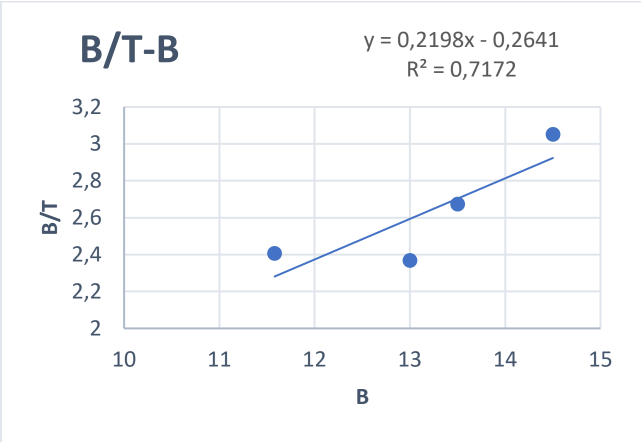
$$\boldsymbol{D = 5,67\ m}$$

Cálculo del calado

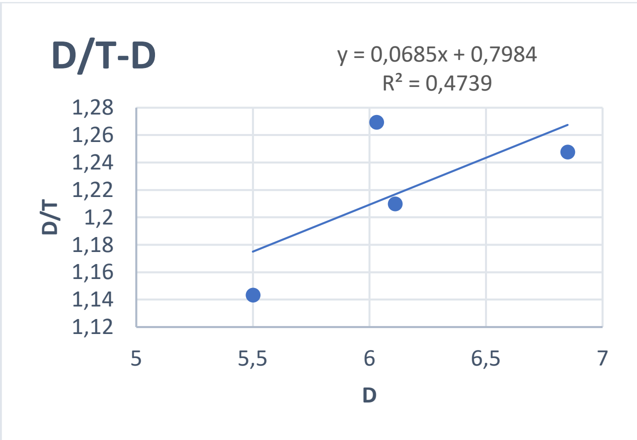
Para la realización del cálculo del calado realizamos tres regresiones lineales, enfrentando el calado con la eslora entre perpendiculares, la manga y el puntal.



$$T = \frac{LPP}{0{,}1752 * LPP + 0{,}8417} = 4{,}98\ m$$



$$T = \frac{B}{0{,}2198 * B - 0{,}2641} = 5{,}00\ m$$



$$T = \frac{D}{0{,}0685 * D + 0{,}7984} = 4{,}78\ m$$

Tras la obtención de dichos valores, se realiza una media entre ellos para obtener el valor final del calado.

$$\boldsymbol{T = 4{,}92\ m}$$

Cálculo del coeficiente de bloque

Para el cálculo del coeficiente de bloque del buque proyecto se realiza mediante diversas fórmulas como la de Alexander, Van Lameren, Luna y Luna 2, obtenidas del libro ``*El proyecto básico del buque mercante*´´.

En primer lugar, se ha de calcular el Nº de Froude, ya que es necesario en varias fórmulas:

$$Nº\ Froude = \frac{v}{\sqrt{LPP \cdot g}} = 0{,}34$$

Fórmula de Alexander:

$$CB = 1{,}06 - 1{,}68 * Nº\ Froude$$

$$CB = 0{,}48$$

Fórmula de Van Lameren:

$$CB = 1{,}137 - \frac{0{,}6v}{\sqrt{L}}$$

$$CB = 0{,}49$$

Fórmula de Luna:

$$CB = 0{,}826 - FN + 0{,}8 * \frac{v^{\frac{1}{3}}}{L}$$

$$CB = 0{,}53$$

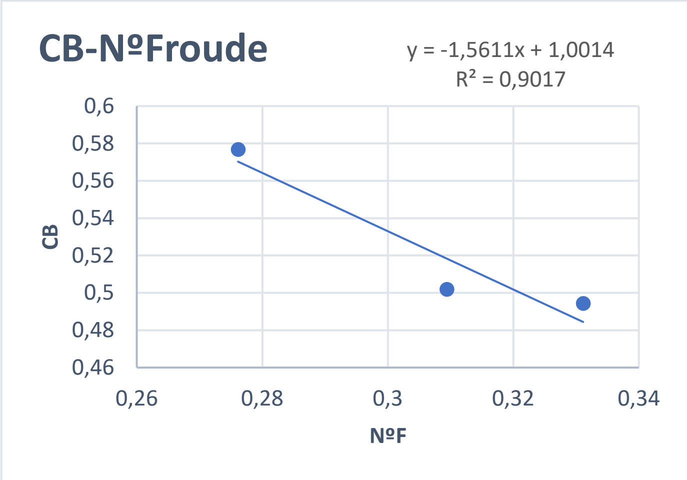
Fórmula de Luna 2:

$$CB = 0{,}88 - 0{,}7 * FN + 0{,}01 \left(\frac{L - 100}{L}\right)^3$$

$$CB = 0{,}56$$

Una vez realizados y estudiados los cálculos obtenidos mediante las diversas fórmulas, se decide calcular dicho coeficiente mediante una recta de regresión. En dicha recta de regresión se enfrentan los coeficientes de bloque frente al número de froude.

Debido a que en la base de datos no tenemos todos los coeficientes de bloque ni los nº de Froude de todos los buques, únicamente se realiza la recta con los tres barcos de los que se disponen dichos datos.



Con dicha ecuación obtenida a través de la regresión, obtenemos el coeficiente de bloque de nuestro buque.

$$CB = (-1{,}5611 * NºF) + 1{,}0014$$

$$CB = 0{,}46$$

Con todos los resultados obtenidos se decide que el coeficiente de bloque final para el buque proyecto es:

$$\boldsymbol{CB = 0,50}$$

Coeficiente de la sección media

El coeficiente de la maestra influye sobre la resistencia al avance y sobre la extensión de la curvatura del casco en la zona del pantoque.

El cálculo de este coeficiente se realizará por el método utilizado en el libro de ¨Fernando Junco¨.

$$CM = 1 - 2 \cdot NºF^4$$

Como valor final para el coeficiente de la maestra obtenemos:

$$\boldsymbol{CM = 0,97}$$

Coeficiente prismático

El valor del coeficiente prismático se obtiene a través de la relación entre el coeficiente de bloque y el coeficiente de la sección media, siendo estos coeficientes los obtenidos anteriormente.

$$CP = \frac{CB}{CM}$$

$$\boldsymbol{CP = 0,52}$$

Coeficiente de flotación

El coeficiente de la flotación tiene influencia sobre la resistencia hidrodinámica y sobre la estabilidad inicial.

Su valor se calcula mediante la fórmula del libro de ´´Fernando Junco´´.

$$Cf = 1 - 0,3 \cdot (1 - CP)$$

$$\boldsymbol{Cf = 0,86}$$

Dimensiones finales

Como se ha podido observar en muchas de las rectas de regresión, el coeficiente de correlación es muy bajo. Esto es debido a que los buques seleccionados para la base de datos son de dimensiones muy diferentes en relación con los TPF, es decir, dos buques con los mismos TPF pueden tener características principales muy desiguales. Por lo tanto, los buques que se han escogido han sido en base a los TPF de los buques. Debido a esto, los coeficientes de correlación en las rectas de regresión de las dimensiones son bajos.

Aquí se muestran todas las dimensiones principales del buque proyecto obtenidas a través de la RPA o mediante su respectivo cálculo realizado anteriormente:

CARACTERISTICAS PRINCIPALES	
LPP	32,93
B	13,42
D	5,67
T	4,92
BHP	6022,11
L	35,28
DWT	324,59
Desplazamiento	1029,82
CB	0,50
CM	0,97
CP	0,52
N º Froude	0,34
Velocidad (m/s)	6,17
Velocidad (nudos)	12

4. ELECCIÓN DE LA CIFRA DE MÉRITO

En este apartado se realizará una primera estimación de lo que costará el buque del proyecto.

Cabe destacar que esta primera evaluación económica tiene una validez temporal muy breve, ya que se apoya en los precios que están sometidos a las reglas del mercado y su estabilidad es muy precaria.

Esta evaluación se desglosa en los siguientes puntos:

- Coste de construcción
- Coste de adquisición
- Inversión total
- Estudio de costos de operación
- Balance de ingresos y gastos

En esta parte, se realizará únicamente el coste de construcción. Esto se debe a que la cifra de mérito elegida para el proyecto es el coste de construcción mínimo.

Las fórmulas y nomenclatura que se aplicarán a continuación vienen reflejados en *"El proyecto básico del buque mercante*" y "*Proyectos de buques y artefactos".*

El coste de construcción viene definido por la siguiente fórmula:

$$\boldsymbol{CC = CMg + CEq + CMo + CVa}$$

Donde:

- CC: Coste de construcción
- CMg: Coste de materiales a granel
- CEq: Coste de equipos del buque
- CMo: Coste de la mano de obra necesaria en el buque
- CVa: Representa el coeficiente de los costes varios que tendrá el astillero, como gastos por sociedades de clasificación, entre otros.

Coste del material a granel

En este apartado, se considera que únicamente están incluidos los costes relativos al acero necesario para el buque. Se calcula a partir de la siguiente fórmula:

$$\boldsymbol{CMg = cmg \cdot PS = ccs \cdot cas \cdot cem \cdot ps \cdot PS}$$

- cmg = Coeficiente de costo de material a granel
- ccs = Coeficiente ponderado de chapas y acero de distintas calidades de acero:

$$1{,}05 < ccs < 1{,}5$$
$$ccs = 1{,}3$$

- cas = Coeficiente de aprovechamiento del acero:

$$1{,}08 < cas < 1{,}15$$
$$cas = 1{,}11$$

- cem = Coeficiente de incremento por equipo metálico incluido en la estructura.

$$1{,}03 < cem < 1{,}10$$
$$cem = 1{,}06$$

- ps = precio unitario de acero para referencia.

$$ps = 850\frac{€}{t}$$

- PS = Estimación del peso de acero.

$$PS = K \cdot L \cdot B \cdot D \cdot \frac{L}{D}^{1/2}$$
$$PS = 1{,}08 \cdot 0{,}094 \cdot 35{,}28 \cdot 13{,}42 \cdot 5{,}67 \cdot \frac{35{,}28}{5{,}67}^{1/2}$$

$$PS = 679{,}73\ tn$$

Por lo tanto, el coste de materiales a granel es el siguiente:

$$\boldsymbol{CMg = 1{,}3 \cdot 1{,}11 \cdot 1{,}06 \cdot 850 \cdot 679{,}73}$$

$$\boldsymbol{CMg = 883.743{,}67€}$$

Coste de la mano de obra

El coste de la mano de obra se desglosa en el montaje del material a granel y de los equipos.

$$\boldsymbol{CMo = CMm + CMe = chm \cdot csh \cdot PS + CMe}$$

- CMm = Coste de la mano de obra de montaje del material a granel.
- chm = Coste horario medio del astillero en horas/tonelada.

$$\frac{21}{25} < chm < \frac{10}{40}$$

$$chm = 30€/h$$

- csh = Coeficiente de horas por unidad de peso.

$$\frac{20}{30} < csh < \frac{80}{100}$$

$$csh = 50\ h/t$$

- PS = Estimación del peso de acero. PS = 679,73 Tn
- CMe = Coste de la mano de obra de montaje de equipos e instalaciones.

$$CMe = 35\%Per$$

Per = Peso del equipo restante

$$Per = K \cdot L^{1.3} \cdot B^{0.8} \cdot D^{0.3}$$

$$Per = 0{,}045 \cdot 35{,}28^{1.3} \cdot 13{,}42^{0.8} \cdot 5{,}67^{0.3}$$

$$Per = 62{,}12\ tn$$

Por lo tanto, el coste de mano de obra será el siguiente:

$$\boldsymbol{CMo = 30 \cdot 50 \cdot 679,73 + 0,35 \cdot 62,12}$$

$$\boldsymbol{CMo = 1.019.613,83€}$$

Coste de los equipos del buque

En este apartado se estimará el coste de los equipos del buque. Se obtiene a partir de la siguiente fórmula.

$$\boldsymbol{CEq = CEp + CHf + CEr}$$

- CEp = Coste de los equipos de propulsión, auxiliares y su montaje.
  $$CEp = cep \cdot BP$$
  El cep es el coste por unidad de potencia de equipos de propulsión y auxiliares, con un cep de 350 €/KW.
  $$CEp = 350 \cdot 6022{,}11$$
  $$CEp = 2.107.738{,}5€$$

- Chf = Coste de habilitación y su montaje
  $$CHf = chf \cdot nch \cdot NT$$
  chf = Coeficiente unitario de la habilitación por tripulante.
  $$chf = 32.000$$
  nch = Coeficiente de nivel de calidad de la habilitación.
  $$0{,}9 < nch < 1{,}2$$
  $$nch = 1{,}1$$
  NT = Número de tripulantes
  $$CHf = 32.000 \cdot 1{,}1 \cdot 6$$
  $$CHf = 211.200€$$

- CEr = Coste de equipos restantes
  $$CEr = ccs \cdot ps \cdot Per$$
  $$CEr = 1{,}3 \cdot 850 \cdot 62{,}12$$
  $$CEr = 68.643{,}9€$$

Por lo tanto, el coste de los equipos del buque será el siguiente:

$$\boldsymbol{CEq = 2.107.738,5 + 211.200 + 68.643,9}$$

$$\boldsymbol{CEq = 2.387.582,4\ €}$$

Costes varios aplicados

Los costes varios aplicados son los que representan otros gastos del astillero. Incluyendo, ensayos en el canal, sociedades de clasificación, gastos de representación, etc. Se estima como un porcentaje del coste de construcción del buque.

$$CVa = cva \cdot cc$$

- cva = es el porcentaje del costo de construcción estimado en un 0,07%
- CC = Costes de construcción hasta el momento.

$$\boldsymbol{CVa = 0,07 \cdot (883.743,67 + 1.019.613,83 + 2.387.582,4)}$$

$$\boldsymbol{CVa = 300.365,79€}$$

Coste total de construcción

Una vez obtenidos todos los costes anteriores, se calculará el coste total de construcción. La fórmula que se aplica es la que hemos visto anteriormente.

$$\boldsymbol{CC = CMg + CEq + CMo + CVa}$$

$$\boldsymbol{CC = 883.743,67 + 1.019.613,83 + 2.387.582,4 + 300.365,79}$$

$$\boldsymbol{CC = 4.591.305,64\ €}$$

5. ELECCIÓN DE LA ALTERNATIVA MÁS FAVORABLE

El objetivo para la elección de la alternativa más favorable se basa en minimizar el coste de construcción utilizando el programa *Excel*.

Para el estudio de las distintas alternativas, se procede cambiando las siguientes variables:

- $\pm$10% Eslora
- $\pm$10% Manga
- $\pm$0.03 Coeficiente de bloque.

El proceso seguido para la realización de las diversas alternativas, es el siguiente. Se ha calculado el valor máximo y mínimo de la eslora y de la manga, en base a las variaciones mencionadas. Las distintas esloras varían desde un valor máximo de 39 metros, hasta un valor mínimo de 31 metros. Las mangas varían desde un valor máximo de 15,2 metros, hasta un valor mínimo de 12,5 metros, y se han combinado de manera que cada manga se haya evaluado con todas las variaciones de eslora, y viceversa. Los valores del coeficiente de bloque se ha evaluado de la misma forma que las anteriores variables, desde 0,48 hasta 0,54.

Una vez completadas las alternativas, se han impuesto una serie de requisitos basados en las medidas de los buques de la base de datos.

	LPP/B	B/D	T/D
MINIMO	2,08	1,9	0,77
MAXIMO	3,05	2,62	0,87

En base al proceso explicado anteriormente, se han estudiado un total de 700 alternativas, de las cuales han cumplido todos los requisitos impuestos 70 alternativas del total. De las alternativas que han cumplido los requisitos, ninguna tenía un valor de coste de construcción menor a la alternativa inicial. Las alternativas con mayor coste de construcción superan en 300.000 € el coste de la alternativa inicial, siendo el valor medio muy similar al coste de construcción de dicha alternativa.

En cuanto al cálculo de las dimensiones para cada alternativa se han utilizado las siguientes ecuaciones dependiendo de la dimensión a calcular:

- Desplazamiento:

$$\boldsymbol{\Delta = \Delta inicial + \delta\ P.acero + \delta\ P.Equipos\ restantes\ +\ \delta\ maquinaria}$$

- Calado:

$$\boldsymbol{T = \frac{\Delta}{1.025 \cdot CB \cdot L \cdot B}}$$

El resto de cálculos se obtienen siguiendo las mismas fórmulas indicadas en apartados anteriores.

A continuación, se muestran las alternativas que cumplen los requisitos exigidos.

LPP	B	D	T	CB	CM	CP	DESPLAZAMIENTO	NºF	POTENCIA	CC
32,93	**13,42**	**5,67**	**4,92**	**0,50**	**0,97**	**0,52**	**1029,82**	**0,34**	**6022,11**	**4385044,06**
39	12,8	5,02	3,92	0,53	0,98	0,54	1062,68	0,32	6022,11	4683264,02
39	12,8	5,02	3,99	0,52	0,98	0,53	1062,68	0,32	6022,11	4683264,02
39	12,8	5,02	4,07	0,51	0,98	0,52	1062,68	0,32	6022,11	4683264,02
39	12,8	5,02	4,15	0,5	0,98	0,51	1062,68	0,32	6022,11	4683264,02
39	12,8	5,02	4,24	0,49	0,98	0,50	1062,68	0,32	6022,11	4683264,02
39	12,8	5,02	4,33	0,48	0,98	0,49	1062,68	0,32	6022,11	4683264,02
38	13,1	5,03	3,96	0,52	0,98	0,53	1051,61	0,32	6022,11	4651799,9
38	13,1	5,03	4,04	0,51	0,98	0,52	1051,61	0,32	6022,11	4651799,9
38	13,1	5,03	4,12	0,5	0,98	0,51	1051,61	0,32	6022,11	4651799,9
38	13,1	5,03	4,21	0,49	0,98	0,50	1051,61	0,32	6022,11	4651799,9
38	13,1	5,03	4,29	0,48	0,98	0,49	1051,61	0,32	6022,11	4651799,9
38	12,8	5,15	4,02	0,52	0,98	0,53	1042,82	0,32	6022,11	4626802,49
38	12,8	5,15	4,10	0,51	0,98	0,52	1042,82	0,32	6022,11	4626802,49
38	12,8	5,15	4,18	0,5	0,98	0,51	1042,82	0,32	6022,11	4626802,49
38	12,8	5,15	4,27	0,49	0,98	0,50	1042,82	0,32	6022,11	4626802,49
38	12,8	5,15	4,36	0,48	0,98	0,49	1042,82	0,32	6022,11	4626802,49
38	12,5	5,27	4,08	0,52	0,98	0,53	1033,92	0,32	6022,11	4601510,39
38	12,5	5,27	4,16	0,51	0,98	0,52	1033,92	0,32	6022,11	4601510,39
38	12,5	5,27	4,25	0,5	0,98	0,51	1033,92	0,32	6022,11	4601510,39
38	12,5	5,27	4,33	0,49	0,98	0,50	1033,92	0,32	6022,11	4601510,39
38	12,5	5,27	4,42	0,48	0,98	0,49	1033,92	0,32	6022,11	4601510,39
37	13,1	5,17	4,07	0,51	0,98	0,52	1031,52	0,32	6022,11	4594680,53
37	13,1	5,17	4,15	0,5	0,98	0,51	1031,52	0,32	6022,11	4594680,53
37	13,1	5,17	4,24	0,49	0,98	0,50	1031,52	0,32	6022,11	4594680,53
37	13,1	5,17	4,33	0,48	0,98	0,49	1031,52	0,32	6022,11	4594680,53
37	12,8	5,29	4,13	0,51	0,98	0,52	1022,95	0,32	6022,11	4570340,96
37	12,8	5,29	4,21	0,5	0,98	0,51	1022,95	0,32	6022,11	4570340,96
37	12,8	5,29	4,30	0,49	0,98	0,50	1022,95	0,32	6022,11	4570340,96
37	12,8	5,29	4,39	0,48	0,98	0,49	1022,95	0,32	6022,11	4570340,96
37	12,5	5,42	4,20	0,51	0,98	0,52	1014,29	0,32	6022,11	4545714,44
37	12,5	5,42	4,28	0,5	0,98	0,51	1014,29	0,32	6022,11	4545714,44
37	12,5	5,42	4,37	0,49	0,98	0,50	1014,29	0,32	6022,11	4545714,44
37	12,5	5,42	4,46	0,48	0,98	0,49	1014,29	0,32	6022,11	4545714,44
36	13,4	5,19	4,04	0,51	0,98	0,52	1019,66	0,33	6022,11	4560973,28
36	13,4	5,19	4,12	0,5	0,98	0,51	1019,66	0,33	6022,11	4560973,28
36	13,4	5,19	4,21	0,49	0,98	0,50	1019,66	0,33	6022,11	4560973,28
36	13,4	5,19	4,30	0,48	0,98	0,49	1019,66	0,33	6022,11	4560973,28
36	13,1	5,31	4,18	0,5	0,98	0,51	1011,42	0,33	6022,11	4537561,17
36	13,1	5,31	4,27	0,49	0,98	0,50	1011,42	0,33	6022,11	4537561,17

36	13,1	5,31	4,36	0,48	0,98	0,49	1011,42	0,33	6022,11	4537561,17
36	12,8	5,44	4,25	0,5	0,98	0,51	1003,09	0,33	6022,11	4513879,42
36	12,8	5,44	4,33	0,49	0,98	0,50	1003,09	0,33	6022,11	4513879,42
36	12,8	5,44	4,42	0,48	0,98	0,49	1003,09	0,33	6022,11	4513879,42
36	12,5	5,57	4,31	0,5	0,98	0,51	994,66	0,33	6022,11	4489918,48
36	12,5	5,57	4,40	0,49	0,98	0,50	994,66	0,33	6022,11	4489918,48
36	12,5	5,57	4,49	0,48	0,98	0,49	994,66	0,33	6022,11	4489918,48
35	13,7	5,22	4,10	0,5	0,98	0,51	1007,25	0,33	6022,11	4525711,95
35	13,7	5,22	4,18	0,49	0,98	0,50	1007,25	0,33	6022,11	4525711,95
35	13,7	5,22	4,27	0,48	0,98	0,49	1007,25	0,33	6022,11	4525711,95
35	13,4	5,34	4,16	0,5	0,98	0,51	999,33	0,33	6022,11	4503203,58
35	13,4	5,34	4,24	0,49	0,98	0,50	999,33	0,33	6022,11	4503203,58
35	13,4	5,34	4,33	0,48	0,98	0,49	999,33	0,33	6022,11	4503203,58
35	13,1	5,46	4,30	0,49	0,98	0,50	991,32	0,33	6022,11	4480441,81
35	13,1	5,46	4,39	0,48	0,98	0,49	991,32	0,33	6022,11	4480441,81
35	12,8	5,59	4,37	0,49	0,98	0,50	983,22	0,33	6022,11	4457417,89
35	12,8	5,59	4,46	0,48	0,98	0,49	983,22	0,33	6022,11	4457417,89
35	12,5	5,73	4,44	0,49	0,98	0,50	975,03	0,33	6022,11	4434122,53
35	12,5	5,73	4,53	0,48	0,98	0,49	975,03	0,33	6022,11	4434122,53
34	13,7	5,38	4,22	0,49	0,97	0,50	986,70	0,34	6022,11	4467299,16
34	13,7	5,38	4,31	0,48	0,97	0,49	986,70	0,34	6022,11	4467299,16
34	13,4	5,50	4,28	0,49	0,97	0,50	979,01	0,34	6022,11	4445433,89
34	13,4	5,50	4,37	0,48	0,97	0,49	979,01	0,34	6022,11	4445433,89
34	13,1	5,62	4,43	0,48	0,97	0,49	971,23	0,34	6022,11	4423322,45
34	12,8	5,76	4,50	0,48	0,97	0,49	963,36	0,34	6022,11	4400956,35
34	12,5	5,89	4,57	0,48	0,97	0,49	955,40	0,34	6022,11	4378326,58
33	14	5,42	4,28	0,48	0,97	0,49	973,53	0,34	6022,11	4429877,42
33	13,7	5,54	4,34	0,48	0,97	0,49	966,15	0,34	6022,11	4408886,36
33	13,4	5,67	4,41	0,48	0,97	0,49	958,68	0,34	6022,11	4387664,19
32	14,3	5,47	4,26	0,48	0,97	0,49	959,84	0,35	6022,11	4390966,56

En cuanto a la elección de la alternativa más favorable, se ha escogido una en la que las dimensiones del barco sean más grandes, ya que en la primera espiral del proyecto se escogió una alternativa en la que en cuadernos posteriores se tuvieron problemas de espacio.

La alternativa que se muestra a continuación es la más favorable:

ALTERNATIVA	
LPP	38
B	12,5
D	5,27
T	4,08
BHP	6022,11
Desplazamiento	1033,92
CB	0,52
CM	0,98
CP	0,53
NºFroude	0,32
Velocidad (m/s)	6,17
Velocidad (nudos)	12,00

Tras el avance del proyecto, en cuadernos posteriores se puede observar que la alternativa escogida da una serie de problemas en cuanto al dimensionamiento de la cámara de máquinas ya que los motores generadores no caben en dicha cámara en altura, por lo tanto, se dispone de una nueva alternativa final en la cual se varía el puntal del buque a proyectar.

ALTERNATIVA FINAL	
LPP	38
B	12,5
D	6,65
T	5,27
BHP	6022,11
Desplazamiento	1033,92
CB	0,52
CM	0,98
CP	0,53
NºFroude	0,32
Velocidad (m/s)	6,17
Velocidad (nudos)	12,00
L	40,36

6. FRANCOBORDO

Para el cálculo del francobordo, se sigue el reglamento del "*Convenio Internacional de Líneas de Carga de 1996 y Protocolo de 1988*".

Los valores utilizados corresponden con las dimensiones finales del buque elegidas en la alternativa final, complementando con valores medidos del plano del buque base, el *"RT Emotion"*, cuya ficha técnica está adjuntada en el ANEXO.

A continuación, se explicará el proceso de cálculo de francobordo:

Valores iniciales:

Manga: B = 12,5 m;

Puntal: D = 6,65 m;

85% Puntal: $D_{0.85}$ = 5,65 m;

La eslora de francobordo es la máxima de la eslora entre perpendiculares o la eslora al 85% del puntal, por lo tanto, la eslora de francobordo es: L_{fb} = 38 m;

Coeficiente de bloque: Cb = 0,52 m;

Volumen al 85% del puntal: V = 1262,03 m^3;

REGLA 27: Tipo de buque.

El buque proyecto es un buque de tipo B ya que no cumple los requisitos para buques tipo A.

REGLAS 28: Francobordo tabular.

El francobordo tabular se obtiene mediante unas tablas a través de la eslora de francobordo.

Table	
L	***freeboard***
38	316
38	316

L	***freeboard***
38	316

R-28	316

Se obtiene un francobordo tabular de 316 mm.

La corrección que se obtiene de esta regla es de: R-28 = 316 mm.

REGLA 29: Corrección para buques de eslora menor de 100 m.

Esta regla es aplicable ya que la eslora de la superestructura entre la eslora de francobordo es mayor que 0.35.

$$\frac{L_{sup}}{L_{fb}} = \frac{11{,}57}{38} > 0{,}35$$

R-29	22

La corrección que se obtiene de esta regla es la siguiente: R-32 = 22 mm

REGLO 30: Corrección por coeficiente de bloque.

Esta regla no es aplicable ya que el coeficiente de bloque del buque proyecto es menor a 0.68, por lo tanto, no hay corrección.

REGLA 31: Corrección por puntal.

Esta corrección es aplicable ya que D excede de L/15, (5,67>2,37).

Al tener una eslora inferior a 120 m, R es igual a L/0,48 y por lo tanto, la corrección que se aplica es la siguiente:

$$Corrección = \left(D \cdot \frac{L}{15}\right) \cdot R$$

R	79,1667
Correction	326

La corrección que se obtiene de esta regla es la siguiente: R-31 = 326 mm

REGLA 32 Y 32.1: Corrección por posición de la línea de cubierta.

Esta regla no es aplicable en el buque proyecto ya que no necesita corrección por posición de cubierta ni por hueco de banda a banda en la superestructura.

REGLA 33: Altura estándar para superestructuras.

La altura normal de una superestructura será la que se indica en la siguiente tabla:

Altura normal (en m)		
L (m)	Cubierta de saltillo	Todas las demás superestructuras
30 o menos	0,9	1,8
75	1,2	1,8
125 o más	1,8	2,3

Raised quarterdeck	*Todas las demás superestructuras*
0,918	1,8

REGLA 34 Y REGLA 35: Eslora efectiva de superestructura.

En el buque proyecto hay una superestructura situada a proa, por lo que solo se estudiará la superestructura en el castillo de proa.

La eslora de la superestructura es de 17,35 m, la manga es de 10,35 m y la altura de esta es de 1,2 m, por lo que la eslora efectiva de la superestructura es de 11,57 m.

Superestructura	Longitud (S)	Sup. Manga. (b)	Ship Manga. (Bs)	Altura	Longitud Efectiva (E)
Castillo	17,350	10,350	10,350	1,200	11,567

REGLA 36: Longitud efectiva del tronco.

Esta regla no es aplicable en el buque proyecto debido a la inexistencia de troncos en nuestro buque.

REGLA 37: Reducción por superestructuras y troncos.

Ya que nuestro buque no tiene troncos, la única reducción posible es la de la superestructura. La reducción si la superestructura fuese a lo largo de toda la eslora sería de 467 mm. El coeficiente nos lleva a un porcentaje de reducción de 26.4%.

Por lo tanto, la corrección es de:

$$Corrección = R \cdot 26.4\%$$

Lenght of Superestructure	11,567	m
Lenght of Trunks	0	m
Effective Lenght (E)	11,567	m
Effective Lenght (E)	0,3044	*L
Deduction for 1L	467	mm

Table 37.1	
E	%
0,3	21
0,3044	21,4
0,4	31

La corrección que se obtiene de esta regla es la siguiente: R-37 = -100 mm.

REGLA 38: Arrufo.

El buque proyecto tiene un arrufo que lo calculamos del perfil estándar del arrufo del buque, que es el siguiente:

Sheer Profile

Station	Ordinate	Sum for Le=L	Total	Factor	Product		
After perpendicular	522	0	522	1	522		
1/6 L from A.P.	232	0	232	3	696		
1/3 L from A.P.	58	0	58	3	174		
Amidships	0	0	0	1	0	**After Sheer**	1392
Amidships	0	0	0	1	0		
1/3 L from F.P.	117	0	117	3	351		
1/6 L from F.P.	464	0	464	3	1392		
Forward perpendicular	1044	0	1044	1	1044	**Forward Sheer**	2787

El factor de corrección de arrufo se obtiene de:

$$F.corrección = 0{,}75 - (\frac{L_{sup}}{2 \cdot L_{fb}})$$

La variación de arrufo es la media de la variación de arrufo a popa y de la variación de arrufo a proa, de la que se obtiene una variación de -67.

Por lo tanto, la corrección por arrufo se calcula multiplicando la variación por arrufo cambiada de signo por el factor de corrección.

La corrección que se obtiene de esta regla es la siguiente: R-38 = 35 mm.

REGLA 39.1: Altura mínima de proa.

En esta regla se calcula en primer lugar el área de flotación en la mitad de proa del buque.

$$Awf\ =\ L_{fb} \cdot B \cdot \frac{CF}{2} = 185\ m^2$$

Por lo tanto, la altura mínima de proa equivale a 2175 m.

La altura mínima de francobordo en proa es de 2125 mm que es menor que la altura en proa del buque proyecto, por lo tanto, la corrección que se aplica es la resta de la altura mínima de francobordo en proa menos el francobordo en agua salada.

Bow depth corrected for R39	6,7	m
Minimum bow heigth freeboard	1225	mm
Salt water freeboard	599	mm

La corrección que se obtiene de esta regla es la siguiente: R-39.1 = 1526 mm.

REGLA 39.2: Reserva de flotabilidad.

El buque no necesita ninguna corrección por reserva de flotabilidad.

RESULTADOS:

Por último, se calcula el desplazamiento y las toneladas por centímetro de inmersión del buque al 85% del puntal.

Desplazamiento: 2181,2 ton.

TPCM: 3.79 ton/cm.

Las correcciones obtenidas se muestran en la siguiente tabla:

R-28	316	mm
R-29	22	mm
R-30		mm
R-31	326	mm
R-32.1		mm
R-37	-100	mm
R-38	35	mm
Sum	**599**	**mm**
R-39.1	1526	mm
R-39.2	0	mm
Sum	**2125**	**mm**

Con las correcciones obtenidas tenemos un calado máximo de verano de 4572 mm, que es igual a la suma del francobordo tabular más las correcciones aplicadas.

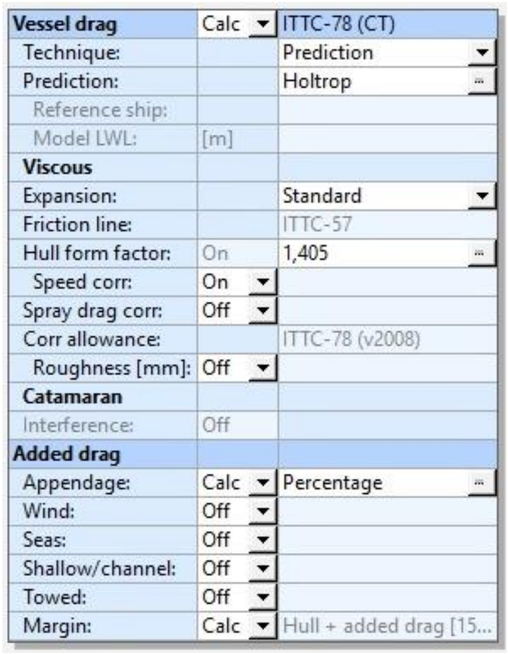
A continuación, se muestran los francobordos mínimos obtenidos:

Summer Freeboard	***2125***	***mm***
Summer Draught	***4525***	***mm***
Tropical Freeboard	***2031***	***mm***
Winter Freeboard	***2220***	***mm***
Winter N. Atlantic Freeboard	***2270***	***mm***
Fresh Water	***2107***	***mm***

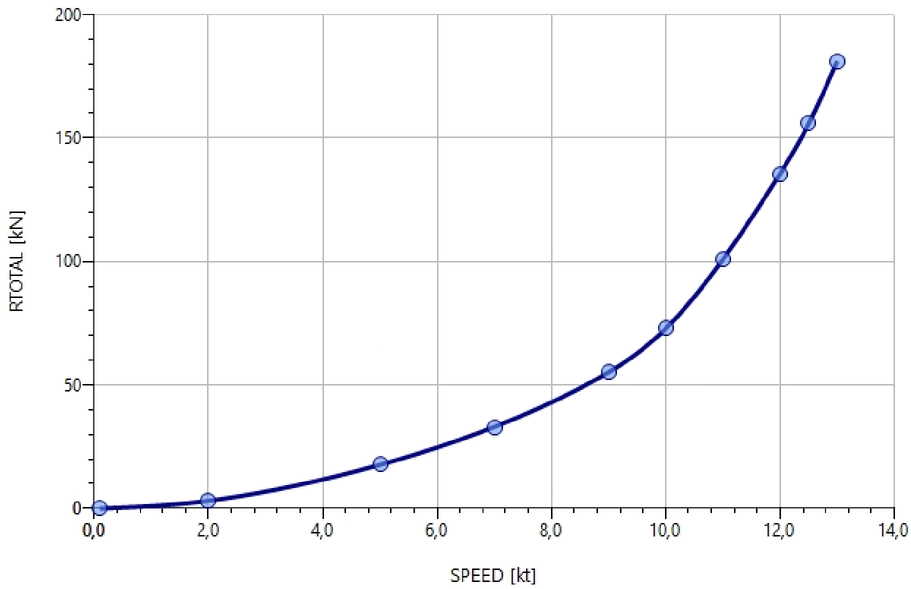
7. PREDICCIÓN DE POTENCIA

La predicción de potencia realizada para el buque proyecto, se ha hecho con el programa *"NavCad 2018"*. Se ha realizado un cálculo de potencia efectiva para resistencia al avance y predicción de potencia para un propulsor determinado.

Estimación resistencia al avance.



Vessel drag	Calc	ITTC-78 (CT)
Technique:		Prediction
Prediction:		Holtrop
Reference ship:		
Model LWL:	[m]	
Viscous		
Expansion:		Standard
Friction line:		ITTC-57
Hull form factor:	On	1,405
Speed corr:	On	
Spray drag corr:	Off	
Corr allowance:		ITTC-78 (v2008)
Roughness [mm]:	Off	
Catamaran		
Interference:	Off	
Added drag		
Appendage:	Calc	Percentage
Wind:	Off	
Seas:	Off	
Shallow/channel:	Off	
Towed:	Off	
Margin:	Calc	Hull + added drag [15...



Para la resistencia del buque se obtienen los siguientes resultados:

Resistance

7 oct 2020 08:02
HydroComp NavCad 2018

Project ID: Tug IB
Description
File name: Tug IB.hono

Analysis parameters

Vessel drag	ITTC-78 (CT)	Added drag	
Technique:	[Calc] Prediction	Appendage:	[Calc] Percentage
Prediction:	Holtrop	Wind:	[Off]
Reference ship:		Seas:	[Off]
Model LWL:		Shallow/channel:	[Off]
Expansion:	Standard	Towed:	[Off]
Friction line:	ITTC-57	Margin:	[Calc] Hull + added drag [15%]
Hull form factor:	[On] 1,405	**Water properties**	
Speed corr:	[On]	Water type:	Salt
Spray drag corr:	[Off]	Density:	1026,0000 kg/m3
Corr allowance:	ITTC-78 (v2008)	Viscosity:	1,18820e-6 m2/s
Roughness [mm]:	[Off]		

Prediction method check [Holtrop]

Parameters	FN [design]	CP	LWL/BWL	BWL/T	Lambda
Value	0,32	0,68	3,04*	2,40	0,76
Range	0,06--0,80	0,55--0,85	3,90--14,90	2,10--4,00	0,01--0,83

Prediction results

	SPEED COEFS		ITTC-78 COEFS						
SPEED [kt]	FN	FV	RN	CF	[CV/CF]	CR	dCF	CA	CT
0,10 !	0,003	0,005	1,84e6	0,004220	1,405	0,000001	0,000000	-0,000867	0,004972
2,00 !	0,063	0,099	3,29e7	0,002464	1,405	0,002499	0,000000	0,000617	0,006578
5,00	0,133	0,248	8,22e7	0,002144	1,403	0,002218	0,000000	0,000739	0,005963
7,00	0,187	0,348	1,15e8	0,002042	1,393	0,002079	0,000000	0,000759	0,005681
9,00	0,240	0,447	1,48e8	0,001970	1,364	0,002280	0,000000	0,000766	0,005734
10,00	0,266	0,497	1,64e8	0,001941	1,341	0,002764	0,000000	0,000768	0,006135
11,00	0,293	0,547	1,81e8	0,001916	1,311	0,003742	0,000000	0,000768	0,007021
+ 12,00 +	0,320	0,596	1,97e8	0,001893	1,276	0,004744	0,000000	0,000767	0,007926
12,50	0,333	0,621	2,05e8	0,001882	1,257	0,005261	0,000000	0,000767	0,008384
13,00	0,346	0,646	2,14e8	0,001872	1,238	0,005839	0,000000	0,000767	0,009024

	RESISTANCE							
SPEED [kt]	RBARE [kN]	RAPP [kN]	RWIND [kN]	RSEAS [kN]	RCHAN [kN]	RTOWED [kN]	RMARGIN [kN]	RTOTAL [kN]
0,10 !	0	0	0	0	0	0	0	0
2,00 !	3	0	0	0	0	0	0	3
5,00	15	1	0	0	0	0	2	18
7,00	27	1	0	0	0	0	4	33
9,00	46	2	0	0	0	0	7	55
10,00	60	3	0	0	0	0	10	73
11,00	84	4	0	0	0	0	13	101
+ 12,00 +	112	6	0	0	0	0	18	136
12,50	129	6	0	0	0	0	20	156
13,00	150	8	0	0	0	0	24	181

	EFFECTIVE POWER		OTHER		
SPEED [kt]	PEBARE [kW]	PETOTAL [kW]	CTLR	CTLT	RBARE/W
0,10 !	0,0	0,0	0,00001	0,05238	0,00000
2,00 !	2,7	3,2	0,02633	0,06930	0,00020
5,00	37,7	45,6	0,02336	0,06282	0,00112
7,00	98,6	119,1	0,02190	0,05985	0,00208
9,00	211,6	255,5	0,02402	0,06041	0,00348
10,00	310,5	376,0	0,02912	0,06463	0,00459
11,00	473,0	571,2	0,03943	0,07397	0,00636
+ 12,00 +	693,3	837,1	0,04998	0,08350	0,00854
12,50	829,9	1002,1	0,05543	0,08844	0,00981
13,00	1003,5	1211,7	0,06267	0,09507	0,01141

Estimación de la potencia propulsora.

La estimación de potencia realizada es para la condición de navegación en libres, en la cual el buque navega a la velocidad de servicio.

En primer lugar, se definen las condiciones tomando como velocidad de diseño 12 nudos. También se define el casco del buque, en la pestaña Hull, donde se introducen los datos del buque ya calculados, mientras el propio programa estimará otros.

Hull-propulsor	Calc	
Technique:		Prediction
Prediction:		Holtrop
Reference ship:		
Max prop diam:	[m]	2,600
Corrections		
Viscous scale corr:	On	Custom
Rudder location:		Free stream
Friction line:		ITTC-57
Hull form factor:		1,405
Corr allowance:		0,000482
Roughness [mm]:	Off	
Ducted prop corr:	On	
Tunnel stern corr:	Off	
Effective diam:	[m]	
Recess depth:	[m]	
System analysis		
Cavitation criteria:		Keller eqn
Analysis type:		Free run
CPP method:		Fixed RPM
Engine RPM:		
Mass multiplier:		
RPM constraint:		
Limit [RPM/s]:		

Project		
Project ID:	Tug IB	
Description:		
Summary		
Scope:	ITTC-78 (CT)	
Configuration:	Monohull	
Chine type:	Round/multiple	
Length on WL:	38,00	m
Displacement:	1341,00	t
Propulsor type:	Propeller	
Count:	2	
Water properties		
Water type:	Salt	
Density:	1026,0000	kg/m3
Viscosity:	1,18920e-6	m2/s
Speeds		
Speed [01]	0,10	kt
Speed [02]	2,00	kt
Speed [03]	5,00	kt
Speed [04]	7,00	kt
Speed [05]	9,00	kt
Speed [06]	10,00	kt
Speed [07]	11,00	kt
Speed [08]	12,00	kt
Speed [09]	12,50	kt
Speed [10]	13,00	kt

Hull		
Configuration:	Monohull	
Chine type:	Round/multiple	
General		
Length on WL:	38,00	m
Max beam on WL:	12,50	m
Max molded draft:	5,21	m
Displacement:	1341,00	t
Wetted surface:	724,71	m2
Demi-hull spacing:		m
ITTC-78 (CT)		
LCB fwd TR:	20,16	m
LCF fwd TR:	17,14	m
Max section area:	59,20	m2
Waterplane area:	415,40	m2
Bulb section area:	0,00	m2
Bulb ctr below WL:	0,00	m
Bulb nose fwd TR:	0,00	m
Imm transom area:	9,76	m2
Transom beam WL:	13,06	m
Transom immersion:	1,21	m
Half entrance angle:	37,52	deg
Bow shape factor:	0,0	[AVG flow]
Stern shape factor:	1,0	[WL flow]

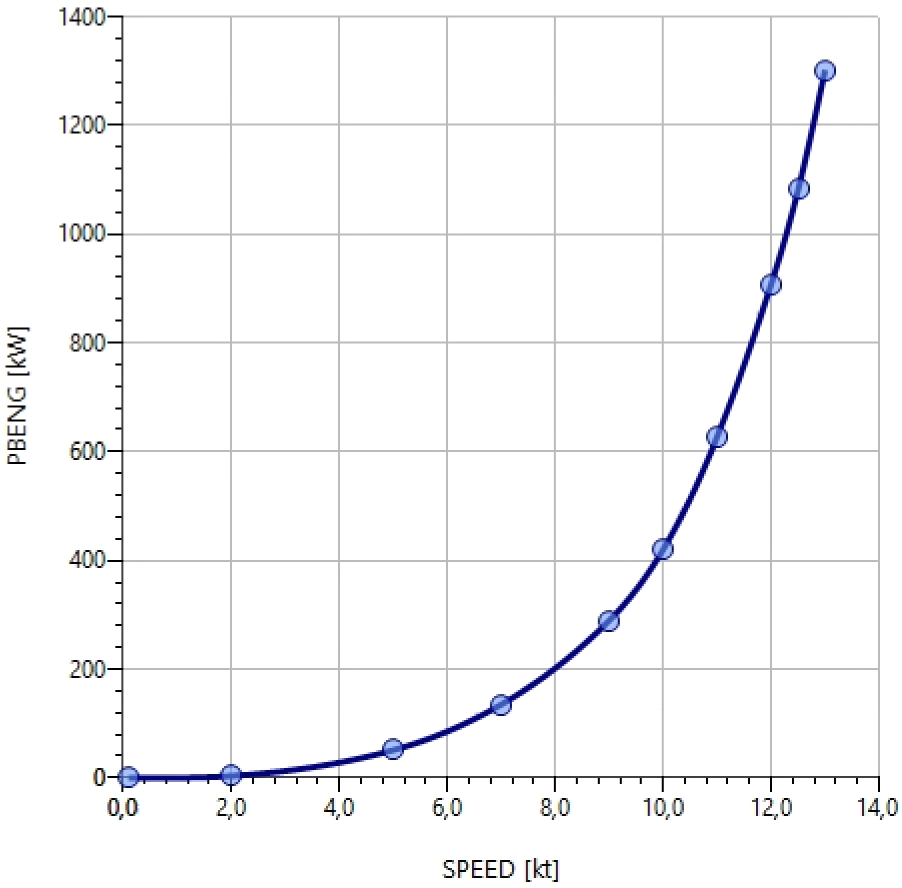
También se introducirán otros parámetros como el margen de mar y apéndices.

Appendage		
Definition:	Percentage	
Percent of hull drag:	5,00	%

Margin		
Design margin:	15	%
Basis:	Hull + added dr...	

En último lugar, se añaden los datos relativos a la hélice, en donde se establece 4 como el número de palas ya que los propulsores que llevará el buque proyecto son azimutales comúnmente de 4 palas.

Propulsor		
Count:	2	
Propulsor type:	Propeller series	
Propeller type:	FPP	
Propeller series:	B Series	
Propeller sizing:	By thrust	
Reference prop:		
Blade count:	4	
Expanded area ratio:	0,3000	
Propeller diameter:	2,600	m
Propeller mean pitch:	1,300	m
Hub immersion:	4,900	m
Engine/gear		
Drive line:	Standard	
Gear input:	Single engine	
Engine data:	None defined	
Rated RPM:		RPM
Rated power:		kW
Primary fuel:	Defined	
Secondary fuel:	None	
Gear efficiency:	1,000	
Load correction:	Off	
Gear ratio:	3,372	
Shaft efficiency:	0,980	



Propulsion

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HydroComp NavCad 2018

Project ID: Tug IB
Description
File name: Tug IB.hono

Analysis parameters

Hull-propulsor interaction		
Technique:	[Calc] Prediction	
Prediction:	Holtrop	
Reference ship:		
Max prop diam:	2,600 m	
Corrections		
Viscous scale corr:	[On] Custom	
Rudder location:	Free stream	
Friction line:	ITTC-57	
Hull form factor:	1,406	
Corr allowance:	0,000482	
Roughness [mm]:	[Off] 0,00	
Ducted prop corr:	[On]	
Tunnel stern corr:	[Off]	

System analysis	
Cavitation criteria:	Keller eqn
Analysis type:	Free run
CPP method:	
Engine RPM:	
Mass multiplier:	
RPM constraint:	
Limit [RPM/s]:	
Water properties	
Water type:	Salt
Density:	1026,0000 kg/m3
Viscosity:	1,18820e-6 m2/s

Prediction method check [Holtrop]

Parameters	FN [design]	CP	LWL/BWL	BWL/T
Value	0,32	0,68	3,04*	2,40
Range	0,06--0,80	0,55--0,85	3,90--14,90	2,10--4,00

Prediction results [System]

	HULL-PROPULSOR				ENGINE			FUEL PER ENGINE	
SPEED [kt]	PETOTAL [kW]	WFT	THD	EFFR	RPMENG [RPM]	PBENG [kW]	LOADENG [% rated]	VOLRATE [L/h]	MASSRATE [t/h]
0,10 !	0,0	0,0662	0,1109	0,9990	8	0,0	0,0	—	—
2,00 !	3,2	0,0661	0,1109	0,9990	161	3,6	0,0	—	—
5,00	45,6	0,0647	0,1109	0,9990	396	51,2	0,0	—	—
7,00	119,1	0,0642	0,1109	0,9990	548	135,1	0,0	—	—
9,00	266,5	0,0639	0,1109	0,9990	707	289,5	0,0	—	—
10,00	376,0	0,0638	0,1109	0,9990	796	420,1	0,0	—	—
11,00	571,2	0,0637	0,1109	0,9990	899	627,7	0,0	—	—
+ 12,00 +	837,1	0,0636	0,1109	0,9990	1007	908,2	0,0	—	—
12,50	1002,1	0,0635	0,1109	0,9990	1062	1082,0	0,0	—	—
13,00	1211,7	0,0635	0,1109	0,9990	1123	1302,1	0,0	—	—

	EFFICIENCY			THRUST	
SPEED [kt]	EFFO	EFFOA	MERIT	THRPROP [kN]	DELTHR [kN]
0,10 !	0,4813	0,4300	0,23687	0	0
2,00 !	0,4866	0,4525	0,28703	2	3
5,00	0,4779	0,4447	0,2686	10	18
7,00	0,4737	0,4407	0,25978	19	33
9,00	0,4745	0,4412	0,2613	31	55
10,00	0,4800	0,4463	0,27339	41	73
11,00	0,4894	0,4549	0,29814	57	101
+ 12,00 +	0,4968	0,4609	0,32092	76	138
12,50	0,4982	0,4631	0,33183	88	158
13,00	0,5006	0,4653	0,3457	102	181

	POWER DELIVERY							
SPEED [kt]	RPMPROP [RPM]	QPROP [N·m]	QENG [N·m]	PDPROP [kW]	PSPROP [kW]	PSTOTAL [kW]	PBTOTAL [kW]	TRANSP
0,10 !	2	1,45	0,43	0,0	0,0	0,0	0,0	—
2,00 !	48	696,58	206,27	3,5	3,6	7,1	7,1	—
5,00	117	4083,28	1210,86	50,2	51,2	102,4	102,4	330,2
7,00	163	7763,97	2302,31	132,4	135,1	270,3	270,3	176,2
9,00	210	12912,54	3829,06	283,8	289,5	579,1	579,1	106,1
10,00	238	16848,07	4836,18	411,7	420,1	840,2	840,2	80,5
11,00	267	22010,55	6526,98	615,2	627,7	1255,5	1255,5	59,3
+ 12,00 +	298	28445,22	8435,08	890,0	908,2	1816,4	1816,4	44,7
12,50	316	32119,26	9524,67	1060,3	1082,0	2163,9	2163,9	39,1
13,00	333	36556,67	10840,43	1276,1	1302,1	2604,3	2604,3	33,8

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Prediction results [Propulsor]

	CAVITATION								
SPEED [kt]	SIGMAV	SIGMAN	SIGMA07R	TIPSPEED [m/s]	MINBAR	PRESS [kPa]	CAVAVG [%]	CAVMAX [%]	PITCHFC [m]
0,10 !	125807,06	30100,38	6830,69	0,31	0,067	0,00	2,0	2,0	1,422
2,00 !	314,44	67,77	13,42	6,60	0,073	1,10	2,0	2,0	1,390
5,00	50,16	11,24	2,22	15,96	0,093	6,25	2,0	2,0	1,402
7,00	26,57	5,84	1,15	22,15	0,114	11,68	2,0	2,0	1,407
9,00	15,48	3,52	0,69	28,54	0,145	19,48	2,0	2,0	1,406
10,00	12,62	2,78	0,55	32,12	0,170	25,73	2,0	2,0	1,399
11,00	10,34	2,17	0,43	36,30	0,210	35,63	2,0	2,0	1,383
+ 12,00 +	8,69	1,74	0,34	40,63	0,260	47,88	2,0	2,0	1,369
12,50	8,01	1,58	0,31	42,87	0,288	55,02 !!	2,7	2,7	1,362
13,00	7,40	1,39	0,28	45,33	0,324	63,97 !!	4,0	4,0	1,353
	PROPULSOR COEFS								
SPEED [kt]	J	KT	KQ	KT/J2	KQ/J3	CTH	CP	RNPROP	
0,10 !	0,4881	0,0496	0,00838	0,20712	0,071465	0,52741	1,1448	8,37e4	
2,00 !	0,4842	0,0592	0,00900	0,27452	0,089893	0,69906	1,4414	1,79e6	
5,00	0,4735	0,0556	0,00877	0,2481	0,082624	0,63177	1,3233	4,33e6	
7,00	0,4779	0,0539	0,00866	0,23617	0,079342	0,6014	1,2708	6,01e6	
9,00	0,4771	0,0542	0,00868	0,23819	0,079897	0,60658	1,2797	7,74e6	
10,00	0,4711	0,0565	0,00883	0,25477	0,084472	0,64876	1,3529	8,70e6	
11,00	0,4586	0,0613	0,00914	0,29149	0,094797	0,74227	1,5183	9,82e6	
+ 12,00 +	0,4469	0,0657	0,00943	0,32901	0,10561	0,83781	1,6915	1,10e7	
12,50	0,4413	0,0678	0,00958	0,3484	0,11129	0,88719	1,7826	1,16e7	
13,00	0,4340	0,0706	0,00974	0,3745	0,11906	0,95367	1,9069	1,22e7	

Para el buque proyecto en este primer estudio preliminar se concluye que es más eficiente una hélice de 4 palas.

- PB TOTAL = 1818,4 KW

La potencia obtenida por medio del programa "*NavCad*" es mucho más baja que la obtenida mediante la regresión lineal con respecto a los TPF necesarios, por lo tanto, esto viene a decir, que necesitaremos más potencia que la obtenida mediante el programa para que el buque pueda mantener los TPF exigidos en la RPA.

Por lo tanto, se instalará una planta diésel-eléctrica, cuyo funcionamiento se basa en dos motores eléctricos encargados de suministrar el movimiento a la hélice, los cuales son alimentados por varios generadores con su correspondiente alternador.

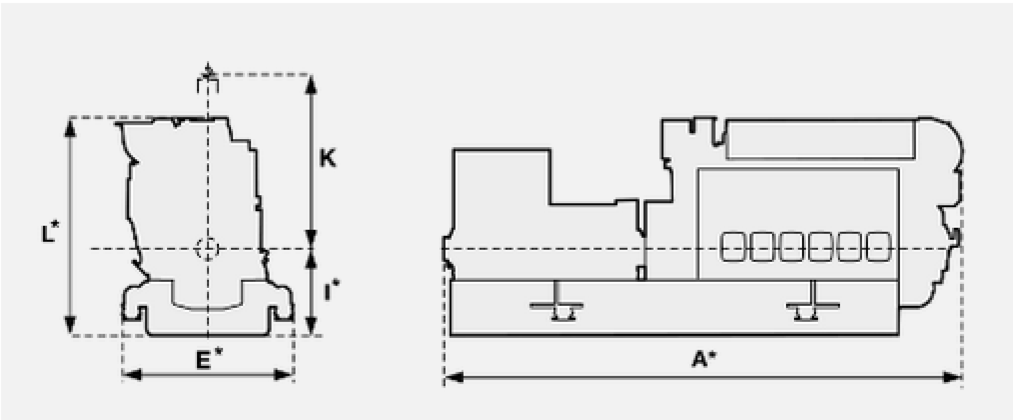
La potencia necesaria para el buque proyecto será la necesaria para la condición de remolque que es de 6022KW.

ELECCION DE LA PLANTA GENERADORA:

El motor generador seleccionado es el Wärtsilä 12V26 con una potencia de 3915 kW. Se instalarán dos motores de las mismas características.

Genset 26, Rated power

Engine type	60 Hz		50 Hz	
	325 kW/cyl, 900 rpm		340 kW/cyl, 1000 rpm	
	Eng. kW	Gen. kW	Eng. kW	Gen. kW
6L26	1 950	1 870	2 040	1 960
8L26	2 600	2 495	2 720	2 610
9L26	2 925	2 810	3 060	2 940
12V26	3 900	3 745	4 080	3 915
16V26	5 200	4 990	5 440	5 220



8. CÁLCULO PREELIMINAR DE PESOS

Se realizará un estudio preliminar de los pesos del buque con las dimensiones finales obtenidas anteriormente.

El desplazamiento se puede dividir en:

- Peso en rosca
- Peso muerto

Peso en rosca

El peso en rosca del buque puede ser desglosado en tres bloques, peso del acero, peso de la maquinaria y pesos de equipos y habilitación.

PESO DEL ACERO:

En cuanto al peso del acero utilizamos la fórmula del libro ``*Cálculo del desplazamiento*`` de Fernando Junco, a la cual le añadimos un 8% mas de peso ya que el buque es un rompehielos. Por lo tanto:

$$P.acero = 1{,}08 \cdot 0{,}14 \cdot Lpp \cdot B \cdot D$$

$$P.acero = 1{,}08 \cdot 0{,}14 \cdot 38 \cdot 12{,}5 \cdot 6{,}65$$

$$P.acero = 477{,}6\ t$$

El cálculo del peso del acero del buque también se puede realizar de otra manera, tal y como hemos realizado en el cálculo de alternativas, a través de la siguiente fórmula.

También tendremos en cuenta un 8% más de acero por el hecho de que el buque es un rompehielos.

$$P.acero = 1{,}08 \cdot 0{,}094 \cdot Lpp \cdot B \cdot D \cdot \frac{Lpp^{\frac{1}{2}}}{D}$$

$$P.acero = 1{,}08 \cdot 0{,}094 \cdot 38 \cdot 12{,}5 \cdot 6{,}65 \cdot \frac{38^{\frac{1}{2}}}{6{,}65}$$

$$P.acero = 766{,}56\ t$$

Viendo las diferencias de peso de una fórmula respecto la otra, se realiza una media entre ambas para alcanzar un valor estimado.

$$P.acero = 622\ t$$

PESO MAQUINARIA:

El peso de la maquinaria se obtendrá mediante la fórmula utilizada en el libro *Proyectos de buque y artefactos*

$$P.maq = 0{,}03 \cdot BHP$$

$$P.maq = 0{,}03 \cdot 6022 \cdot 1{,}34\ cv$$

$$P.maq = 242{,}08\ t$$

PESO DE EQUIPO Y HABILITACIÓN:

El peso de equipo y habilitación puede deducirse aproximadamente a partir de esta fórmula.

$$P.equ = 0{,}8 \cdot L^{0{,}797} \cdot (B + 0{,}8245 \cdot D + 1{,}85 \cdot T)^{0{,}787}$$

$$P.equ = 205{,}23\ t$$

En conclusión, se obtiene un valor de peso en rosca de:

$$P.Rosca = 622 + 242{,}08 + 205{,}23$$

$$P.Rosca = 1069{,}4\ t$$

Peso muerto

El peso muerto se obtiene mediante un cálculo de los distintos pesos que lo componen.

- Consumos
- Tripulación y pasaje
- Pertrechos

CONSUMOS:

Los consumos son cargas que varían durante la navegación que dependen de la autonomía del buque. Se pueden clasificar en combustibles, aceites, agua dulce y víveres.

- Combustible:
  A efectos de consumos, se utiliza una cifra orientativa de la autonomía: 3000 millas. Para una velocidad de 12 nudos, el número de horas será de 250 horas.
  Según las especificaciones de nuestro motor, el consumo es de 190g/Kwh trabajando al 85% de MCR.
  El combustible necesario para cumplir dicha autonomía es:

$$Consumo = 190 \cdot 1280 \cdot 250 \cdot 2 \cdot 10^{-6}$$

$$Consumo\ combustible = 121{,}6\ t$$

- Aceites:
  En el buque se utilizan diversos aceites para los distintos servicios como la lubricación de motores. En los servicios de lubricación es normal disponer de un tanque igual o ligeramente superior al de servicio, como reserva.
  Según el libro *El proyecto básico del buque mercante* el peso del tanque de servicio se puede estimar un peso del 3% del peso del combustible.

$$Aceites = 0{,}03 \cdot 121{,}6$$
$$Aceites = 3{,}65\ t$$

- Agua dulce:
  En el buque se utiliza agua dulce en diversos servicios como el de refrigeración, alimentación de calderas, sanitarios y agua potable.
  Para el agua sanitaria y potable se estima un consumo de 150 litros por persona y día, teniendo en cuenta los 6 tripulantes que lleva a bordo el buque proyecto.

$$P.agua = 150 \cdot 6 \cdot \frac{250}{24}$$

$$P.agua = 9{,}37\ t$$

  En cuanto al agua de refrigeración se estima un valor de 3 toneladas, de manera que el peso total de agua dulce será de:

$$P.agua\ dulce = 12{,}37\ t$$

- Víveres:
  En cuanto a los víveres, se recomiendan 5 kg por persona y día, por lo tanto:

$$P.víveres = 5 \cdot 6 \cdot 250/24$$

$$P.víveres = 0{,}31\ t$$

PERTRECHOS:

Se consideran pertrechos todos aquellos elementos que el armador añade como repuestos o necesidades adicionales del buque. El peso de los pertrechos es muy variable y para el buque proyecto se estima en un valor de:

$$P.Pertrechos = 14\ t$$

TRIPULACIÓN Y PASAJE:

Se estima un peso de 125 kg por persona, teniendo en cuenta que el buque proyecto lleva una tripulación de 6 personas:

$$P.tripulación = 6 * 125$$

$$P.tripulación = 0{,}75\ t$$

Sumando todos los valores obtenidos, se obtiene un valor de peso muerto de:

$$Peso\ Muerto = 152{,}68\ t$$

A continuación, se observan todos los pesos calculados anteriormente

PESO ACERO	
1ªForma	477,60
2ªForma	766,56
Total peso acero	**622,08**
PESO MAQUINARIA	
Peso maquinaria	**242,08**
PESO EQUIPOS Y HABILITACIÓN	
Peso equipos y habilitación	**205,22**
PESO EN ROSCA	**1069,40**

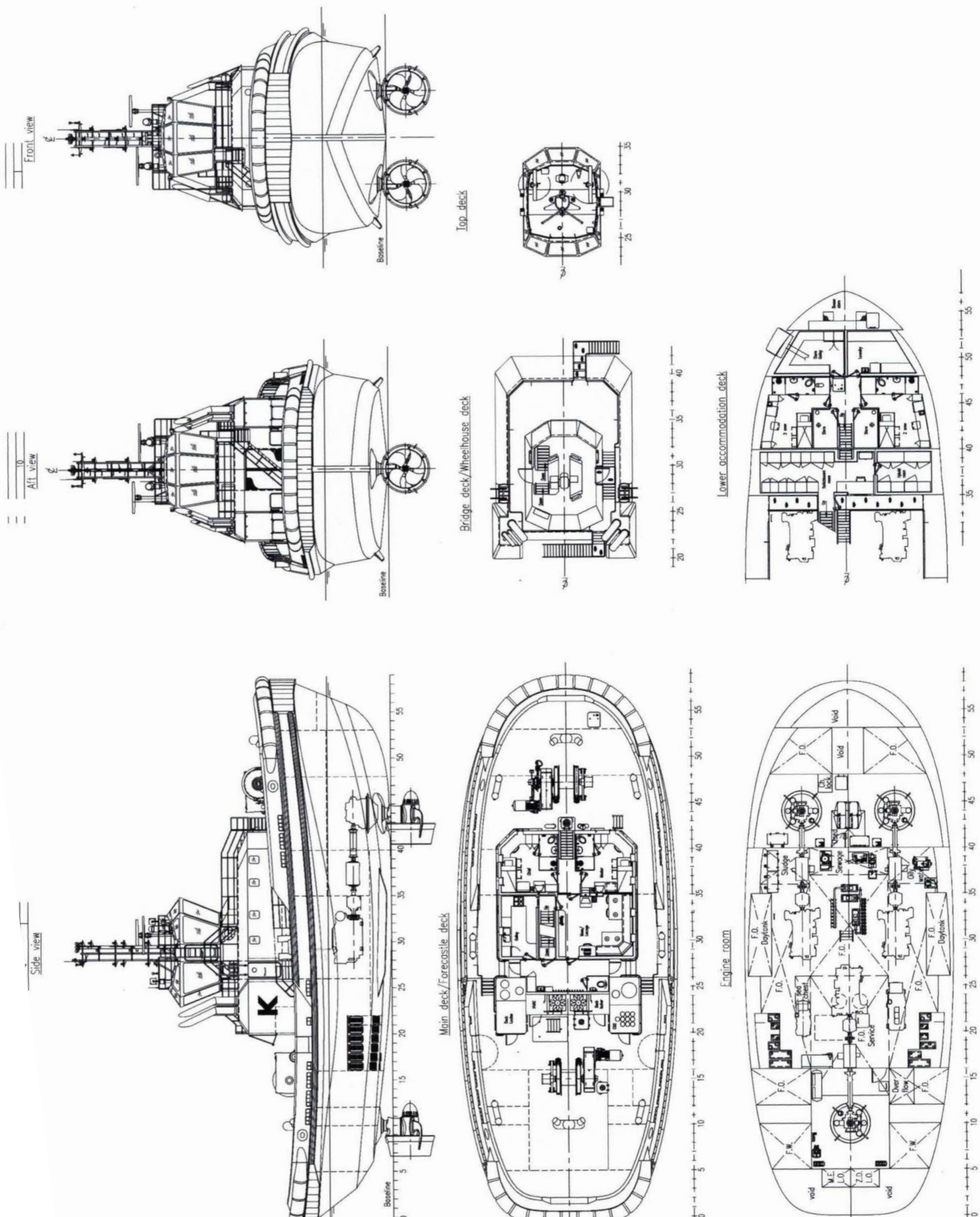
PESOS CONSUMOS	
Peso combustible	**121,6**
Peso aceites	**3,64**
Agua potable	9,37
Agua refrigeración	3
Agua dulce	**12,37**
Víveres	**0,31**
TOTAL	**137,93**
PERTRECHOS	
Pertrechos	**14**
TRIPULACIÓN Y PASAJE	
Tripulación	**0,75**
PESO MUERTO	**152,68**

La suma del peso en rosca y del peso muerto debe ser el desplazamiento del buque proyecto.

$$Desplazamiento = 152{,}68 + 1069{,}4 = 1222\ t$$

El desplazamiento obtenido en las alternativas es de 1034 t, por lo que hemos obtenido un valor aproximado a este. Podemos deducir que las toneladas restantes no las tenemos en cuenta y que están dentro de un margen.

ANEXO I: Disposición general "RT Emotion"


Front view
Aft view
Top deck
Bridge deck/Wheelhouse deck
Lower accommodation deck
Side view
Main deck/Forecastle deck
Engine room
Baseline

ANEXO II: Buques de la base datos

DUX: Dual-fuel LNG/diesel escort tug, designed for ops in harsh environments

Builder	**Astilleros Gondán**
Designer	**Robert Allan Ltd**
Vessel's name	***Dux***
Owner/operator	**Østensjø Rederi AS**
Country	**Norway**
Flag	**Norway**
Total number of sister ships already completed	**2**
Total number of sister ships still on order	**0**
Contract date	**August 2015**
Delivery date	**May 2017**

Built at Astilleros Gondán's yard in Spain, the dual-fuel tug *Dux* represents the first in Robert Allan Limited (RAL)'s RAstar 4000-DF dual-fuel LNG/diesel escort tug class, specifically designed for operations at Statoil's Melkøya LNG terminal at Hammerfest, Norway, where temperatures can easily plummet to -8°C or lower.

In addition to her escort tug duties, the 40.2m loa, steel vessel has also been equipped to undertake firefighting and oil spill clean-up duties, in temperatures as low as -20°C.

The power arrangement aboard *Dux* comprises two Wärtsilä 6L34 dual-fuel (DF) main engines, rated 3,000kW apiece, and Wärtsilä's integrated LNGPac gas handling system. Based on an IMO Type C LNG storage tank (as most commonly used aboard small-to-medium-sized hybrid or LNG-powered ferries and offshore support vessels), the LNGPac is a vacuum-isolated tank which, in *Dux*'s case, can be accessed via the engine room via an A-60-rated watertight door.

The LNGPac contains a tank connection space (TCS) within the LNG tank hold, and this TCS contains: liquid and vapour LNG tank connections; a pressure build-up evaporator (PBE), which builds up and maintains adequate pressure within the tank (approximately 5bar, Wärtsilä claims); a main gas evaporator; and a gas valve unit (GVU) for each tank. Wärtsilä says: "By combining the LNGPac and the GVU into a single system, considerable space can be saved… [as can] installation time and costs for the yard." RAL adds: "The TCS is accessed from within the tank hold by an air lock, which is integrated with the TCS and is supplied as part of the LNGPac system."

The LNG bunker station is located on *Dux*'s main deck, and bunkering can be conducted either from bunkering barge-to-ship or from a quayside tank truck. To protect the hull from any cryogenic damage that might result from spilled LNG, the LNG bunker station has been fitted with a foldable drip tray and features provisions for water flushing.

Whilst assessing *Dux*'s needs, one particular challenge concerned the vessel's vent mast. Typically, LNG-fuelled vessels release small quantities of gas as a natural result of pressure build-up, commonly via pressure relief valves and 'block and bleed' piping valves. The onboard vent mast, therefore, provides an outlet for these emissions and a means of dispelling natural gas into the atmosphere.

Obviously, for safety reasons, it is strongly recommended that the vent mast is not located near potential sources of ignition (such as engine exhaust outlets). Under the terms of the International Code for Ships using Gases and other Low Flashpoint Fuels (IGF Code), which applies to all vessels of more than 500gt and deploying LNG fuel systems, the vent mast should be positioned at a distance of 10m from such sources of ignition.

Given the RAstar 4000-DF's 40.2m length, this recommended distance would be rather difficult to guarantee. Not only that but, in relation to the tug's size, the vent mast would have to feature a low profile so as not to impact on ship-handling and manoeuvrability.

Instead of deploying a conventional vent mast, therefore, RAL produced what it describes as "a unique double-wall vent mast". The architect says: "Ventilation air forced through the outer annulus mixes with any vented gas carried by the inner pipe at the outlet. The resulting mixture is carried safely away by the ventilation air flow."

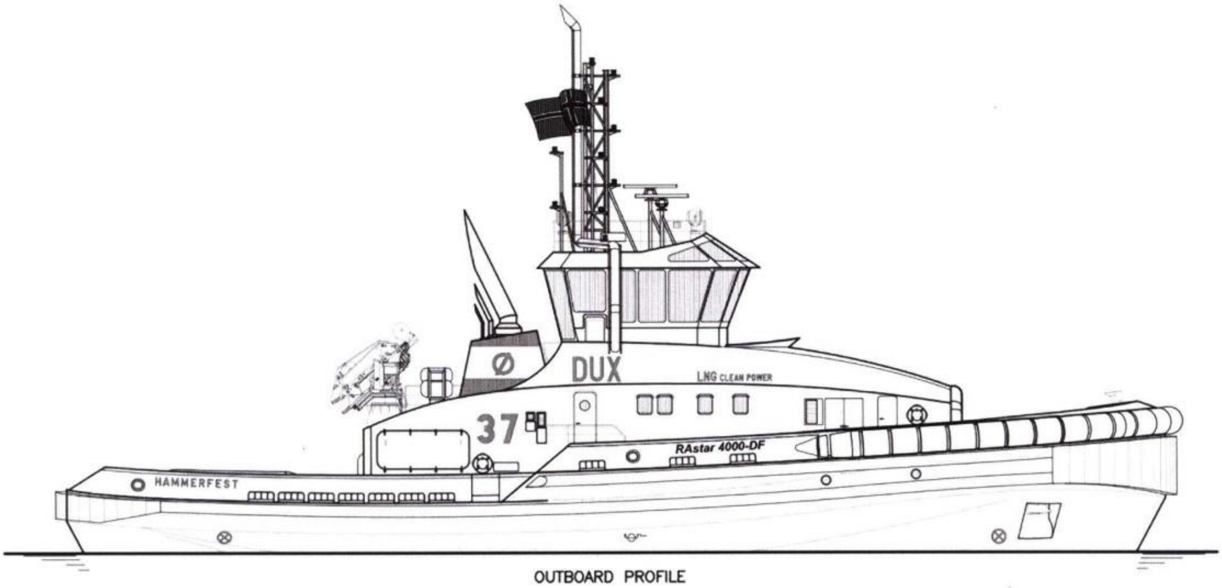
Additionally, noise has been reduced to just 56dBA on the bridge and to 50.8dBA in the mess/galley area and 50dBA in the master's cabin. Crew members sleeping in the four cabins situated on the lower deck get an even better deal, with noise levels restricted to 45-47dBA in these quarters. The machinery control room also manages to reduce noise levels to a respectable 73dBA – certainly loud but, arguably, not unbearably so, given that room's function.

Dux has been reinforced with a 1,000mm-diameter cylindrical fender extending well aft along with a lower course of 400mm-thick W-fender, designed to limit fender contact pressures to 20tonnes per m². Sheer fendering comprises 400mm x 400mm D-fender, while the stern is protected by a 400mm-thick W-fender.

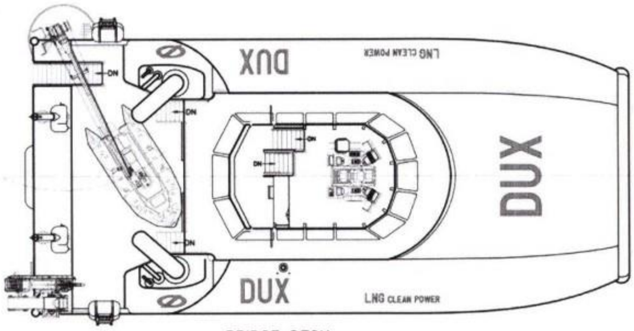
Dux's firefighting system can throw water at 2.4 million litres per hour over distances of more than 120m. The arrangement includes two Eureka pumps, rated 1.5 million litres per hour, driven off the front of the main engines via Kumera gearboxes, and Jason monitors rated 1.2 million litres per hour for water and 300,000litres per hour for foam.

TECHNICAL PARTICULARS

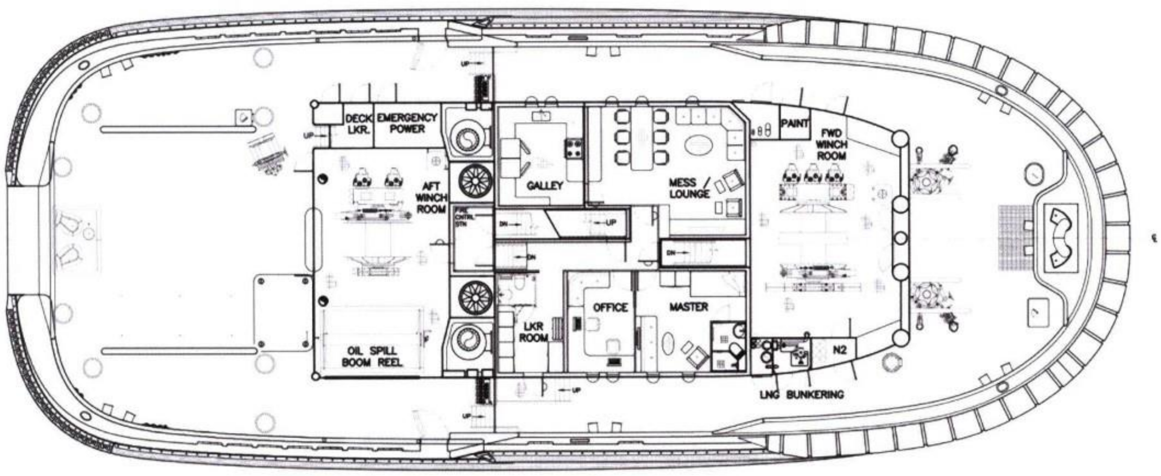
Length, oa	40.2m
Length, bp	38.5m
Breadth, moulded	16m
Depth, moulded	6.10m
Gross tonnage	1,056tonnes
Displacement	1,545.9tonnes
Design, draught	6.7m
Design, deadweight	241.6tonnes
Max speed	15knots
Bollard pull	100tonnes
Classification society	Bureau Veritas
Notations	BV ✠ 1 ✠ Hull, ✠ Mach, Escort Tug (design max steering force = 167tonnes, design max braking force = 212tonnes, rated escort speed = 10knots), FireFighting Ship 1, Water spraying, Oil recovery ship, Dual fuel, Unrestricted navigation, ✠AUT-UMS
Main engine(s)	
Make	Wärtsilä
Model	6L34DF
Number	2
Output of each engine	3,000kW@750rpm
Z-Drive(s)	
Manufacturer	Schottel SRP 3030 CP
Number	2
Fixed/controllable pitch	Controllable
Diameter	3,400mm
Speed	750rpm input speed
Special adaptations	Low drag nozzle
Open or nozzled	Nozzled
Alternator(s)	
Make	Volvo Penta D7A T KC
Number	3
Output of each set	129kWe@1,500rpm
Bow thruster(s)	
Make	Schottel STT 170 FP
Number	1
Output of each	250kW
Crane(s)	1 x crane, SWL 65 metric tonnes
Winch(es)	
Manufacturer	Karmoy Winch
Number	3
Capacities	
Hawser/escort	235tonnes pull w' 300tonnes brake
Towing	131tonnes pull w' 300tonnes brake
Tugger winch	9tonnes pull
Onboard capacities	
Fuel oil	313,800litres
LNG	33,000litres gross
Fresh water	45,600litres
Recovered oil	254,200litres
Ballast water	114,000litres
Complement	
Crew	8
Passengers	0
Number of cabins	5



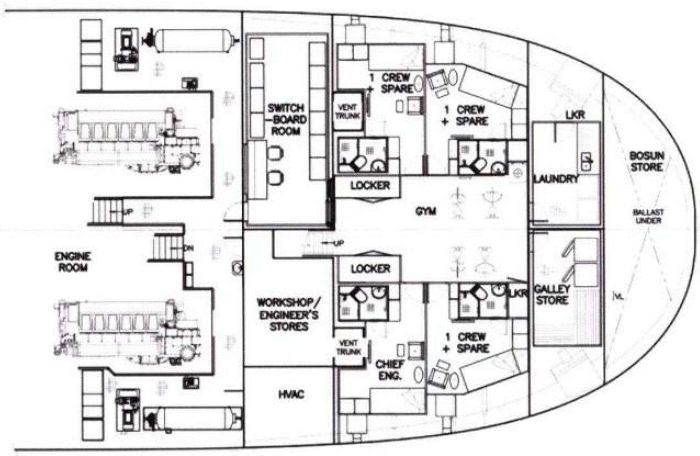
OUTBOARD PROFILE



BRIDGE DECK



MAIN DECK



LAMNALCO SANA'A: High-performance fire-fighting tug for Lamnalco Group

Builder's name	**Med Marine, Eregli Shipyard, Turkey**
Designer	**Robert Allan Limited, Canada**
Vessel's name	***Lamnalco Sana'a***
Owner/operator	**Lamnalco Group**
Country	**Sharjah, United Arab Emirates**
Flag	**British Virgin Islands**
Total number of sister ships already completed	**3 (including *Lamnalco Sana'a*)**
Total number of sister ships still on order	**1**
Contract date	**October 2007**
Delivery date	**April 2009**

Lamnalco Sana'a, the first in a series of four new high-performance terminal/escort tugs, was delivered by Med Marine of Turkey to Lamnalco Group of the United Arab Emirates in April 2009. Two of the other sister vessels *Lamnalco Aden* and *Lamnalco Mukalla* were delivered later in 2009.

Lamnalco Sana'a is the latest in a series of RAstar tugs being built for liquefied natural gas (LNG) terminal operations worldwide to new designs developed by Robert Allan Ltd., naval architects of Vancouver, British Columbia.

This powerful escort tug is equipped for typical ship-handling and escort work, with a Plimsoll model PC-HAETW/CDDG-26-50/250 double-drum hawser winch on the fore deck, with a capacity for each drum of 300m, 64mm diameter plus 150m of 80mm UHMWPE synthetic hawser. The escort-rated winch is driven by a twin-pump electro-hydraulic set, and features a two speed drive system, capable of line recover/rendering at 50tonnes line pull at 20m/minute, or 16tonnes at 60 m/minute (first layer).

The aft deck is fitted with a heavy duty towing winch, a Plimsoll model PC-HTW/SD-80/150, fitted with 750 m of 52 mm diameter SWR, with a brake capacity of 150 t. The aft deck is also fitted with Plimsoll pneumatic towing hook with rated load of 100tonnes and a large knuckle boom crane.

Accommodations are to a very high standard for a crew of up to ten persons. Two spacious officer's cabins on the main deck each have private en-suite facilities, while two of the four double cabins below deck also have private en-suite facilities.

The fully equipped galley serves a large common lounge/mess area, equipped with the latest in video and audio entertainment systems.

Attention was paid throughout the design process to mitigating the propagation of noise and vibration through the essential resilient mounting of the main engines, isolation of all exhaust system components, and the extensive use of visco-elastic floating floor systems throughout.

The wheelhouse is designed to provide maximum all-round visibility from a single split type master console.

Lamnalco Sana'a is built in accordance with Bureau Veritas regulations for a 1 ✠ Hull, ✠ Mach ✠ Escort Tug, Fire Fighting Ship 1 with water spray, AUT UMS, unrestricted service.

The fire-fighting capability is provided by a pair of FFS main-engine driven pumps, each rated 1378m³/hour, which serve a pair of FFS-1200SB water/foam monitors, each rated at 1,200m³/hour, and the self-protection waterspray system.

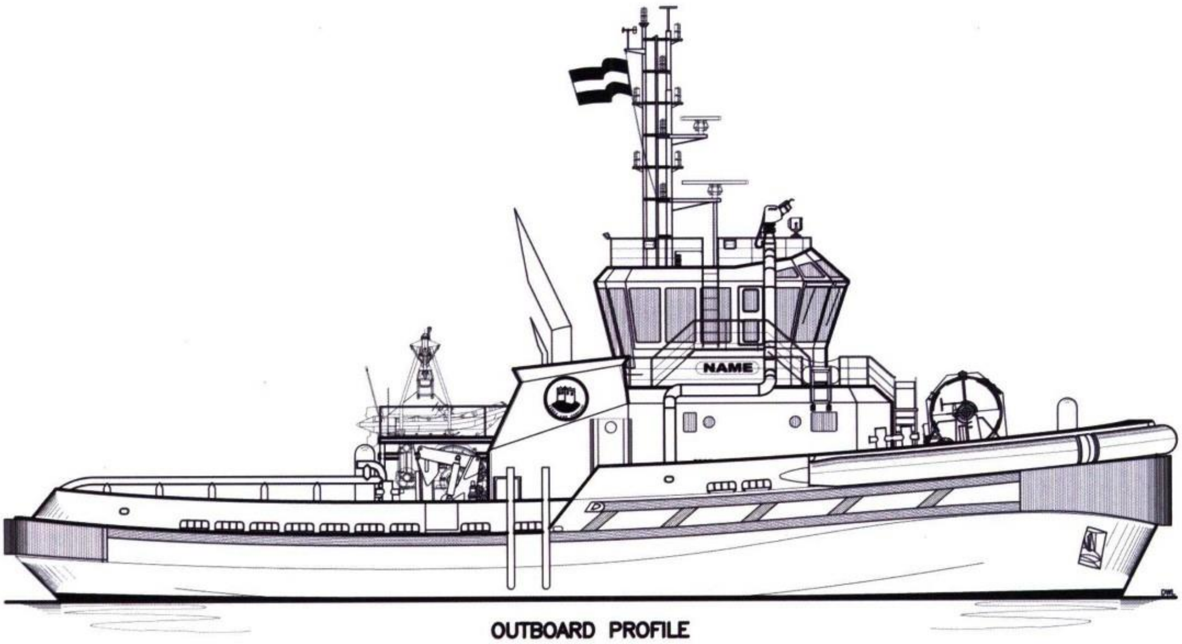
Electric power is developed by three 315kW diesel gensets, and by a third harbour/emergency genset, rated at 90kW.

The main propulsion components include a Wärtsilä 9L26 rated at 3060kW at 1000rpm at 100% MCR and LIPS Model CS300-S1WN-K Z-Drives with an input power of 3060kW at 1000rpm.

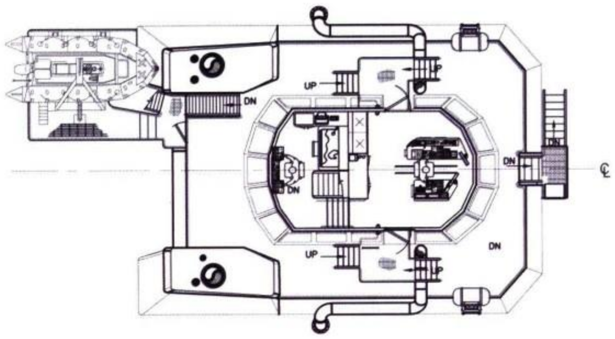
The RAstar design hull form incorporates a significant sponson on the upper hull sides. When the tug is heeled over under influence of the towline during an escort operation, the "downhill" sponson is submerged and a large righting force is generated to improve the stability, thus increasing the towline force. In addition, the hull has a large foil-shaped skeg, also designed to increase indirect towline forces. The RAstar hull form also provides dramatic reductions in roll amplitude and roll accelerations, thus providing a safer and more comfortable platform for crews, who are now being asked to conduct docking operations at LNG terminals and similar installations in up to sea-states of 3.0m significant wave heights.

TECHNICAL PARTICULARS

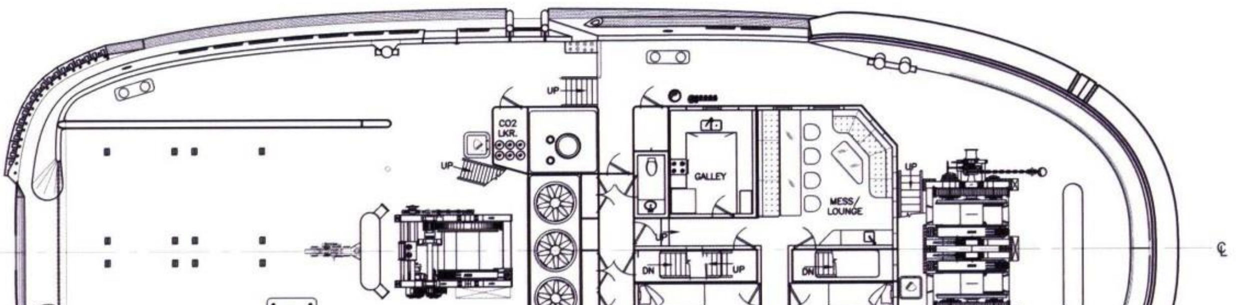
Length, oa	35.8m
Length, bp	32.93m
Breadth moulded	14.50m
Depth, moulded	6.03m (above design baseline)
Gross tonnage	724gt
Displacement	1355tonnes (full load, without deck cargo)
Design, draught	4.75m
Draught, max operating	6.50m (to underside of drives)
Design, deadweight	490tonnes including 100tonnes of deck cargo
Lightweight	963tonnes
Maximum speed	15kts
Bollard pull, ahead	118tonnes max
Classification society and notations	Bureau Veritas 1 ✠ HULL, ✠ Mach, Escort Tug, Fire Fighting Ship 1 with water spray, AUT UMS, unrestricted service
Main engine(s) kW units preferred	
Make	Wärtsilä
Model	9L26
Number	2
Output of each engine	3060kW at 1000rpm at 100% MCR
Gen-set	
Make	Scania
Model	DI12 62M
Number	2
Output power	315kW
Propeller(s)	Z-drives - 2
Material	Ni-Al-Bronze
Manufacturer of Z-drive	Wärtsilä LIPS
Number	CS300-S1WN-K
Fixed/Controllable pitch	CPP
Diameter	3m
Speed	218rpm
Open or nozzled	nozzle LIPS HR
Bow thruster(s)	
Make	Aqua-Manoeuvra Systems
Number	1
Output of each kW (bhp) and rev/min	200kW at 2925kg-f
Deck machinery (winches, two pins, tow hooks, stern rollers, cranes etc)	
Hawser winch: Plimsoll PC-HAETW/CDDG-26-50/250 double drum	
Towing winch: Plimsoll PC-HTW/SD-80/150	
Towing hook: Plimsoll 100tonnes SWL	
Bridge electronics	
Radars make/model	2 x JRC JMA-5210-6 and JRC JMA-5104
Autopilot make/model	Navitron NT990-G
GMDSS make/model	JRC JUE-85
GPS make/model	JRC NWZ 4570
Gyro	Yokogawa CMZ-900B
Chart plotter	JRC
Engine monitoring/fire detection system	Thorn
Complement	
Crew	10
Number of cabins	6
Other significant or special items of equipment	
Fire pumps:	
Number	2
Capacity	1378m³/hour
Water/foam monitors:	
Number	2
Make	FFS-1200SB
Capacity	1200m³/hour



OUTBOARD PROFILE



WHEELHOUSE PLAN



MAIN DECK PLAN

LUISA NERI: Advanced tug with special winch for improved safety and flexibility

Builder .... **Damen Shipyards Group**
Designer .... **Damen Shipyards Group**
Vessel's name .... ***Luisa Neri***
Owner/operator ...... **Fratelli Neri S.p.A Livorno**
Country .... **Italy**
Flag .... **Italy**
Total number of sister ships
already completed **0**
Total number of sister ships
still on order **0**
Contract date **2015**
Delivery date .... **January 2016**

As the first Damen-designed and built ASD Tug 3212, *Luisa Neri* arrived at her home port of Livorno (Leghorn), Italy at the beginning of 2016, just five months after owner/operator Fratelli Neri signed the contract for her construction. Having been built for stock simplified this process, freeing up Damen Maaskant Shipyards Stellendam to concentrate on the final outfitting works. The Port of Livorno is acknowledged as being a challenging harbour in which to operate, due to a series of tight turns that require optimal vessel manouevrabilty to negotiate.

One of *Luisa Neri*'s key significant features is a render-recovery towing winch, also designed by Damen, which is intended to lead to improved safety and flexibility when the vessel is partaking in towing and escorting operations – and which enables the tug's operators to work in a variety of tough offshore environments.

The render-recovery winch works by preventing the high peak loads that can occur in the towing wire in rough conditions, Damen explains. This is accomplished by rendering speeds of up to 100m/min with a line force of 100tonnes and recovery speeds up to 50m/min with a line force of 60tonnes.

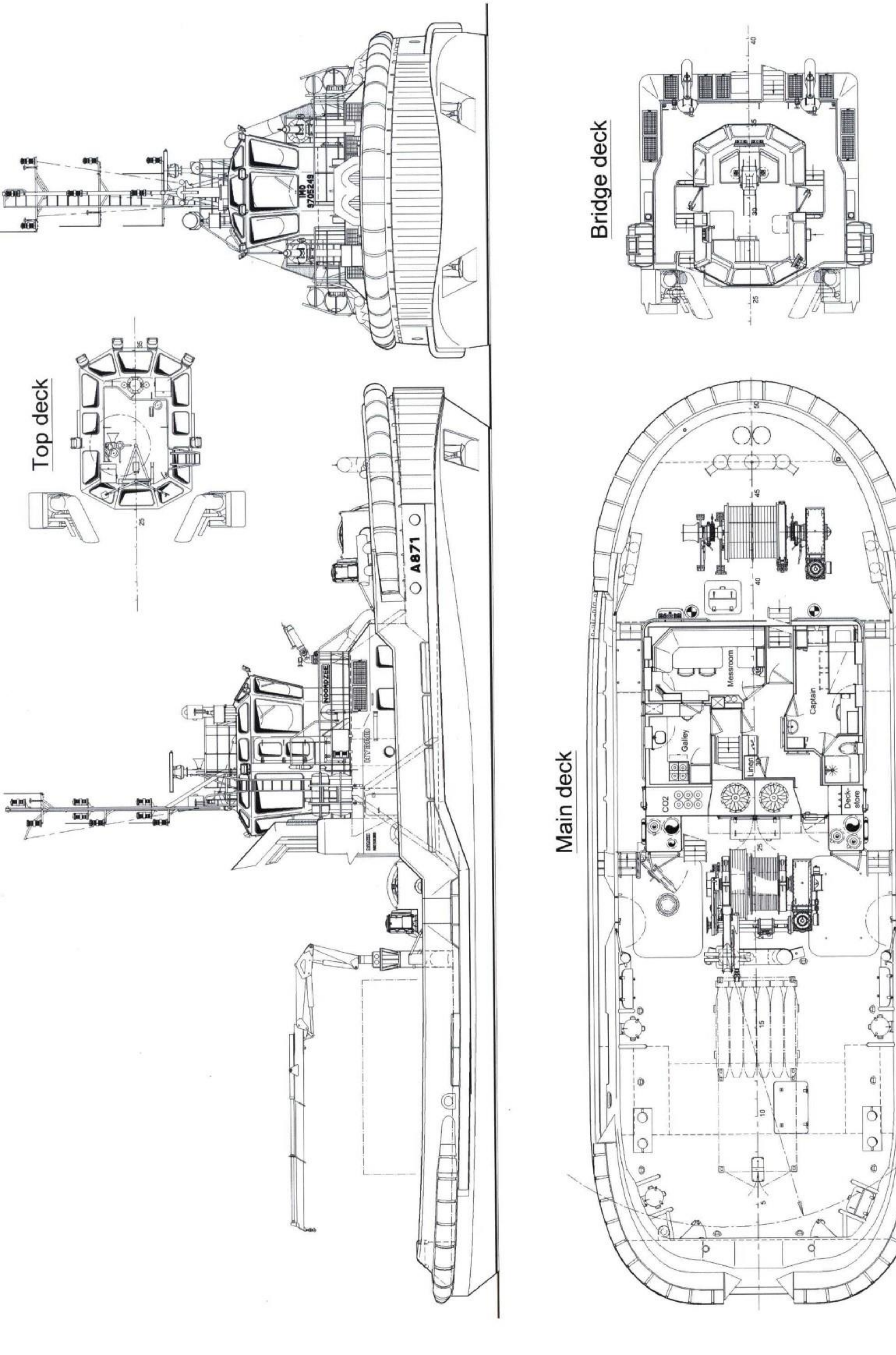
According to Erik van Schaik, Damen senior design and proposal engineer: "The render-recovery winch gives tug captains an outstanding degree of flexibility; they can work with various operating modes depending on the weather, the sea conditions and the work needed to be done. These modes are used to control either the distance or the forces acting between tug and the vessel it is assisting."

The aft towing winch, meanwhile, is a single drum towing winch, with 750m of steel towing wire on the drum. Because the winches are not provided with gearboxes, the design has been kept relatively compact and maintenance-friendly.

Other features include a high degree of dynamic stability, conferred by *Luisa Neri*'s deep skeg, bilge keels and relatively low wheelhouse, which ensure low accelerations for increased comfort, safety and seakeeping performance. The vessel is also equipped with a fendering system with a large contact area, for low static contact pressure, while a combination of a large freeboard, more pronounced V-shaped frames in the lines of the fore ship and a raised forecastle deck help to keep the working deck dry.

TECHNICAL PARTICULARS

Length, oa 32.7m
Breadth, oa 12.82m
Depth .... 5.35m (at sides)
Gross tonnage 453tonnes
Displacement 815tonnes
Design, draught 5.51m
Max speed 14.3knots
Classification society .... RINA
Notations .... C ✠ HULL • MACH
Escort Tug Unrestricted Navigation AUT UMS INWATERSURVEY Fire Fighting Ship 1 Water spray Oil Recovery Ship, Second Line, Supply vessel, Oil product (flame point>60°C)
Bollard pull .... 80.8tonnes (ahead)
74.9tonnes (astern)
Main engine(s)
Make .... Caterpillar
Model .... 3516C HD+ TA/D
Number 2
Output of each engine ...... 5,050bkW@1,800rpm
Propeller(s)
Material .... NiAlBr
Manufacturer .... Rolls-Royce
Model .... US 255 P30 CP Special
Number 2
Fixed/controllable pitch .... Fixed
Diameter 2,800mm
Open or nozzled .... Nozzled
Thuster(s)
Make .... Rolls-Royce US 255 P30 CP Special
Number 2
Deck machinery ..... 1 x Heila HLM 20-3S crane, 1.7tonnes@10.56m SWL
2 x Damen Marine Components winches, hauling speed anchor part minimal 10m/min
1 x render/recovery towing winch
1 x capstan, 5tonnes@15m/min
1 x Mampaey towing hook, aft, 100tonnes SWL
1 x towing winch, aft (hydraulically driven, single drum winch with spooling device and warping head, pull 30tonnes up to 40m/min and 200tonnes brake)
Bridge electronics
Radar(s) .... Furuno FSR 2117
Other communications systems .... 2 x Sailor 6222 VHF and 2 x hand-held
2 x Furuno Felcom 18 (Inmarsat)
Autopilot .... Robertson AP-70
GPS .... Furuno GP-150D
Gyro compass .... Anschütz Compact 22
AIS .... Furuno FA-150
Echo sounder .... Furuno FE-800
EPIRB .... Jotron Tron-40S
SART .... Jotron TronSart20
Onboard capacities
Fuel oil 141,800litres
Fresh water 15,200litres
Sewage 5,100litres
Lube oil 8,100litres
Bilge water 6,800litres
Foam 12,600litres
Dispersant 5,400litres
Oil recovery 42,600litres
Complement
Crew 10
Passengers 0
Number of cabins 6



Top deck
Bridge deck
Main deck
A871
NOORDZEE
Messroom
Captain
Galley
Linen
CO2
Deck-store

MOJAWEB: Powerful evolved hybrid fireboat / tug, with Fi-Fi 2 capabilities

Builder	**Simulation Tech Inc.**
Designer	**Robert Allan Ltd**
Vessel's name	***Mojaweb***
Owner/operator	**Kuwait Fire Services**
Country	**Kuwait**
Flag	**Kuwait**
Total number of sister ships already completed	**0**
Total number of sister ships still on order	**0**
Contract date	**September 2008**
Delivery date	**March 2011**

When it comes to developing hybrid fireboat / tug designs, Canada's Robert Allan would appear to be on a mission to extend as far as possible beyond the standard Fi-Fi 1 classification requirements that cover the bulk of these boats, and the March 2011- launched RAstar 3900 class *Mojaweb* seems to be further proof of this strategy. The 39.1m vessel, which was ordered by Kuwait Fire Services for safety operations within the Kuwaiti port of Shuwaikh, has been certified by Lloyd's Register as a Fi-Fi 2 craft, packing a punch with a combined pump capacity of 8400m^3 per hour.

Robert Allan was commissioned to come up with the vessel design by Kuwait-based Al Boom Marine, while Korean builder Simulation Tech Inc (STI) was tasked with her physical construction. Featuring a moulded beam of 13.5m, a top operating draught of 5.1m and a minimum bollard pull of 60tonnes ahead (68tonnes ahead was recorded during her sea trials), the vessel has the capacity to carry 252m^3 of fuel oil, 57m^3 of potable water, 38m^3 of fire-fighting foam and just under 3m^3 of lubricant oil. *Mojaweb's* ballast capacity is measured at 67.8m^3 and her top speed has been recorded at 13.1knots during trials, although 12knots is her intended operating speed.

As well as handling fire-fighting duties, *Mojaweb* has been designed to undertake ship-handling and tanker support work. Subsequently, the vessel's deck comes equipped with a 75tonne safe working load (SWL) tow hook on the aft deck and a hawser winch on the foredeck. The vessel is capable of accommodating a maximum operating crew of 14, and features a total of 13 berths. Nine of these berths can be considered dedicated for crew, while the remaining four can accommodate survivors or additional fire-fighters.

As with previous Robert Allan Fi-Fi tugs, *Mojaweb* incorporates the company's signature RAstar hull form, featuring an outward sponson on the upper hull sides for increased stability. When conducting vessel-escorting duties, should the tug be heeled over as a result of the angle or influence of the towline, the sponson is submerged and acts to right the vessel.

The hull also features an extended skeg, positioned forward, for roll-damping purposes, and the overall hull form is intended to reduce roll amplitude and roll accelerations, for added safety and crew and passenger comfort. The designer claims that, following a series of private model tests, the roll accelerations recorded for the RAstar concept were some 60% lower than in equivalently sized, 'wall-sided' or conventional hull forms. Additionally, the design of the hull is capable of guaranteeing superior fuel economy during the vessel's operational cycle, Robert Allan claims.

The tug's power comes courtesy of a pair of Wärtsilä 6L26 medium-speed diesel engines, each rated 1946kW at 1000rpm, which drive a Wärtsilä-Lips CS250-CP Z-drive unit, with a 2400mm diameter propeller. Twin CAT C-18 diesel gensets, each rated 275ekW, provide the vessel's auxiliary power.

Before submitting its plans to Al Boom Marine, Robert Allan opted for a Wärtsilä 8L26 diesel pump engine, rated 2590kW at 1000rpm. The centreline Wärtsilä 8L26 auxiliary engine drives two 2400m^3 FFS ENM 350 fi-fi pumps, supplied by Fire Fighting Systems AS [FFS], off each end, while the two Wärtsilä 6L26 propulsion engines each drive an 1800m^3 FFS ENM 300 Fi-Fi pump off the front end. The end result would appear to be a potent means of combating fires and handling various generic vessel-escorting tasks, combined in one package.

TECHNICAL PARTICULARS

Length, oa	39.1m
Length, bp	35.37m
Breadth, moulded	13.5m
Depth, moulded	6.11m
Gross tonnage	759tonnes
Displacement	1221.8tonnes
Design, draught	5.05m
Design, deadweight	364.4tonnes
Lightweight	857.4tonnes
Speed, service	12knots
Max speed	13.1knots
Range (nautical miles)	4000
Daily fuel consumption (tonnes/day)	13.5 (max power)
Classification society and notations	Lloyd's Register, ✠100 A1 Escort Tug, Fi-Fi 2 with waterspray, ✠LMC
Main engine(s)	
Make	Wärtsilä
Model	6L26
Number	2
Output of each engine	1946kW @ 1000rpm
Gearbox(es)	
Included in Z-drive unit	
Propeller(s)	
Material	CuNiAl
Manufacturer	Wärtsilä Lips CS250-CP Z-drive unit
Number	2
Fixed /controllable pitch	Controllable
Diameter	2400mm
Open or nozzled	Nozzled
Alternators	
Make	Caterpillar C-18
Number	2
Output / speed of each set	275eKw @ 1800rpm
Bow thruster(s)	
Make	Wesmar V2-34 Hydraulic Bow Thruster
Number	1
Output of each	261kW @2600rpm

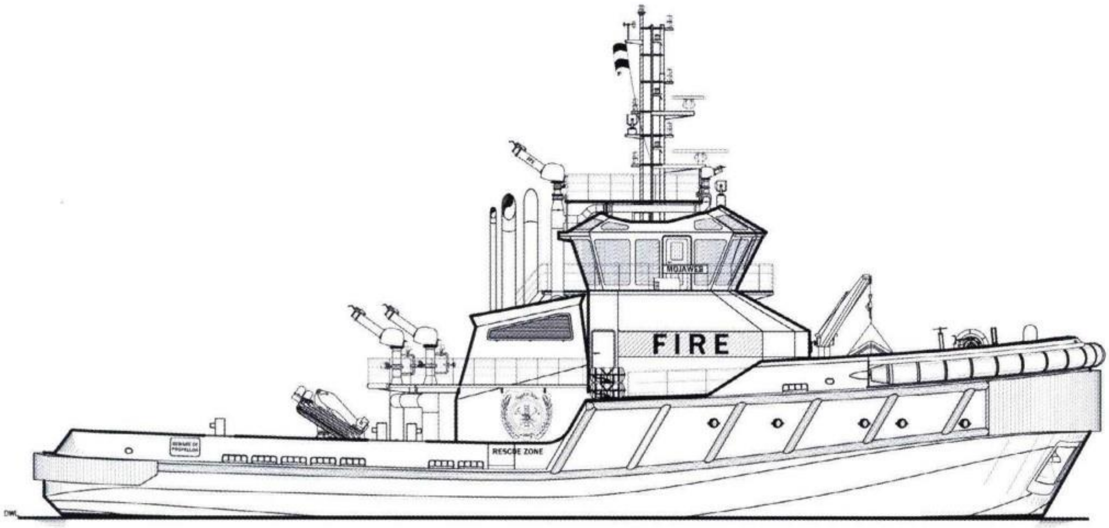
Deck machinery

- Sekwang Marine Machineries Co. Ltd hydraulic windlass towing winch, 120tonne brake capacity
- Nor Crane Marine & Offshore Equipment hydraulic capstan, 5tonnes x 10m/min
- Nor Crane Marine & Offshore Equipment tow hook with quick release, 100tonne capacity
- Sekwang Marine Machineries Co. Ltd rescue boat davit, 1.1tonne @ 5.2m, with Vogo 480 workboat
- Palfinger PK23500MD hydraulic, foldable marine crane, 1.21tonnes @ 14.5m

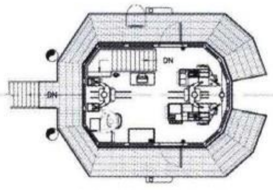
Complement	
Crew	14 max
No. of cabins	4

Other significant or special items of equipment

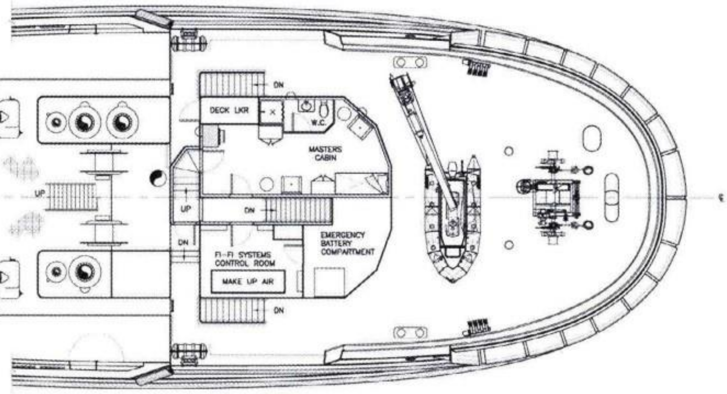
- FFS fire-fighting system – 8400m^3/hr flow capacity, five monitors



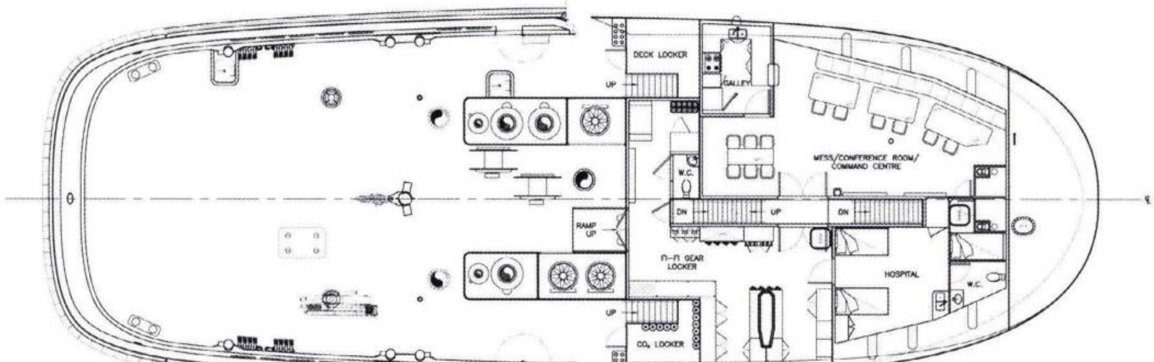
PROFILE



BRIDGE DECK PLAN

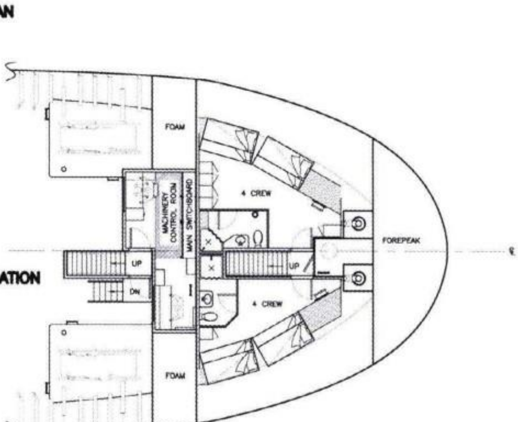


FO'C'SLE DECK PLAN



MAIN DECK PLAN

LOWER ACCOMMODATION FLAT



OCEAN TUNDRA: Heavy-duty tug with fire-fighting power

Builder	**Ocean Industries**
Designer	**Robert Allan Ltd**
Vessel's name	***OCEAN TundRA***
Owner/operator	**Ocean Group**
Flag	**Canada**
Total number of sister ships already completed	**0**
Total number of sister ships still on order	**1**
Contract date	**December 2011**
Delivery date	**December 2013**

Hailed as Canada's most powerful ever tug, featuring bollard pull (bp) of 110.3tonnes when sailing ahead, the icebreaking vessel *OCEAN TundRA* has been put to use by Ocean Group, handling escort duties along Canada's east coast and the St Lawrence River and Seaway system. Built at Ocean's own facilities in Quebec, the 36m x 13m *OCEAN TundRA* was designed by compatriot naval architect Robert Allan Limited (RAL), and has been classed by Lloyd's Register.

OCEAN TundRA's propulsive arrangement includes twin MAK 9M25C diesel engines, rated 3,000kW at 750rpm apiece, each driving a Rolls-Royce US 305 controllable-pitch propeller in ASD configuration. This results in a free running speed of just over 15knots ahead in calm water conditions, and an escort steering force of approximately 122tonnes when the vessel is operating at 10knots. The main and auxiliary engines have been resiliently mounted, for decreased noise and vibrations. The tug's icebreaking hull form, meanwhile, was partly inspired by a design utilised by smaller tugs working in the ice-prone Sakhalin region, Russia, and has been extensively model-tested to ensure uninterrupted escort performance in ice conditions common to eastern Canadian climes.

The tug has been designed to accommodate a maximum of 10 crew members, dependent on mission; for short runs, three or four seafarers will suffice, while seven people would most likely partake in longer voyages. The deckhouse is accessed via a spacious corridor and wet lobby, which has been laid out so as to isolate the engine room and exhaust noise from the crew's mess area. The lower deck houses four twin crew cabins, a laundry zone, separate toilet and shower rooms and galley stores. The wheelhouse has a split-level design, for optimised, 360degs visibility.

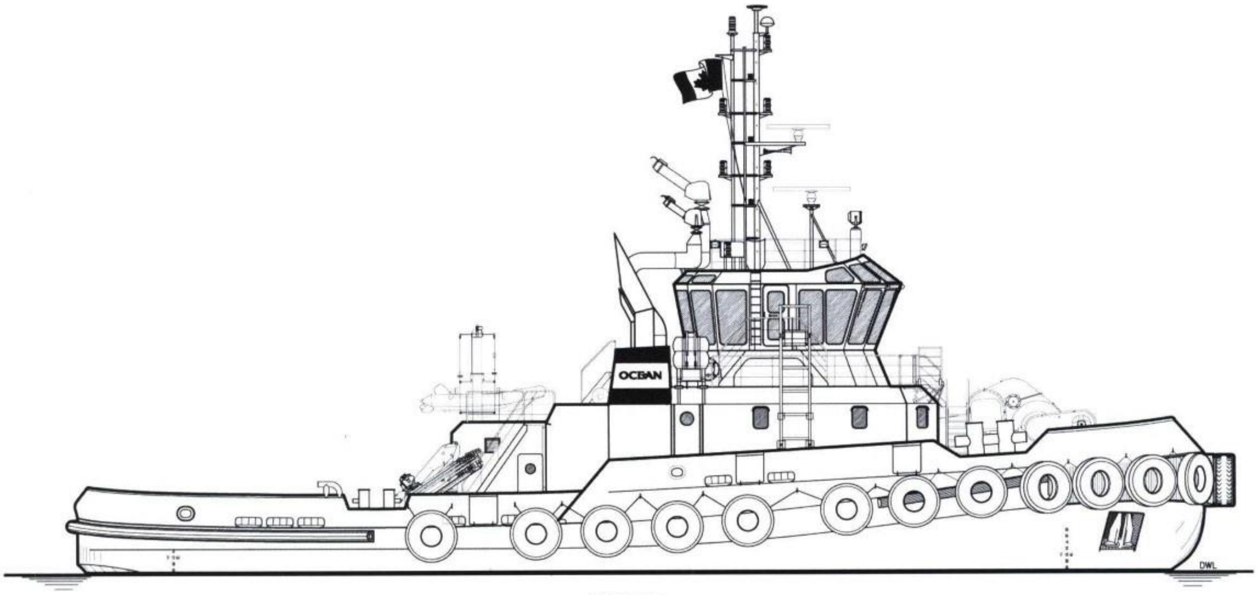
The fenders at the bow comprise extruded, 300mm-thick 'W' fenders and large heavy duty rubber tyres, while the main and forecastle deck sheer lines are protected by a 300mm x 300mm hollow 'D' fender and rubber tyre configuration. The stern incorporates 350mm x 350mm hollow 'D' type fendering.

The deck layout is complemented by a Palfinger 15500 hydraulic knuckle boom crane, with 14tonnes maximum capacity and an out reach of 14.4m. Two fire-fighting pumps, each rated 2,978m³/hr at 11bar, are driven from front end power takeoffs from the main engines, and feed three monitors located on a large header above the wheelhouse top; one water-only model, rated 2,400m³/hr, and two mixed foam/water monitors, rated 1,200m³/hr.

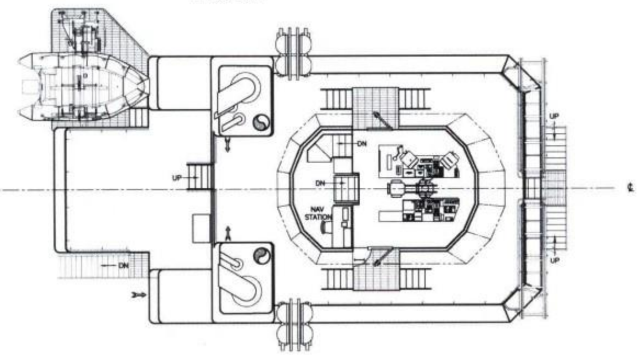
Onboard tank capacities include 294m³ of fuel oil, 18m³ of fresh water, 11m³ of fire-fighting foam and 5.4m³of oily water.

TECHNICAL PARTICULARS

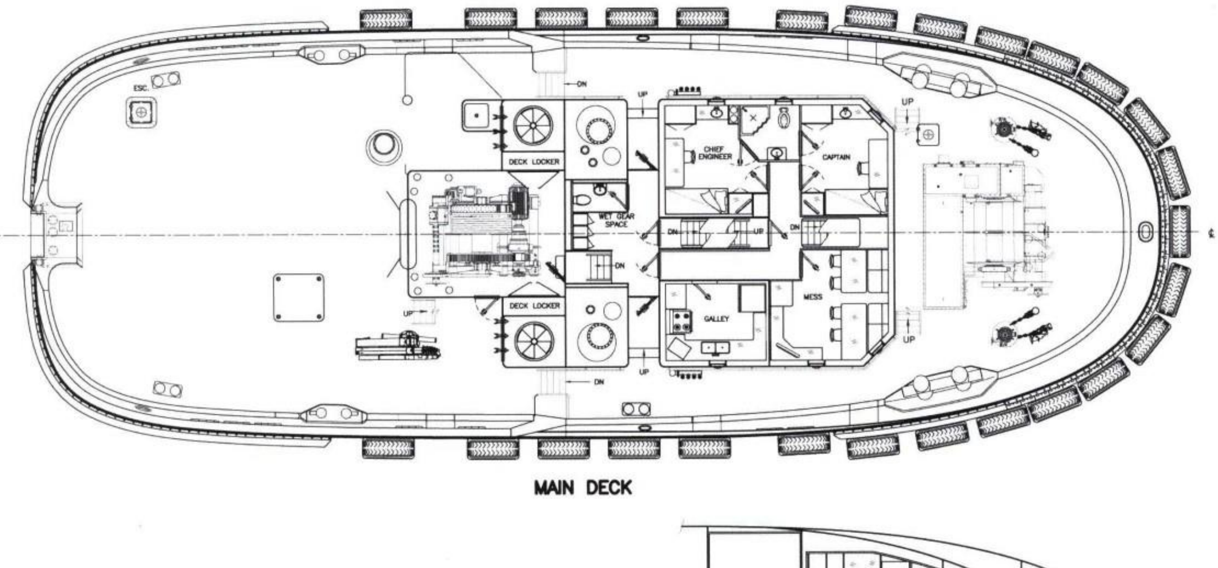
Length, oa	36m
Length, bp	34.04m
Breadth, moulded	13m
Depth, moulded	6.85m
Gross tonnage	708tonnes
Displacement	1,250tonnes
Design, draught	5.49m ABL
Design, deadweight	300tonnes
Lightweight	950tonnes
Service speed	11knots
Max speed	14knots
Range (nautical miles)	4,580
Classification society and notations	✠100 A1 Escort Tug, Fire-Fighting 1 with water spray
Other important international regulations complied with	+LMC, UMS Ice Class 1AS FS
Main engine(s)	
Make	MAK
Model	9M25C
Number	2
Output of each	3,000kW
Propeller(s)	
Material	CuNiAl bronze
Manufacturer	Rolls-Royce
Number	2
Fixed/controllable pitch	Controllable
Diameter	3,000mm
Special adaptations	ASD configuration
Open or nozzled	Nozzled
Alternators	
Make	Caterpillar C9
Number	3
Output of each set	250kWe / 1,800rpm
Deck machinery	1 x Markey DESDF-48-200HP escort hawser winch 1 x Markey TES-40UL aft towing winch 1 x Palfinger 15500 hydraulic knuckle boom crane Western Machine Works tow pins with hold-down block ..... and wire roller (100tonnes SWL) 1 x capstan, 10tonnes, forward and aft staples 1 x rescue boat davit
Complement	
Crew	3-10
Number of cabins	6
Other significant or special items of equipment	Bow 'W' and Stern 'D' fendering 3 x fi-fi monitors above wheelhouse top, 2 x 1,200m³/hr and 1 x 2,400m³/hr



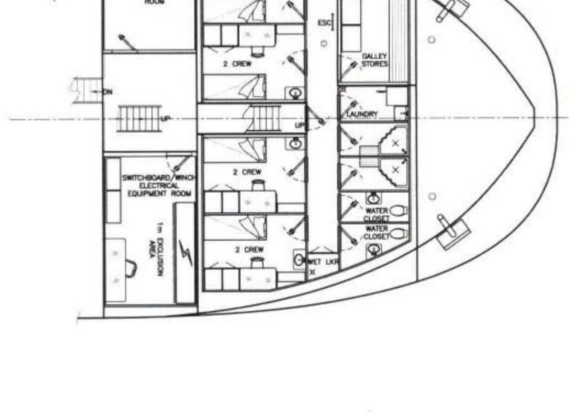
PROFILE



WHEELHOUSE



MAIN DECK



RT EMOTION: First hybrid tug to operate within German waters

Builder	**Damen Shipyards Hardinxveld**
Designer	**Robert Allan Ltd**
Vessel's name	***RT Emotion***
Owner/operator	**Elisabeth Ltd/ KOTUG**
Country	**Malta**
Flag	**Malta**
Total number of sister ships already completed	**1**
Total number of sister ships still on order	**0**
Contract date	**March 2013**
Delivery date	**June 2015**

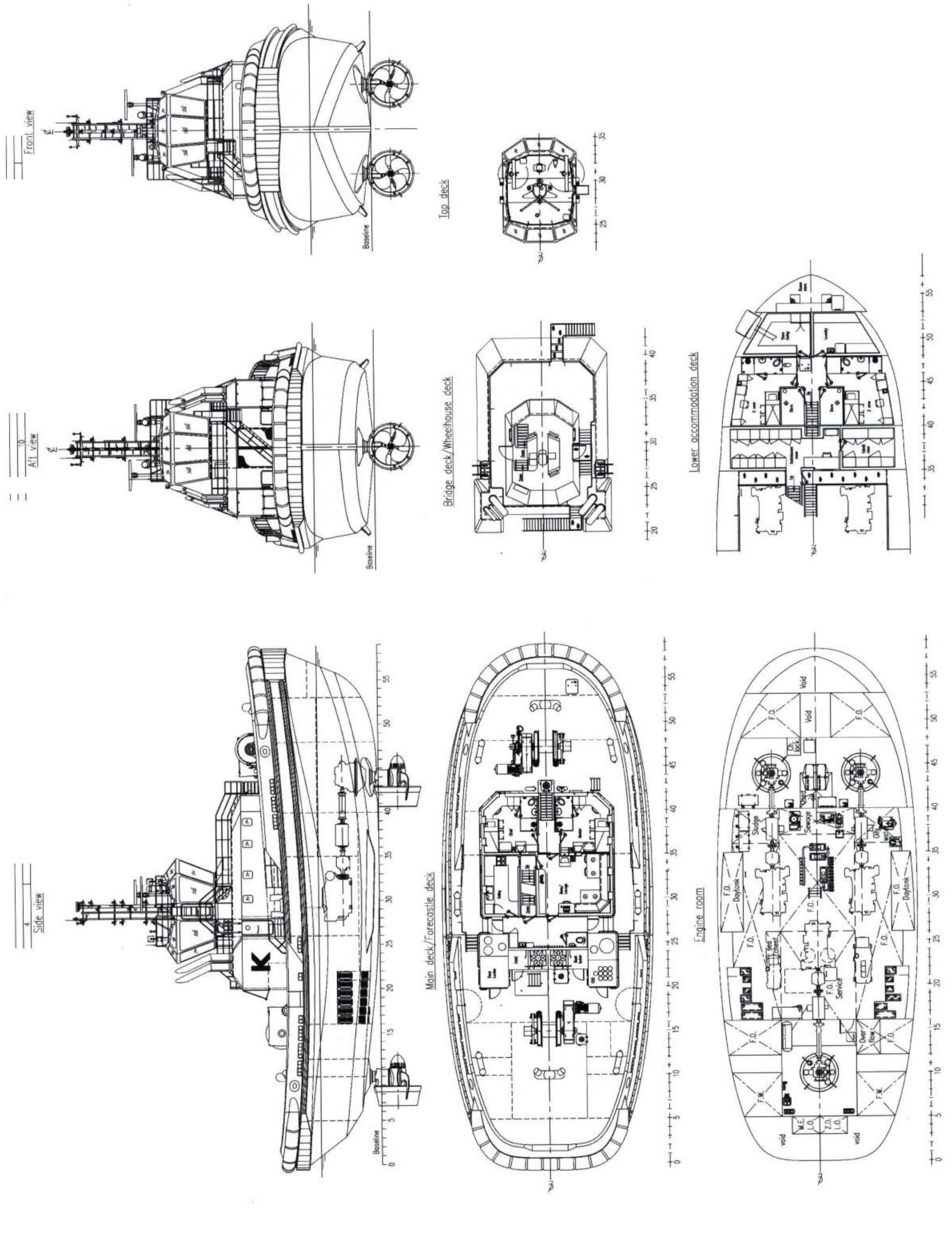
June 2015 saw the handover of the 32m *RT Emotion*, the next-generation ART80-32 Rotortug built by Damen and designed by an alliance of Rotortug B.V, in the Netherlands, and Canada-based naval architect Robert Allan Ltd. *RT Emotion* has subsequently been hailed as the first hybrid tug to operate within German waters.

The key drive behind this class has been to blend environmentally clean, hybrid technology with high performance and significant pulling power. Dubbed the 'E-KOTUG' series, the designer and builder claim 50% less harmful emissions, notable noise reduction, cleaner combustion and substantial maintenance savings thanks to the vessel's improved fuel economy. The tug's XeroPoint hybrid propulsion system oversees three electric motors and the Corvus-supplied battery pack.

The ART80-32's optimised hull shape enables ahead and astern speeds of more than 13knots and, in terms of bollard pull, the tug can achieve 84tonnes over the stern and 82tonnes over the bow. Similarly, versatility and flexibility were key considerations; as KOTUG puts it, the "ability to respond very quickly to changes in manoeuvring requirements" was of prime importance when developing the tug as a "highly responsive" addition to its fleet.

TECHNICAL PARTICULARS

Length, oa	31.95m
Breadth, moulded	12.6m
Depth, moulded	4.82m
Gross tonnage	498tonnes
Displacement	598tonnes
Design, draught	6.25m
Max speed	13.1knots
Bollard pull	86tonnes (ahead) 82.1tonnes (astern)
Classification society	Lloyd's Register
Notations	✠100A1 TUG, [✠] LMC, UMS, IWS
Main engine(s)	
Make	Caterpillar
Model	3512C TA/HD+
Number	3
Output of each engine	1,765kW
Hybrid system	Aspin Kemp Associates / Xeropoint
Electric motor	Teco Westinghouse
Output of electric motor	500kW
Batteries	Corvus Energy, Corvus Lithium Polymer
Slipping / disengagement clutch	
Make	Twin Disc
Model	MCD 3000-3 LD
Number	3
Output	1,800rpm max
Rudder propeller(s)	
Material	GS-CuA110Fe5Ni5-C
Manufacturer	Schottel
Type	SRP-3000
Number	3
Fixed or controllable pitch	Fixed
Diameter	2,300mm
Speed	266rpm
Open or nozzled	Nozzled
Alternators	
Make	CAT C9 / CAT C18
Number	2
Output of each set	250kVA, 50 Hz (C9) 575kVA, 50 Hz (C18)
Deck machinery	2 x DMT winches, fwd and aft 30tonnes@0-15m/min 10tonnes @0-45m/mi 225tonnes holding force 250m wire capacity 70mm diameter 1 x HHP AC-14 anchor, 360kg 165m / 22mm studlink chain
Bridge electronics	
Radar(s)	2 x JRC, JMA 5312-6 / JMA 610-7
Autopilot	Alphatron Alphaseapilot MFC
GMDSS	Thrane 6310 Mini-C LRIT
GPS	Alphatron
Chart plotter	Alpha T ECDISchart
Engine monitoring / fire detection system	Böning
Onboard capacities	
Fuel oil	204.6m³
Fresh water	33m³
Sullage/sewage	8.8m³
Lube oil, engines	2.4m³
Lube oil, thrusters	2.4m³
Hydraulic oil	3.1m³
Used oil	5.4m³
Sludge	4.6m³
Complement	
Crew	3
Passengers	0
Number of cabins	4 (2 single, 2 double)


Front view
Aft view
Side view
Top deck
Bridge deck/Wheelhouse deck
Lower accommodation deck
Main deck/Forecastle deck
Engine room
Baseline

SIGRID DUNLAP: Ocean tug with refined environmental and crew comfort features

Builder	**Hansen Boat Company**
Designer	**Hockema Whalen Myers Associates**
Vessel's name	***Sigrid Dunlap***
Owner/operator	**Dunlap Towing Company**
Country	**US**
Flag	**US**
Total number of sister ships already completed	**1**
Total number of sister ships still on order	**Not specified**
Contract date	**April 2015**
Delivery date	**June 2018**

When developing the ocean tug *Sigrid Dunlap*, naval architect Hockema Whalen Myers Associates (HWMA) turned to the past for inspiration, drawing on – and "evolving" – the design of its 2002-built tug *Phyllis Dunlap*. HWMA concedes that "outwardly, the two boats appear to be nearly identical" – although the June 2018-delivered *Sigrid Dunlap* has been refined to incorporate current technologies into her arrangement, leading to enhancements related to onboard comfort, equipment and environmental compliance.

The tug's primary role involves towing container barges from Seattle to Honolulu on a scheduled service for Alaska Marine Lines. The vessel is ABS- and SOLAS-classed, with an ABCU endorsement for unattended machinery room operation. HWMA adds: "Redundant controls and monitoring equipment ensure the most automated, reliable platform possible."

Sigrid Dunlap is equipped with twin Caterpillar C175-16 engines turning at 1,600rpm: these were selected to meet Environmental Protection Agency (EPA) Tier 3 and IMO Tier II standards. Reintjes WAF1173 gears provide the reduction to 3,048mm, three-bladed propellers fitted in Nautican triple rudder Integrated Propulsion Units and incorporating Jastram independent steering controls. Engine controls and shaft brakes were provided by Propulsion Systems, Inc. A fuel capacity of just over 557,000litres provides ample range for trans-Pacific crossings.

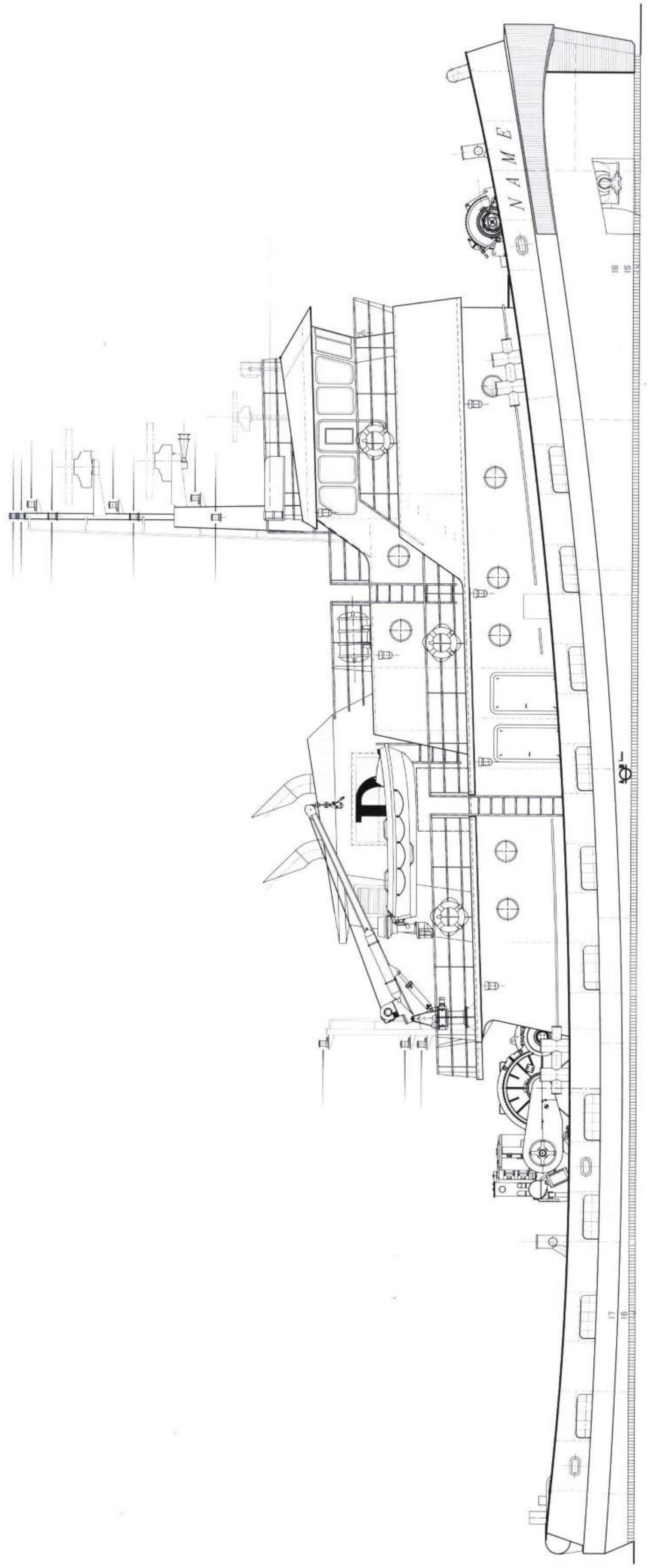
The deck area is fitted with a large double-drum Markey TDSDS-36 tow winch on the aft deck and an electric Markey DESW 32-20 hawser winch with anchor windlass on the bow. The tow pin unit was provided by McEvoy Machine.

Inside, *Sigrid Dunlap* offers three single staterooms and four double cabins, all with individual Dometic climate controls for crew comfort. The boat is insulated with structural fire insulation plus sound insulation and includes a double-layer Norac floating floor system over the engine room to keep vibrations to a minimum – meaning that, while she has the clout to venture across the Pacific, she can also guarantee a relatively pleasant experience for crew while doing so.

TECHNICAL PARTICULARS

Length, oa	37.03m
Length, bp	35.32m
Breadth, moulded	11.58m
Depth, moulded	5.55m
Gross tonnage	559tonnes (193tonnes, US Regulatory)
Displacement (load line)	1,163tonnes
Design, draught (keel amidships to load line)	4.81m
Design, deadweight (load line)	551tonnes
Lightweight	602tonnes
Service speed	10knots towing (approx.)
Max speed	14.5knots
Range	6,500nm (approx.)
Bollard pull	81.7tonnes
Daily fuel consumption	18,000litres/day (approx.)
Classification society	ABS
Notations	ABS ✠A1 Towing Vessel, ✠AMS, ✠ABCU
Other important international regulations complied with	SOLAS Cargo Ship
Main engine(s)	
Make	Caterpillar
Model	C175-16
Number	2
Output of each engine	3,990kW@1600rpm
Gearbox(es)	
Make	Reintjes
Model	WAF 1173
Number	2
Output speed	182.2rpm
Propeller(s)	
Material	Stainless steel
Manufacturer	Nautican
Number	2 (3-Bladed)
Fixed/controllable pitch	Fixed (3,073mm)
Diameter	3,048mm
Speed	182.2rpm
Open or nozzled	Nautican nozzle fitted with triple rudder
Alternators	
Number	3
Make/type	2 × Cat C7.1,118 kWe ea. 1 × MER-IGS40, 40kWe
Output/speed of each set	1,800rpm
Winch(es)	
Manufacturer	Markey
Number	1 × TDSDS-36 aft tow winch 1 × DESW 32-20 bow hawser winch
Capacities	
Aft winch	Two drum, 110tonnes max pull 945m/600mm wire (S) / 731.5m/60mm wire (P)
Bow winch	4.48tonnes rated pull 122m 203mm circumference Spectra/Plasma
Roller(s)	
Type	Stern roller / tow pin unit
Manufacturer	McEvoy Machine
Number	1
Capacities	4 × hydraulic pins with 1,524mm × 610mm roller
Other deck machinery/equipment	Palfinger RSQ 450 A SOLAS rescue boat with Allied DS 2500S-19 davit
Bridge electronics	
Radar(s)	Furuno FR 8125 & FAR 2117
Autopilot	Simrad AP80
GMDSS	Sailor LRIT
Other communication systems	Jotron (internal communications)
GPS	Simrad MX610
Gyro	Simrad GC 80
Chart plotter	Furuno FMD 3200 ECDIS
Engine monitoring/ fire detection system	Kidde FM200 Extinguishing System by Alexander Gow
Monitoring & control	Marine Controls Inc. Model 8400 TS
Onboard capacities	
Fuel oil	577,071litres
Fresh water	114,641litres
Sullage	12,000litres
Ballast water	35,820litres
Complement	
Crew	6 (berths for 11)
Number of cabins	3 × single 4 × double

SIGRID DUNLAP



SVITZER KILROOM: Quieter escort tug with options for LNG support

Builder's name ....**Freire Construcciones Navales of Vigo, Spain**
Designer ....**Robert Allan Ltd**
Vessel's name ....***Svitzer Kilroom***
Owner/operator .... **Svitzer – Milford Haven Services**
Country ....**UK**
Flag ....**UK**
Total number of sister ships already completed **0**
Total number of sister ships still on order **0**
Contract date ....**-**
Delivery date ... **December 2008/January 2009**

Svitzer Kilroom was delivered from Freire shipyard in December 2008 to her owner at the Dragon LNG terminal in Milford Haven, UK.

Svitzer Kilroom is the largest and most powerful of the 'RAstar' series of tugs designed by Robert Allan Ltd for this major terminal operation. This 'RAstar 3900' class tug completed trials in early December 2008. In addition to this 39m tug, a series of five smaller near-sisters, the 'RAstar 3400' class tugs are also being built by Freire for this demanding service.

Svitzer Kilroom is equipped for typical ship-handling and escort work, with a Rolls-Royce model TW 3000/1000H single drum hawser winch on the fore deck, with a capacity for 250m of 76mm diameter high strength towline. The escort-rated winch is driven by a twin-pump electro-hydraulic pump set, and features a three speed drive system, capable of line recovery at 100 tonne line pull at 5.2m/min or of rendering at 150tonnes at 8m/min in the first speed range, or of recovering at 24tonnes at 18m/min and rendering at 50tonnes line pull at 28m/min in the third speed range. The aft deck is strengthened for an aft towing winch, but that is not presently fitted.

In common with the majority of Robert Allan Ltd. designed tugs, a great deal of attention was paid throughout the design process to mitigate the propagation of noise and vibration. This includes the essential resilient mounting of the main engines, isolation of all exhaust system components, and the extensive use of visco-elastic floating floor systems throughout. The shipyard executed all these requirements exceptionally well, and the reward was an extremely quiet ship throughout.

Svitzer Kilroom is built in accordance with Lloyd's Register of Shipping requirements for a ✠100A1 Escort Tug, Fire Fighting Ship 1 (2400m^3/hr) with water spray, ✠LMC, UMS, 1BS, NAV1 notation, and also in compliance with the UK MCA regulations. The fire-fighting capability is provided by a pair of main-engine driven pumps, each rated 1400m^3 cubic meters per hour, which serve a pair of Kvaerner water/foam monitors and a self-protection waterspray system. Main engines are a pair of General Electric 7FDM 16 diesels developing 3050kW each at 1050rpm at 100% MCR. These are coupled to Schottel SRP 3030 CP azimuthing thrusters.

Svitzer Kilroom successfully completed trials in Spanish waters, delivering performance beyond all expectations during trials with a bollard pull of 117tonnes maximum and 113tonnes sustained ahead and 113/107tonnes astern maximum / sustained. Free running speed ahead was 15.7kts. The 'RAstar' design hull form incorporates a significant sponson on the upper hull sides. When the tug is heeled over under influence of the towline during an escort operation, the 'downhill' sponson is submerged and a large righting force is generated to improve the stability, thus increasing the towline force. In addition, the hull has a large foil-shaped skeg, also designed to increase indirect towline forces. The 'RAstar' hull form also provides dramatic reductions in roll amplitude and roll accelerations, thus providing a safer and more comfortable platform for crews, who are now being asked to conduct docking operations at LNG terminals and similar installations in up to sea-states of 3.0m significant wave heights.

Svitzer Kilroom also features low noise levels in the deck levels and cabins. The recorded noise levels are as follows:

- Bridge Deck: Wheelhouse 65 dBA
- Main Deck: Galley 64 dBA
  Mess/Lounge 64 dBA
- Master's Cabin 58 dBA
- Chief Engineer Cabin 60 dBA
- Lower Deck:
  Engine Room 110 dBA
  MCR 74 dBA
- Crew cabins 58-60 dBA

Svitzer Kilroom has numerous features for operating in LNG service including; such as gas sensors, the ability to positively pressurise accommodation and deck electrical equipment either safety rated or has ability to be de-energised from bridge.

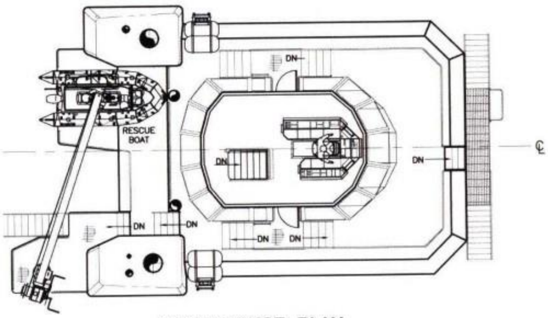
The fire-fighting capability is provided by a pair of main-engine driven pumps, each rated 1400m^3/h, which serve a pair of Kvaerner water/foam monitors and a self-protection waterspray system.

TECHNICAL PARTICULARS

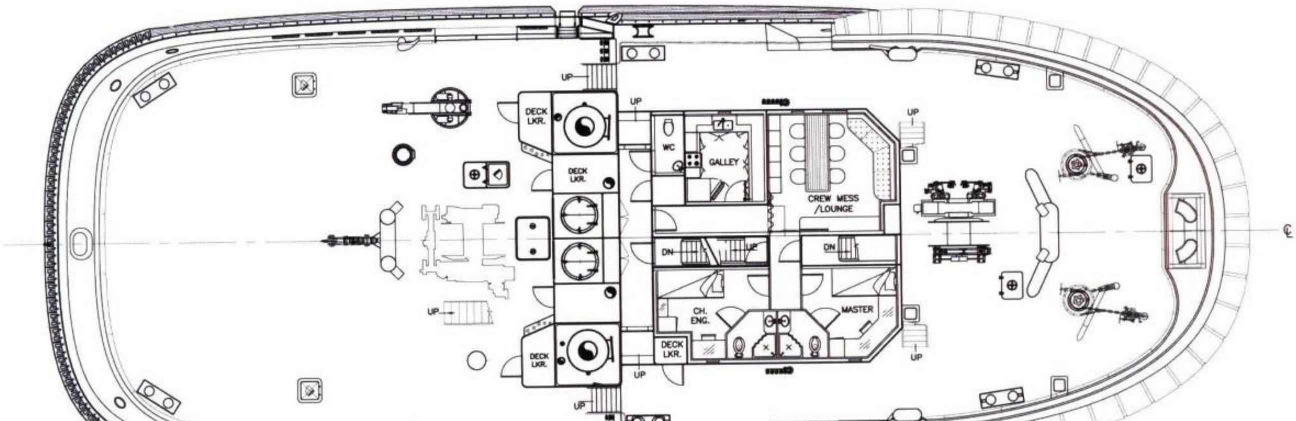
Length, oa 39m
Breadth moulded 14.70m
Depth, moulded ....6.11m (above design baseline)
Gross tonnage 819gt
Displacement ....loadline displacement – 1448tonnes
Design, draught ....harbour 6.9m / loadline 7.3m
Design, deadweight ....harbour 270dwt / loadline 516dwt
Lightweight 932tonnes
Maximum speed 15.7kts
Range (nautical miles) ....approximately 4500nm
Bollard pull
Ahead ....117tonnes maximum, 113tonnes sustained
Astern ....113tonnes maximum, 107tonnes sustained
Tank capacities
Fuel oil ....225m^3
Reserve fuel oil ....175m^3
Potable water ....26m^3
Lube oil ....3m^3
Classification society and notations
......................Lloyd's Register ✠ 100 A1 Escort Tug, Fire-Fighting Ship1 with Water Spray, ✠ LMC UMS IWS
Other important international regulations complied with
UK MCAS regulations
Main engine(s)
Make/Model .... GE / GE 16V-228
Output of each engine .... 3050kW at 1050rpm at 100% MCR
Propeller(s)
Manufacturer/model ....Schottel SRP 3030
Number 2
Fixed/Controllable pitch ....controllable
Diameter .... 3.4m diameter propellers
Open or nozzled ....nozzled
Alternators
Number ....3 (2 main, 1 harbour)
Make/type ....Cummins
Output/speed of each set .... 2 x 390ekW at 50Hz
1 x 80ekW at 50Hz (harbour)
Deck machinery
Hawser winch: Rolls-Royce TW 3000/1000H single drum with 250m of 76mm diameter high strength towline capacity. Render recover capable for escort operations.
Escort tow pins: escort tow pins mounted in bulwarks.
Two combined vertical capstans/anchor chain lifter (hydraulic).
Aft tow hook
Complement
Crew 10
Number of cabins 6
Other significant or special items of equipment
Fendering designed for a maximum of 20tonnes/m^2 maximum pressure on tanker's hull.

SVITZER KILROOM

OUTBOARD PROFILE



WHEELHOUSE PLAN



MAIN DECK PLAN

VORTEX: fast and rugged Voith tractor tug, with impressive deck equipment

Builder's name	**Astilleros Gondan SA, Spain**
Designer	**Robert Allan Ltd**
Vessel's name	***Vortex***
Owner/operator	**Solent Towage Ltd, Southampton**
Country	**United Kingdom**
Flag	**United Kingdom**
Total number of sister ships already completed	**-**
Total number of sister ships still on order	**-**
Contract date	**April 2008**
Delivery date	**June 2010**

The delivery of the Voith tractor tug *Vortex* to Solent Towage of Southampton, UK represented yet another powerful and impressive Robert Allan multi-purpose vessel design. Built to the latter company's AWT 37/80 design specifications, the 38.7m *Vortex* is equipped for tanker handling, escort duties, fire fighting, pollution control and anchor handling.

The vessel's propulsion arrangement consists of Wärtsilä 8L26 diesel engines, each rated 2650kW at 900rpm, and each driving a Voith Model 32R5/265-2 drive unit. This combined output has enabled *Vortex* to record a bollard pull of 73tonnes and a free-running speed of 14.5knots.

Her working deck features a Karmoy model M361783 double drum, side-by-side hydraulic-driven towing/hawser winch, which boasts a pull/brake force of 200/300tonnes; a 51mm working wire measuring 150m in length; a 200m synthetic high modulus polyethylene (HMPE) escort hawser; and a 1000m towing line, consisting of 57mm wire.

In addition, *Vortex* features: Karm Forks; a unique, hydraulically retractable escort towing staple; a forward combination windlass/hawser winch; a 2.96m long x 1.4m diameter stern roller; two 9tonne tugger winches; split towline reels; a spill containment boom winch with 200m of 950mm deep boom; and an EFFER 44000-3SL hydraulic knuckle-boom type deck crane of 36tonne/m capacity.

The vessel accommodates up to 10 crew, and onboard facilities include spacious crew rooms for full complement in four single and three double cabins, with Pullman berths, which all feature en-suite toilet and shower facilities. For the social aspect, *Vortex* has been fitted with a lounge/mess area and a gymnasium.

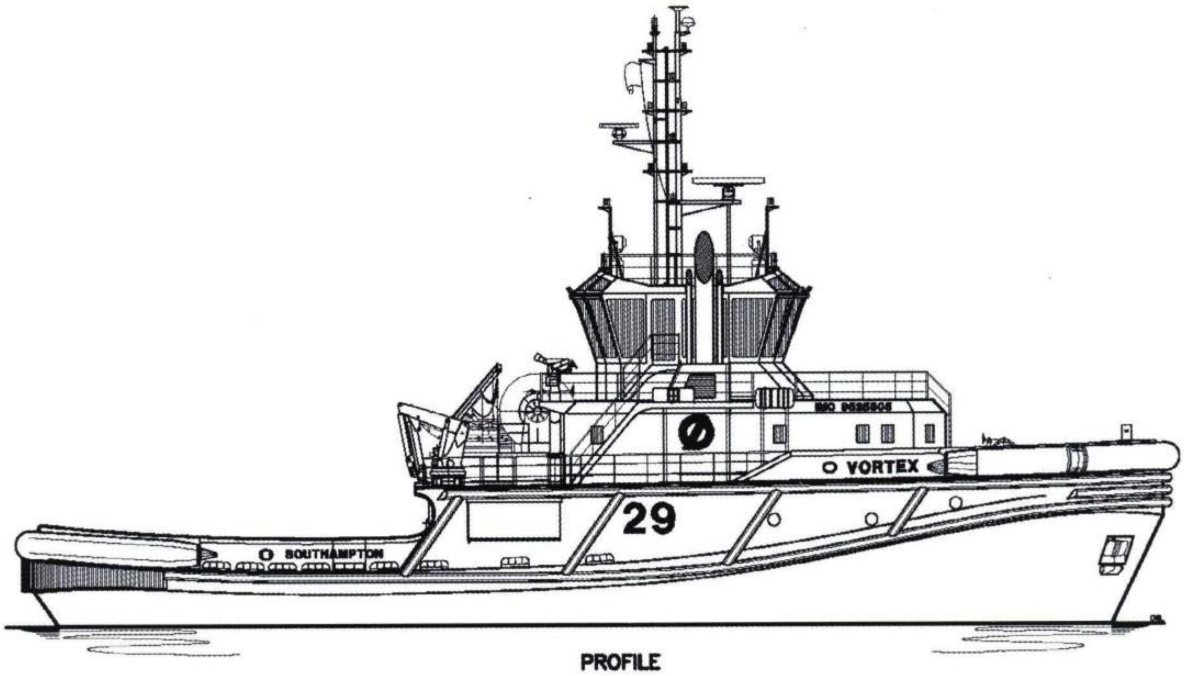
Electrical power is generated via a pair of Volvo Penta D7A-BTA diesel gen-sets, each of which is rated 1500m^3/hr and is driven from the main front engine PTOs.

TECHNICAL PARTICULARS

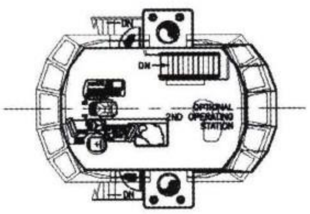
Length, oa	38.7 m (fenders including)
Length, bp	34.6m
Breadth, moulded	14.0m
Depth, moulded	5.9m
Gross tonnage	800gt
Displacement at Loadline Draft	1638tonnes
Loadline Draught	7.55m
Operational Draft	7.05 m (full load of consumables)
Deadweight at Loadline Draft	528tonnes
Lightweight	1110tonnes
Speed, service (economy)	12.0knots
Maximum speed	14.5knots
Range (nautical miles)	4000 nautical miles at 85 % MCR
Fuel consumption	1.04tonnes/hr - 100% MCR, 0.58tonnes/hr - economy
Classification society and notations	Det Norske Veritas ✠1A1 Tug E0 OilRec, Fi-Fi I, Escort (130/10), Anchor Handling Tug

Other important international regulations complied with:
- MCA/DoT / NMD
- U.K. Merchant Shipping Regulations
- Norwegian Ship Control Legislation
- SOLAS
- MARPOL
- International Convention on Load Lines
- International Convention on Tonnage Measurement
- IMO Res. A-167 (ES.IV) Recommendation on Intact Stability
- IMO Res. A-327 (IX). Recommendation concerning Fire Safety
- IMO Res. A-325 (IX). Recommendations concerning Regulations for Machinery and Electrical Installations
- The International Regulations for Preventing Collision at Sea
- The International Electrotechnical Commission (I.E.C.); Standards and Recommendations for Electrical Installations on Ships

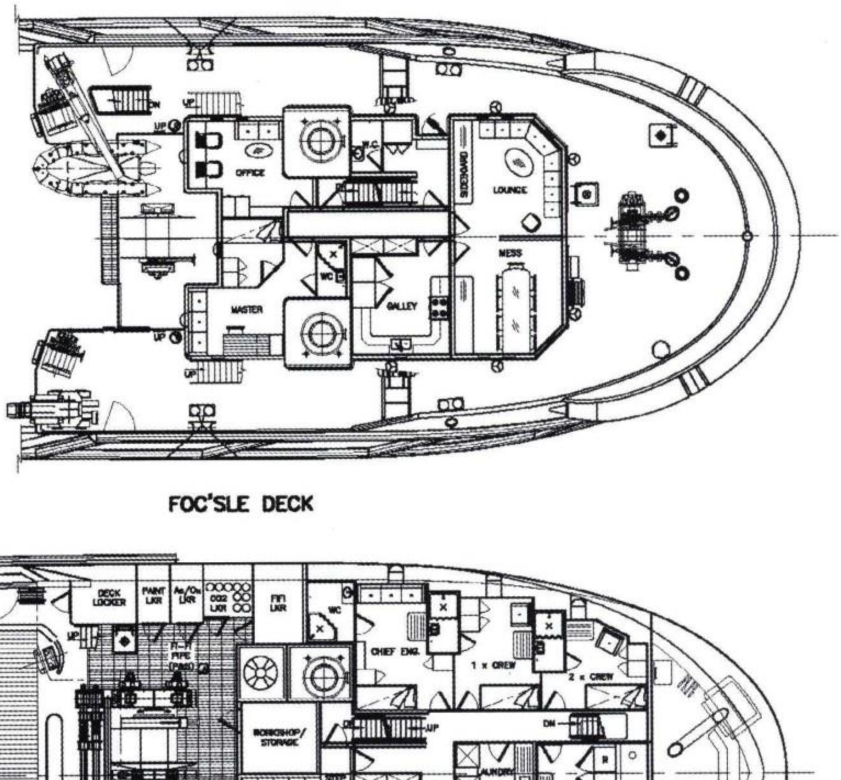
Capacities:	
Fresh water	83m^3
Fuel Oil	388m^3
Foam	24m^3
Dispersant	18m^3
Recovered Oil	226m^3
Main engine(s)	
Make	Wärtsilä
Model	8L26B2
Number	PAAE134730, PAAE134731
Output of each engine	2650 kW @ 1000rpm
Turbo coupling	
Make	Voith Turbo
Model	1150 DTL
Number	2
Propeller(s)	
Type	Voith Schneider Propeller
Manufacture	Voith Turbo Marine
Number	2
Model	VSP 32R5/265-2
Diameter	3200mm
Open or nozzled	Propeller Guard
Alternators	
Number	2
Make/type	Volvo Penta
Type	D7A-BTA
Output	139kW @1500 rpm
Output/speed of each set	Stamford UCM274H-2 163 kVA 400V 50 Hz
Deck machinery:	
Main Towing/Anchor handling winch	"Karmøy winch" hydraulic with two independent inline drums.
Pull / brake force	200/300tonnes
Work Wire	1 x 150m, 51mm
Escort line	1 x 200m synthetic HMPE
Tow line	1 x 1000m, 57mm wire
Spare tow/escort line	1 x 1000m, 57mm wire
Tow line storage reel	1 for 1200m spare towing wire
Handling lines storage reel	1 with split drum for wire/rope
Tugger winch	2 x 9tonnes
Deck crane	1 x EFFER 44000-3SL: 3.1tonne @11.5m 7.35tonne @ 5.2m
Towing pins/shark yaw	1 x "Karmøy winch" Karm fork
Hydraulic retractable staple	1 x "Karmøy winch" of towing pin type
Stern roller	1.4m diameter, 3m length, SWL 150tonnes
Oil Recovery Equipmet:	
Oil boom reel	1x10m^3
Oil skimmer	Arrangement for oil skimmer storage
Fire Fighting equipment:	DnV Fi-Fi I Class
Pumps	2 x pumps 1500m^3/hour
Monitors	2 x water/foam monitor of 1200-300m^3/h
Bridge electronics:	
Radars make/model	One 3cm Furono Arpa radar, FAR-2117BB, One 10 cm Furuno chart radar, FAR-2137S
Autopilot make/model	Furuno AP 50
GMDSS make/model	Furuno A3-150W
GPS make/model	Furuno GP-150
Gyro	Simrad GC 80
Chart plotter	Furuno T-2026
Complement	
Crew	10
Passengers	N/A
Number of cabins	7



PROFILE



BRIDGE DECK



FOC'SLE DECK

MAIN DECK

ZEYCAN Y: Debut tug in new RAmparts 2400SX series

Builder	**Sanmar**
Designer	**Robert Allan Limited**
Vessel's name	***Zeycan Y***
Owner/operator	**Gemport**
Country	**Turkey**
Flag	**Turkey**
Total number of sister ships already completed	**1**
Total number of sister ships still on order	**TBC (ongoing series)**
Delivery date	**July 2013**

Designed specifically for Turkish shipbuilder Sanmar, and representing the yard's 100th tug delivery, Robert Allan Limited's (RAL's) first RAmparts 2400SX series vessel, *Zeycan Y* (formerly *Boğaçay I*), was delivered to Turkish owner Gemport in mid-Summer 2013, followed by a sister vessel, *Boğaçay II*, which joined Sanmar's fleet in September last year. Sanmar has dubbed the RAmparts 2400SX class the Boğaçay class (literally translating as 'bull steam'), and is marketing the vessels as part of its new breed of tug solutions.

The RAmparts 2400SX class builds on RAL's previous RAmparts 2500W tug concept, with the hull remaining essentially the same as its predecessor, having been designed with good dead rise for improved thruster performance, modest side flare, a half-raised forecastle deck for good sea-keeping and RAL's trademark conically shaped double chine stern, to ensure that the tug can run astern at high speeds whilst retaining good stability and control.

The remainder of the RAmparts 2400SX tug has been customised to suit Sanmar's unique requirements for flexibility when it comes to available options and production efficiency. Sanmar raised a number of specifications for the RAL design team; one being the ability to install three different Z-drive sizes, in order to achieve 50tonne, 60tonne and 70tonne bollard pull (bp) versions of the tug, whilst maintaining the same shaft line and same diameter drive well. Additionally, Sanmar wanted the capability to fit both Caterpillar-manufactured CAT 3512C and 3516C engines on the same engine bed, to accommodate the differing power levels required to attain the aforementioned variations in bp. Other considerations requested by Sanmar included: the ability to fit a double drum winch, a split drum winch or a single drum winch on the same deck foundation; an option for firefighting systems capable of meeting FiFi 1 class notation, whether fitted with CP thrusters or half-driven by an independent auxiliary engine; an optional aft winch; and an the ability to fit both a single aperture staple and a double aperture staple on the same seating, to suit the three winch options.

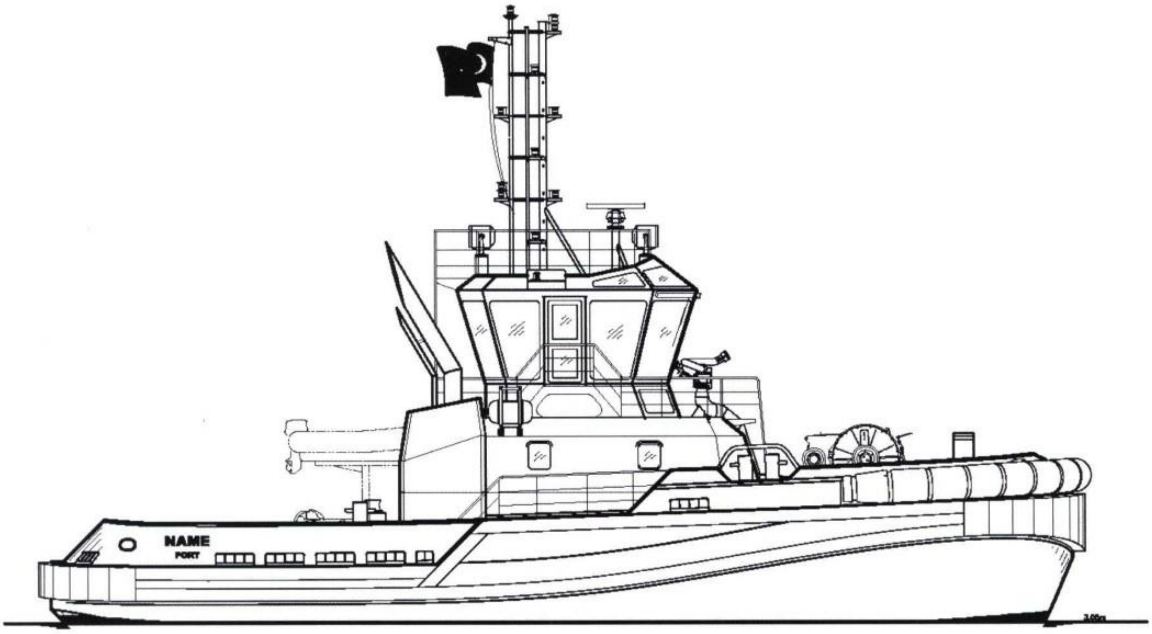
For the first two vessels in this class, Sanmar selected a FiFi pumpset half-driven off the front of the port main engine, and delivering 1,200m^3/hr seawater to one 1,200m^3/hr water/foam remotely operated monitor.

Tank capacities at 98% include: 87.3m^3 for fuel oil; 10.6m^3 for potable water; 41.8m^3 for water ballast; 1.6m^3 for oily water; and 3m^3 for sewage. *Zeycan Y* has been outfitted to accommodate six members of crew, with two double-berth cabins situated on the lower deck, and two officer cabins on the main deck. Ship-handling fenders at the bow comprise an upper row of 800mm-diameter cylindrical fenders and a lower course of W-fenders.

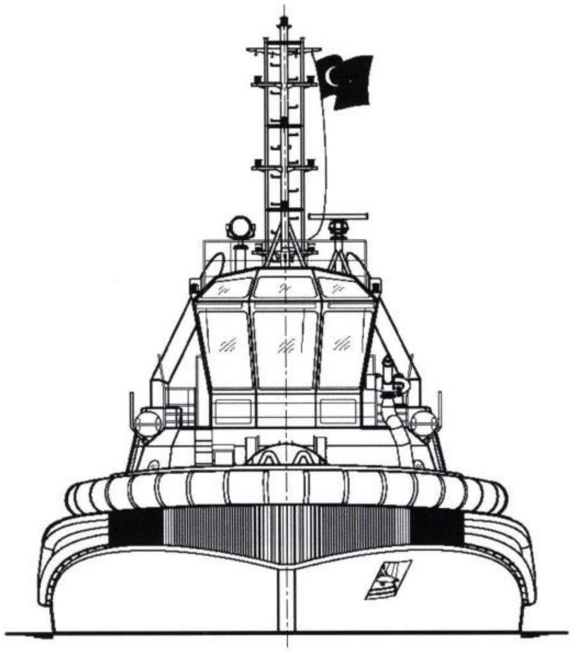
In sea trials, *Zeycan Y* and *Boğaçay II* have achieved a bp of 60tonnes ahead, matched with a free running speed of 12knots. Plans are now underway to tinker with the RAmparts 2400SX design to ensure a bp of 75tonnes on future models.

TECHNICAL PARTICULARS

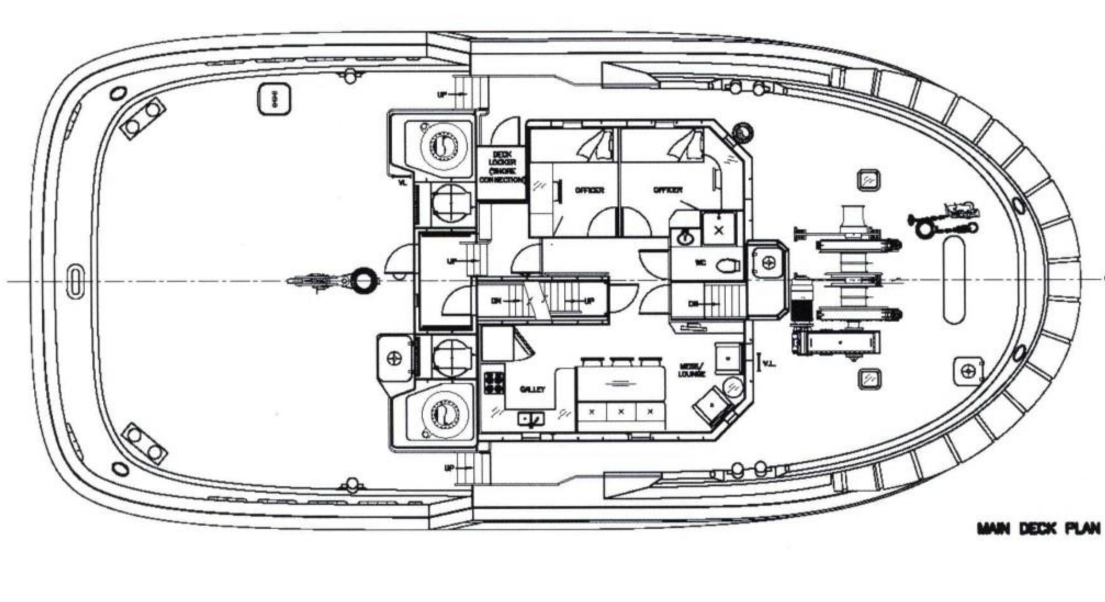
Length, oa	24.4m
Length, bp	23.45m
Breadth, moulded	11.25m
Depth, moulded	4.38m
Displacement	500tonnes
Design, draught	5.2m
Design, deadweight	100tonnes
Lightweight	400tonnes
Max speed	12knots
Classification society and notations	ABS ✠A1 TUG, ✠AMS
Main engine(s)	
Make	CAT
Model	3512
Number	2
Output of each	1,765kW @ 1,800rpm
Propeller(s)	
Manufacturer	Rolls-Royce
Make	US 205
Fixed/controllable pitch	Fixed
Diameter	2,400mm
Open or nozzled	Nozzled
Alternators	
Make	CAT C 4.4
Number	2
Output of each set	86kWe @ 1,500rpm
Deck machinery	
1 x DMT Type TW-E 250KN electric double drum hawser winch, 250kN pull at 0-9m/min, low speed / 80kN at 0-28m/min, high speed	
1 x Data Hidrolik tow hook	
1 x Data Hidrolik aft capstan	
Complement	
Crew	6
Number of cabins	4



OUTBOARD PROFILE



BOW VIEW



MAIN DECK PLAN