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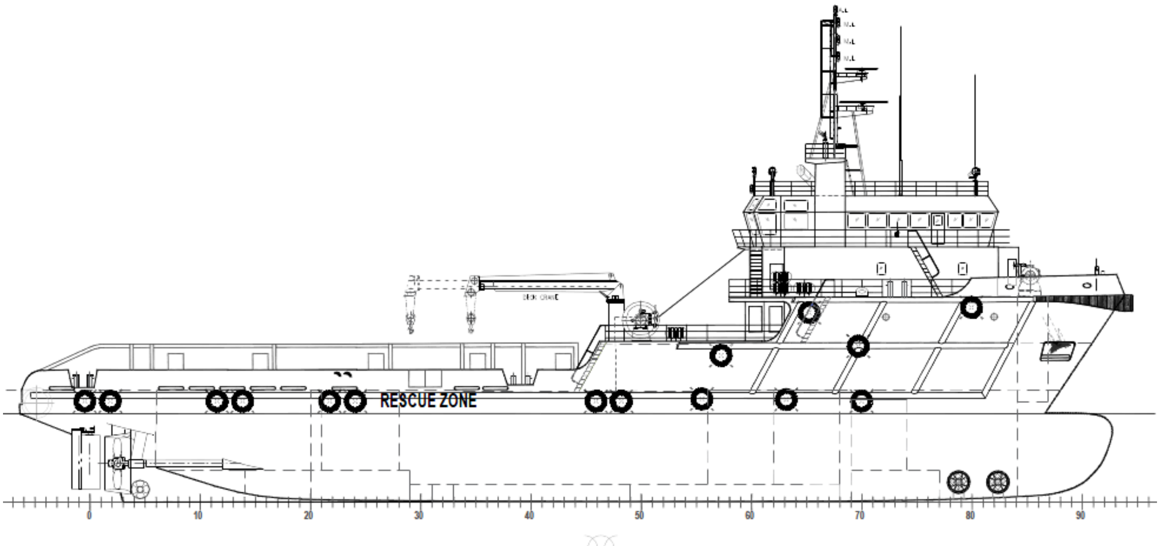
STUDENT SHIP DESIGN COMPETITION 2017

PROJECT OF AN ANCHOR HANDLER TUG SUPPLY 100 TN OF BOLLARD PULL



UNIVERSIDAD TECNOLOGICA NACIONAL

FACULTAD REGIONAL BUENOS AIRES

DEPARTMENT OF NAVAL ENGINEERING

Student Certification

This is to certify that the following members were part of the design team and by this statement, I certify that the work done for this design competition was completed by the student team members.

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- All colleagues that collaborate in the document revision

OWNER'S REQUIREMENTS FOR AN AHTS

Introduction

This section outlines the Owner requirements for the construction and outfitting of an Anchor Handling Tug Supply Safety & Rescue Vessel (AHTS) that will operate in the South Argentinean Sea, will be classed for unrestricted service. The vessel has the following basic functions:

- Towing duties
- Cargo transportation
- Fire fighting
- Oil-spill recovery
- Anchor-handling duties
- Safety stand-by
- ROV operations

This vessel shall include (1) deck, double bottom tanks and wing tanks, main deck shall be strengthened to bear cargo load.

The deadweight of the vessel at the design draft should be of 1700 MT this includes cargo, fuel, Lub oil, fresh water, crew with their personal effects, provisions and inventories and spares, wires, shackles, pelican hooks, deck cargo, cement, foam, dispersant, etc.

The vessel shall also have a superstructure and a deckhouse with accommodations at forward part.

The engine room will be situated forward of the cargo area below the main deck. It shall be fitted with Two (2) independent propulsion plants, ecologic and fuel saving devices shall be included in design. Alternative solutions for Diesel use may be accepted.

The vessel shall be equipped for FI-FI class 1 with a deluge system for self-protection and a dynamic positioning system with redundancy (DP-2)

Accommodation shall be for forty (40) offshore staff shall be available.

Route

The vessel will operate and supply oil platforms at the South Argentinean sea, with sporadic voyages to the Brazilian Sea and the Mexican Gulf Sea. It should be able to guarantee an autonomy of 4000 nautical miles at her service speed of 14 knts

It shall provide food and other services as well as transfer of offshore staff and carry out rescue operations, a hospital area should be considered in the accommodations lay out.

The vessel shall be able to maintain station and deliver materials to offshore rigs and platforms in the following conditions>

-Wind velocity = 35 knts

-Significant Wave Height= 2.5m

-Current velocity= 2.0 knts

-Wave Period= 10 sec

The Duration of a voyage to the next harbor will be estimated at a maximum of twenty (20) days during towing duties and of forty (40) days, for stand-by operations.

Principal utilities and characteristics

- 100 Tn BP.
- Main winch able to cope with standard requirement of anchor operations.
  - Dynamic brake should be provided.
- Chain locker capacity.
- Open deck with availability of > 400m2, with 5tn/m2 + 10tn/m2 for aft skid area
- Cargo tanks, for: Oily based Mud, Drill water, Potable water, Brine, Dry Bulk.
- Rescue crane & one (1) electro-hydraulic telescopic crane to be installed on the port side of the vessel. The crane shall be able to extend about three (3) meters over the side of the vessel
- Dynamic positioning system.
- Rescue zone
- Fixed pitch propeller with nozzle
- Auxiliary generators shall be provided to cover accommodation and electrical needs, (DP-2 - Bow thrusters) + Hydraulics
- Two (2) bow thruster shall be fitted, all tunnel thruster shall have controllable pitch propellers.

Deck Loads:

ISO standard 20-ft containers on deck.

Containerized launch and recovery system for ROV´s Anchors and

chain lifted.

Speed, Range, DWT

Trial speed at Design Draft – 14 knots at 0.80 MCR

Range—4.000 nautical miles at 14 knots and 0.90 MCR with 10% fuel remaining. DWT: Should be estimated as 1700 MT.

Classification

The Vessel including its hull, machinery and outfitting equipment shall be constructed in accordance with the latest International Rules and Regulations and under the survey of ABS: +Al(E), Offshore Support Vessel, Anchor Handling Vessel, Towing Vessel, +Fire Fighting Vessel Class 1, +AMS, +DPS-2, SPS2008, ACOJ, Unrestricted Navigation.

Or the equivalent if another Class society is adopted.

The vessel with equipment shall be built to fulfill but not limited to all applicable Class and Flag State rules and regulations in force according.

- International Load Lines Convention, 1966.
- SOLAS, 1974 and the amendments in force now of contract.
- International Regulations for Preventing Collisions at Sea, 1972 and amendments.
- Marine Pollution Prevention, 1973/1978 and amendments.
- Convention N'68 at Seattle concerning feeding of ship's and crew
- Convention N'93 at Genova 1949 concerning accommodations of ship's crew
- International Convention for Rules of Radio and Wireless communications (Montreal 1965) and its amendments.
- Rules relating to equipment of cargo handling ILO
- IMO Noise code A-468
- Damage Stability in accordance with IMO A-469 (XII)
- The vessel shall be equipped per GMDSS rules

Limiting Particulars

- LOA: Less than 70 meters
- Beam: No restriction
- Draft: Less than 6 meters, to guarantee harbor versatility.
- Cb: Less than 0.8 for hull resistance porpoise. Research of optimum Cb, and hull shape for minimum resistance will be requested.
- Air Draft: No restriction
- Tonnage: No restriction

Registry

- Argentinean flag

Complement

Minimum manning consistent with registry and operational requirements is desired.

Additional accommodations to be provided for 40 technicians as stated by MLC convention and SPS CODE.

Special Design Considerations

The Vessel and its equipment shall be designed and built in accordance with international Shipbuilding Standards concerning the of general hull, marine engineering and electrical equipment and which prevail and/or resolutions passed at time of signing of contract which would come in force before delivering of vessel.

The hull including the deckhouse shall be built of mild steel, of the best commercial shipbuilding quality. The steel shall follow specifications and furnished with the test certificate as required by Classification Society.

The hull is to be built with a combination of transverse and longitudinal frame system. The superstructure shall be made of steel construction.

The after body shall get a well-stiffened transom stern and sheer. Floor plates shall be arranged at every frame with lightening holes for sufficient access to all spaces. Non-watertight wash bulkheads with lightening and access shall be provided as necessary.

The foundation of the main engines shall have ample strengthening and good connection to the Vessel's hull. Foundations of main engines will form part of the bottom construction in way of the engine room. Foundations for main diesel generator units, pumps, separators, deck machinery etc. shall be provided with sufficient strength to suppress vibrations.

The Vessel shall be designed to have double bottom except forepeak tank and steering gear compartment. Tanks for fuel oil, fresh water, dirty oil, sludge, oil, sewage, water ballast etc. are to be arranged as appropriately.

Inner floors and longitudinal girders of bottom construction with sufficient lightening holes (also for good access), limber and air holes are to be provided except where watertight or oil tight construction are required.

Shell plating, Frame, Bulwark; to include:

a) All sea chests plating to be of increased in thickness.

b) The port and starboard main sea chests to be provided with interconnected cross-over sea mains with isolating butterfly valve.

c) Each sea chest (including external FIFI pump sea chest) gratings to have opening area of three (3) times the total area of suction pipes requirement of vessel equipment and provided with air vent valve and pipe to main deck, compressed air valve for weed and anti-marine growth system electrical probes. Sea chest gratings should be hinged and bolted with SUS bolts and nuts, locked with SUS wire, and flushed with hull plates.

Auxiliary system requirements unique to the vessel type include cargo hold ventilation and cargo space fire detection and extinguishing, including dewatering.

Applicable Regulations

The ships shall meet all international regulations for load line, intact stability, and other SOLAS and MARPOL requirements for lifesaving, firefighting, and pollution regulations.

When developing the design, the future course of regulations directed to environmental issues shall be researched and responded to. Evaluations should include but are not limited to features regarding:

- Minimization of NOx and Sox emissions from the main and auxiliary engines
- Disposal of sewage and waste material
- Oil tanks isolated from the ship side shell
- Non-ozone depleting fire fighting and refrigeration systems
- Provision for at-sea ballast water exchange or other effective measures of ballast management to minimize invasive species introduction.

Abstract

The following project consist of the preliminary stage of the design of an ANCHOR HANDLER TUG SUPPLY described in the owner requirements. The design team is formed by 2 senior students and 2 advanced students of Naval Engineer from the UNIVERDIDAD TECNOLOGICA NACIONAL, Facultad de Buenos Aires, from Argentina.

This design team was consulted by the future owner regarding some technical and commercial aspects make their requirements as efficient as possible for the shipping market. A market research was conducted to find the most efficient operational vessel. As the oil market is in regression a very versatile vessel must be designed to obtain the maximum of its profit ant the minimum chance of being non-operational.

It was found that certain characteristics were repeated in the vessels that were non-operational and were also founded that some key features were a must to be suitable and versatile for any kind of offshore vessel job.

As an example, that will be dealt with in the progression of this project, some of the below conclusions were kept in mind to get the most efficient unit.

- Pure PSV are non-operative in Brazil and the North Sea, as the demand is less than offer.
- Pure AHTS are non-operative, as there is less demand than offer.
- Requirements for Dynamic Positioning establish the capacity of getting hired in almost all contracts
- Requirement for FIFI gives the vessel the capacity of getting hired for almost any job
- Towing capacity is not highly required as the semisubmersible platforms are being moved with less frequency between oil holes. An exceeding towing capacity will raise the fuel oil consumption, lowering the margins for payload.
- Diverse variety of products must be carried to be ready for any supply

These conclusions forced the owner to keep in mind the need to build a vessel with a primary function of towing and anchor handling duties but also to mixed with some cargo capacity to reach a rational amount of payload.

With the aim of building a vessel updated as to get a maximum economical profit of the unit, the design of the project is started.

Contents

The Project

Mission

This project is aimed to comply with the owner requirements of an Anchor Handler Tug Supply (AHTS), designed to aid offshore platforms at the Argentinean south sea platform. The owner aims to update his fleet by replacing the old AHTS "Golondrina del Mar", class '68. The Owner offers his services in first instance in the Argentinean Sea, but with prospect of making business in the Brazilian and Caribbean Seas.

Photography of " Golondrina de Mar"

Activities

The principal aim of the vessel is to provide tug capability and supplies to offshore fixed and semi-submergible platforms, and it will be equipped with an Oil spill recovery capabilities and firefighting capability. As almost all commercial contract requires for an offshore vessel to meet.

Drilling technology is in constant development. One of the main consequences of the development of modern technologies is the ability to drill wells in deeper seas and setting the platforms far away from the shore. The AHTS will be designed to comply with the actual requirement for these new drilling units and to offer the best service in the market. This means also that the vessel will be able to perform oceanic towing operations besides to assistance on single point mooring operations. Furthermore, and considering the development of renewable energies around the world and in the fact that Argentina has wind farms and it is expected to establish marine wind farms in the future, the design team suggested that this type of vessel will be highly suitable for assist on their construction and maintenance. The design team suggested the non-utilization of the ROV since is rarely used in normal activities besides high installation costs and high investment on communication devices.

<u>Operation area</u>

The offshore operations at the Argentinean South Sea are composed of the following:

- (5) Five Fixed Rig (TOTAL)
- (6) Six Fixed and Jack up Rig (Sipetrol),

All located in front of the *San Sebastián Bay*. The vessel will have a normal operation from the supporter logistic port *Punta Quilla*, to each platform, where vessel is provisioned with dry cargo, potable water, drilling water, spare parts, etc. Fuel is provisioned from *Puerto Deseado* port.

Drilling units come from Brazil or even Chile. Therefore, the endurance calculation must comply with trips from the operation zone. In addition, the fuel supplied to platforms comes from the same storage tanks used for own consumption.

An extract from H50 navigation chart is added in order to provide clarity of the Operation area.

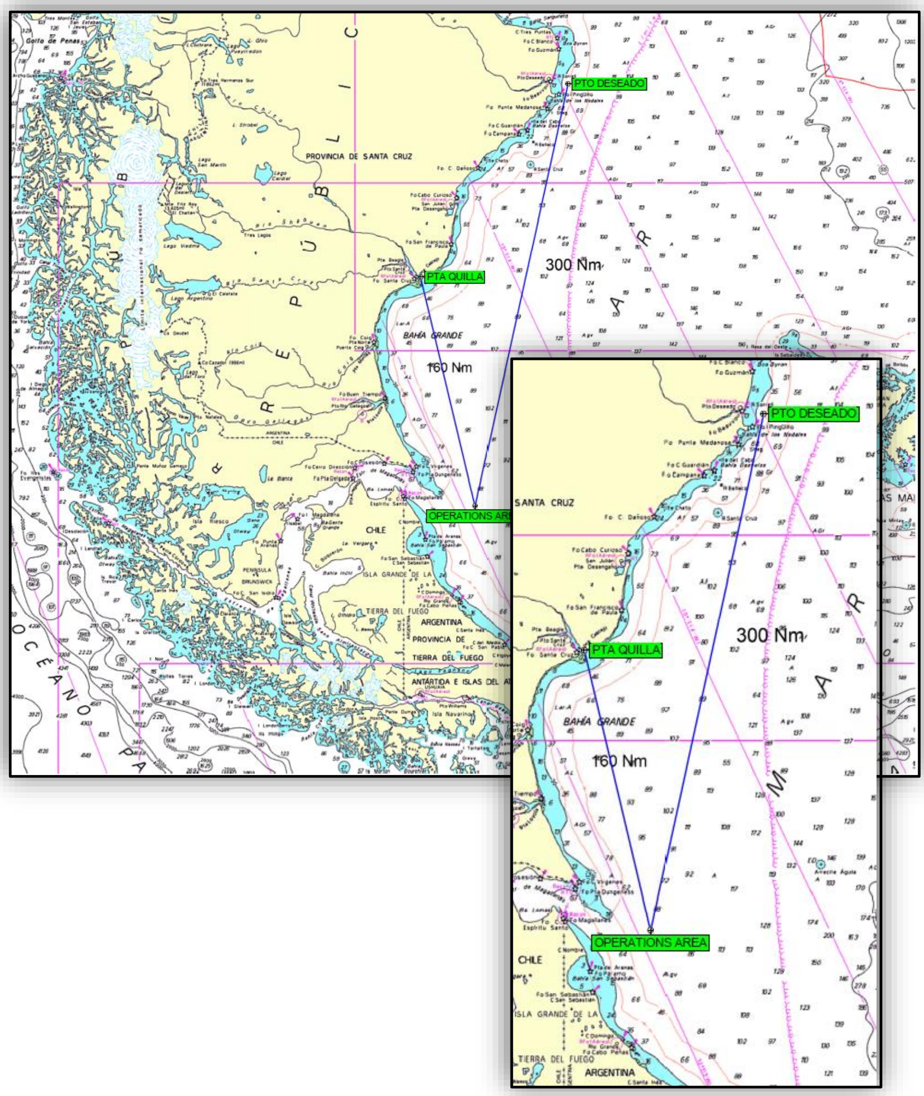


Figure Extract of navigation chart "H50" – Operation area

The vessel

With the basic owner requirements and setting as a must to comply the Bollard Pull the following statistic table was found. It was suggested to the owner, the need of being able to transport platform consumables, in addition of tug capability, for it to be a more versatile vessel in a downing market, Therefore an estimation for a 1700 DWT was done, and verification of this estimation was asked for, and will be verified in this document.

Summary table of the owner project

BULLARD PULL [MT]	DWT [MT]	TRIAL SPEED @ 80% MCR [KNTS]	ENDURANCE	SPECIAL CHARACTERISTIC
100	Aprox 1700	14	4000 nm	FI-FI 1 DPS-2

Principal dimensioning

The process of dimensioning the vessel started by setting up a statistic table of the current similar vessels, using as a filter parameter the bollard pull (with an allowance of ± 10%). A fleet of 23 vessels was evaluated.

While the data base was being built, a trend of capability for carrying Dead Weight Ton of that amount was found.

A big over all spared between maximum and minimum length over all was found, with a minimum of 45.9 meters (Sample #3) and a maximum of 75 meters (Sample #18), giving a Delta of 29 meters. This first sight observation will be deeply analyzed along the following steps.

Statistic data base

ID	Built on	Men on board	Δ	DWT	LSW	BP	Prop	LOA	LBP	B	D	H	BHP	Vs	Fuel capacity	Deck Area	LOA/B	B/D	H/D	LBP/D	Vs/√LBP
	[Year]	[-]	[Tn]	[Tn]	[Tn]	[Tn]	[-]	[m]	[m]	[m]	[m]	[m]	[HP]	[kts]	[m3]	[m2]	[-]	[-]	[-]	[-]	[-]
SAMPLE #1	2011	10				103	FPP	48,8	43,2	13,8	7,0	6,2	6000	12	490	155	3,54	1,97	0,89	6,17	1,83
SAMPLE #2	2015	20				100	Azimutal	50,6	49,0	14,5	7,0	6,5	8550	12,2	599		3,49	2,07	0,93	7,01	1,74
SAMPLE #3	2015	12				90	Azimutal	45,9	35,8	12,8	5,8	4,8	7616	14,5	535		3,59	2,21	0,83	6,17	2,42
SAMPLE #4	2009	32		1700		105	FPP	67,8	63,1	15,0	6,1	5,0	8000	11	606	425	4,52	2,46	0,82	10,34	1,39
SAMPLE #5	2010	50		2515		108	FPP	70,1	65,1	17,0	7,5	6,0	7960	12	698	500	4,12	2,27	0,80	8,69	1,49
SAMPLE #6	2010	42		2500		100	FPP	70,5	65,6	16,6	7,2	5,9	7900	10	988	490	4,25	2,31	0,82	9,11	1,23
SAMPLE #7	2011	28		1575		94	FPP	63,4	59,0	15,8	6,8	5,1	6750	11	804	420	4,01	2,32	0,75	8,67	1,43
SAMPLE #8	2011	42		2485		110	FPP	67,4	62,7	16,0	7,0	5,9	8000	9			4,21	2,29	0,84	8,95	1,14
SAMPLE #9	2005	22	-	1950	-	90	CPP	59,8	55,6	16,0	7,3	5,5	6876	13,2	1370	362	3,74	2,19	0,75	7,62	1,77
SAMPLE #10	1995	24	-	1185	-	90	CPP	64,4	59,9	13,8	4,8	4,7	7080	14	973	421	4,67	2,91	0,99	12,61	1,81
SAMPLE #11	2015	38	-	1900	-	90	CPP	68,8	64,0	18,0	6,8	5,5	8208	12	800	570	3,82	2,65	0,81	9,41	1,50
SAMPLE #12	2006	28	-	1611	-	90	CPP	64,8	60,3	16,0	5,8	4,9	7224	14	607	420	4,05	2,76	0,84	10,39	1,80
SAMPLE #13	2015	26	-	1900	-	90	Azimutal	65,3	60,7	16,0	6,0	5,1	8100	13	600	440	4,08	2,67	0,85	10,11	1,67
SAMPLE #14	2015	50	-	1800	-	90	CPP	65,0	60,5	16,0	6,2	5,0	6682	12,5	580	435	4,06	2,58	0,81	9,75	1,61
SAMPLE #15	1982	32	-		-	102	CPP	72,0	67,0	15,0	7,0	4,9		12	980	430	4,80	2,14	0,70	9,57	1,47
SAMPLE #16	1982	20	-		-	100	CPP	64,4	59,9	13,8	6,9	5,9	8214	10	800	418	4,67	2,00	0,86	8,68	1,29
SAMPLE #17	2008	42	-	2200	-	100	CPP	70,5	65,6	16,0	7,2	6,1	8306	12	1000	500	4,41	2,22	0,85	9,11	1,48
SAMPLE #18	2010	40	-	2500	-	90	CPP	75,0	69,8	16,0	7,5	6,1	7492	10	850	500	4,69	2,13	0,81	9,30	1,20
SAMPLE #19	2009	26	-	2050	-	90	CPP	64,4	59,8	15,0	6,0	5,2	7269	13	894	430	4,29	2,50	0,86	9,97	1,68
SAMPLE #20	1980	23	-	1940	-	90	CPP	64,6	60,0	13,8	6,9	6,0	7128	11	880	400,2	4,68	2,00	0,87	8,70	1,42
SAMPLE #21	2011	20	-		-	92	Azimutal	53,0	49,3	13,8	7,0	5,8	7344	12			3,84	1,97	0,83	7,04	1,71
SAMPLE #22	1999	20	3668	2198	1470	108	CPP	67,0	62,3	14,0	6,0	5,0	8046	11	693	418	4,79	2,33	0,83	10,39	1,39
SAMPLE #23	2011	42	3539	1589	1949,18	90	Azimutal	63,0	58,6	14,0	6,8	5,5	6436	12	747	432	4,50	2,06	0,81	8,62	1,57
AVERAGE VESSEL	**2006**	**30**	**3604**	**1976**	**1710**	**96**		**63,8**	**59,0**	**15,2**	**6,6**	**5,5**	**7182**	**12**	**785**	**430**	**4,3**	**2,3**	**0,8**	**9,0**	**1,6**

Length over all calculation

As there is no much literature for dimensioning an AHTS capable of delivering DWT, like a OSV. There was a need of doing some research before parametrizing.

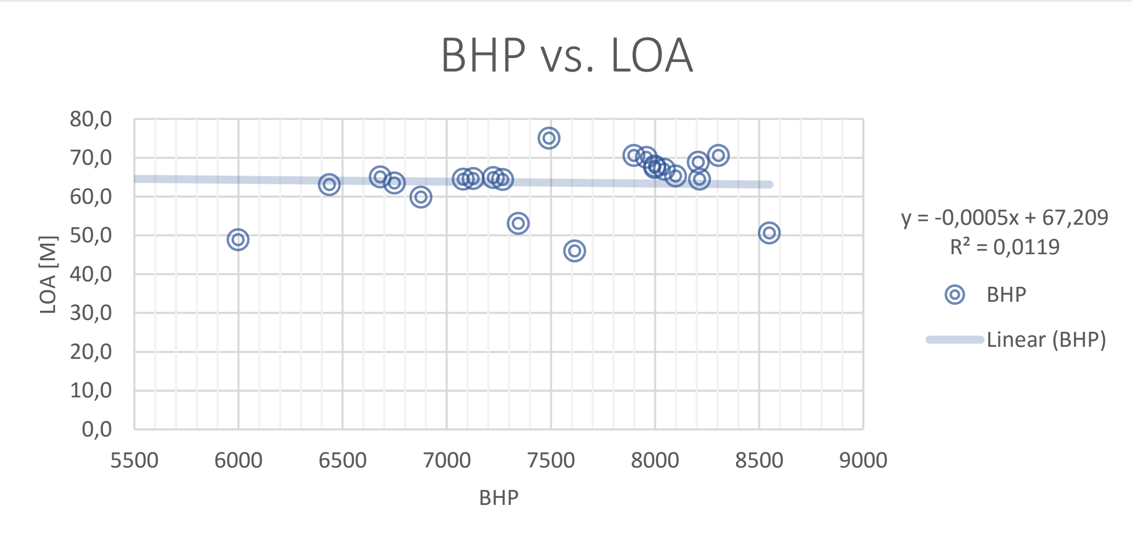
Once the data base was built up, as was said, a big spread in the length was found (Delta of 29 meters). Setting the focus on this parameter, the next step was trying to optimize it as much as possible. Analyzing both extremes to justify such a spread the following was found.

Note: LOA is calculated instead of LBP as in most of the statistics that did not display an GA, figured the LOA figures besides the LBP. In the data base LBP was estimated as a -7% of LOA.

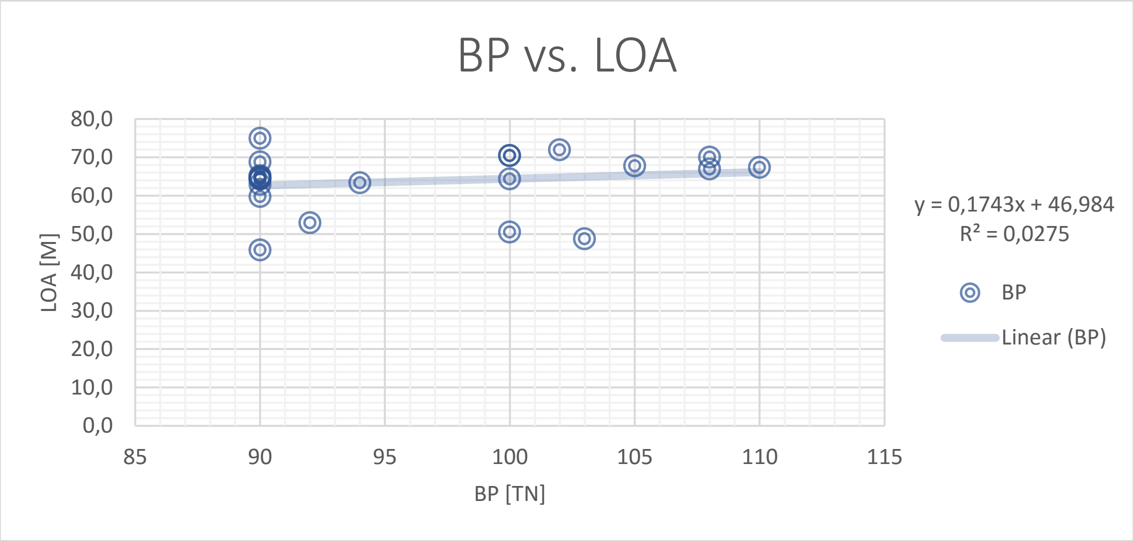
Both candidates were analyzed, with the biggest and lowest LOA. After a brief analysis, the conclusion that length is completely dependent of the DWT carried, was found. And it was believed that this dependency was almost completed derived from Bullard Pull capacity. Although it seems a firm conclusion, the other parameters will be analyzed to find which has the biggest dependency with length. In the following plots the representative statistical regression and it equation will be displayed, from which the quadratic *error* will show, in basic terms, how well a linear or constant function fits to the statistic, (R^2=1 regression perfectly lineal, R^2=0 regression not lineal). And this will be the judge feature for getting a good parametrization.

The following conclusions were found:

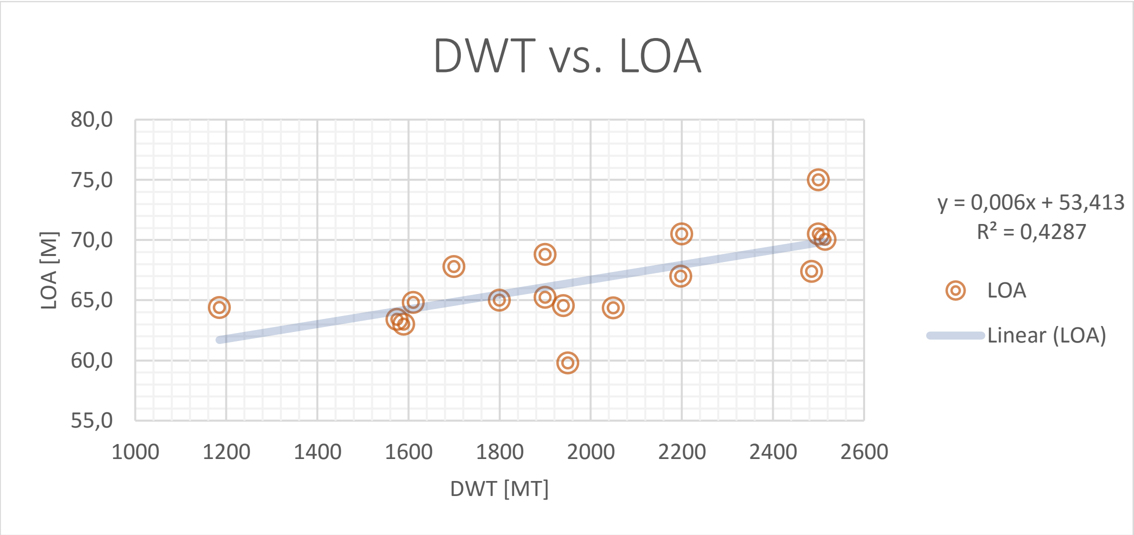
- ✓ BHP: The data base shows a spread of the power values, which reflect in a parameter that should be expected to modify the engine room length. The statistics show that no dependency was found. R^2 is almost null and there is not a good regression between the power and length of the vessel.



- ✓ Bollard Pull: The data base was constrained to a specific bollard pull deviation of 100 Tn was specified and which is not too much. Although it was carried out a dependency analysis was carried out, the following plot display that R^2 is almost null and there is not a good regression between bollard pull and length of vessel (two or more samples with same BP and different lengths).



- ✓ DWT: An analysis for finding dependency between deadweight ton and length was carried out. It was found that there is a good regression R^2=0,43, which means a good relation between both parameters.



Conclusion: The parameter that rules the length was obtained, being this the DWT as it was a cargo vessel. A DWT must be obtained to define the length. The owner set this limit as an estimation of 1700 MT.

For risk mitigation at this stage of project the, estimation of DWT of 1700 Tn + 5% is used. To be on the safe side, the outfitting of tanks and internal permeability included as part of the real calculation of DWT.

DWT (first estimation)	*1785*

From the first estimation of DWT and with the regression equation:

$$LOA = 0,006xDWT + 53,413 \ [m] \rightarrow \ LOA = 65,02\,m \ \rightarrow LOA = 65\,m$$

Principal dimensions

For obtaining the principal dimensions as beam, depth and draft, from the data base, the non-dimensional coefficient of forms were calculated as an average, obtaining the following principal dimensions:

LOA/B	4,3
B/D	2,3
H/D	0,8
Lpp/D	9

Beam	**15,14**	**[m]**
Depth	**6,58**	**[m]**
Draft	**5,21**	**[m]**

Calculation of Light Ship Weight:

Basic LSW calculation:

Unfortunately, only a set of vessels included the LSW in them. The average vessel between both is of the same BP and LOA than the one projected.

ID	Built on	Δ	DWT	LSW	BP	Prop	LOA
	[Year]	[Tn]	[Tn]	[Tn]	[Tn]	[-]	[m]
SAMPLE #22	1999	3668	2198	1470	108	CPP	67,0
SAMPLE #23	2011	3539	1589,82	1949,18	90	Azimutal	63,0
AVERAGE VESSEL	**2006**	**3604**	**1976**	**1710**	**99**		**63,8**

From this average vessel, we can get a statistical estimation of the LSW number

LSW (first estimation) *1710 Tn*

Advanced LSW calculation:

A more specific calculation of LSW will be done using the literature "Tug dimensioning" Eng. Manuel Arnaldos, and "Some Ship Design Methods" D.G.M Watson, A.W. Gilfillan

Steel weight estimation:

Watson Method: Watson proposes a method for calculating the weight of hull steel weight, from the block coefficient @ 80% of Depth, and a series of correction.

Standard Steel Weight: $W_{s7} = K.E^{1.36}$

E: Is an equipment Number obtained from the following formula:

$$E = E_{hull} + E_{Superstructure}$$

$$E = L*(B+H) + 0{,}85*L*(D-H) + 0{,}85*\sum l_1 h_1 + 0{,}75*\sum l_2 h_2$$

$$E_{hull} = L(B+T) + 0{,}85\, L(D-T)$$

$$E_{superstructure} = 0{,}85 \sum l_{1i} h_{1i}$$

l_{1i} y h_{1i}, are the length and height of the various levels of the superstructure

The above values were measured from several sample of general arrangement found on the Internet.

Esuperstructure	173,4
Ehull	1287

$$W_{s7} = K.E^{1.36} = 913.55\, Tn$$

K: Coefficient of type of vessel, from *table III* given in the Watson text, and interlooping for offshore suppliers, we get a: **K=0,0542**

Correction from standard Cb $\quad W_s = W_{s7}\,[1 + 0{,}5\,(Cb^1 - 0{,}7)]$

Cb^1 is the block Coefficient for the vessel projected and can be estimated using the following formula:

$$Cb^1 = Cb + \frac{(1 - Cb)(0{,}8D - T)}{3T} = 0{,}75$$

Obtaining the hull steel weight corrected:

$$W_s = 940\, Tn$$

The procedure for weight calculus was followed as stated in the technical paper. The following table resume the figures obtained.

Light ship weight from Watson.

Category	*Weight [Tn]*
Hull Steel	940
Superstructure	164
Wheelhouse	44
Outfitting	291
Machinery	442
Total w/o margin	1881
LSW w margin 4%	***1957***

Arnaldos Method for steel weight estimation

$$W_{st} = \alpha * L * B * H\ [Tn]$$

α: Constant that varies between 0,13-0,17 for tugs. As this value is for tugs, and the AHTS is supposed to be heavier in structure weight than a tug, the maximum is chosen.

$$W_{st} = 1100.77\ [Tn]$$

Machinery weight

Weight of Main Engine and reduction Gear is obtained from technical brochure for the Engine: **MAK 6 M 32 C 8**. (power plant dimensioning will be later verified)

$$W_{Main\ engine} = 39{,}5\ [tm] \qquad W_{GearBox} = 13{,}5\ [tm].$$

$$W_M = 2 * W_{ME} + W_{GB} + W_{outfitting}$$

$$W_{outfitting} = 1{,}1 * W_{ME}$$

$$W_M = 192{,}9\ [tn]$$

Another way to estimate of machinery weight:

$$W_M = 2{,}5 * 2 * W_{ME}$$

$$W_M = 197{,}5\ [tn]$$

Using the highest number: $W_M = 197{,}5\ [tn]$

Weight of accommodations and equipment.

Arnaldos Method

$$W_{A+E} = \beta * L * B * H\ [tm]$$

β: Constant that varies between 0,13-0,17 for tugs. As this value is for tugs, and the AHTS is supposed to be heavier in structure weight than a tug, the maximum is chosen.

$$W_{A+E} = 518\ [tm]$$

- Another verification: $\mathrm{W_{A+E}} = 0.43 * \mathrm{Wst}$

$$W_{A+E} = 473{,}33\ [tm]$$

Using the biggest of both figures and adding deck Wood "TEKA" (9.27 tm), that is used for protection of deck floor, calculations of the statistical deck area of 430 m^2 and its specific weight were made.

$$W_{A+E} = 527.27\ [tm]$$

Light ship weight from Arnaldos.

$$LSW = W_{A+E} + W_M + W_{st}$$

$$LSW = 527.27 + 197.5 + 1100.77$$

$$LSW = 1825.55\ [tm]$$

Light ship weight estimation.

At this stage of the project, as the LSW calculations match with the one from the statistics, and both method are similar, the estimation of the LSW is done as an average of the three methods.

METHOD	LSW [TN]
STATISTIC	1710
WATSON	1957
ARNALDOS	1826
AVERAGE	***1831***

Consumables Wc

$$W_C = Wfo + Wdo + Woil + Wdrinkable + Wothers$$

Fuel Oil – **Wfo**

$$Wfo = \left(g.\frac{A}{Vs}.BHP\right).1,1$$

- g: specific fuel oil consumption[kg/kWh] of Main Engine, set from technical brochure 177 kg/kW hs.
- A: Range. Set from owner requirements as 4000nm
- Vs: Speed of vessel 14 kts (mn/hs)
- BHP: Obtained from statistics: A engine is selected→ **2 # MAK 6 M 32 C 8**. → 8837 HP.

$$Wfo = \left(0,7457 * 177 * 7779.3 * \frac{6000}{14knts}\right).1,1$$

$$Wfo = 484.05\ tm$$

This engine and its power is verified that will satisfy the Bollard pull requirement as for example using the preliminary parameter that relates Bollard Pull with power installed, the following verification is done:

- Specifying a mechanical efficiency of 95% and a dereating of 10%

$$DHP = BHP\ x\ Deraeting\ x\ \eta Mec$$

$$BP = 15\frac{kg}{DHP}xDHP$$

$$BP = 15\frac{kg}{DHP}x7555DHP$$

$$BP = 113\ mT$$

Diesel Oil – **Wdo**

Estimated as 10% of the Fuel Oil calculated and is meant for use while maneuvering, and on port maneuvers. $Wdo = 10\%\ Wfo = 48,41\ tm$

Oil - **Woils**

From literature is known the following relation for Oil calculation is delivered: 2,5 BHP/1000 [Tn]

$$Woil = 19tm$$

Drinkable water – **Wwater**

$$Wwater = k * N * d/1000$$

Being,

- K: Diary consumption per crew
- N: Total number of crew.
- d: Range in days.

$$Wwater = 150\frac{lts}{crew.day}.10\,.18 = 27{,}5\ tm$$

$$Wwater = 27{,}5\ tm$$

Includes the drinkable water, shower, and water for personal cleaning, was established. A range of 8 days of navigation and a crew of 14 men. For stand-by operations of extra days a extra quantity of consumables will be added. But this calculus is to obtain the average need.

Other weights – **Wothers**
Personal belongings plus food.

$$Wothers = \frac{140kg}{crew} + \frac{5kg}{crew\ and\ day}[kg]$$

$$Wothers = 2{,}29\ tm$$

Obtaining a total weight for consumables:

$$W_C = Wfo + Wdo + Woil + Wdrinkable + Wothers$$

$$W_C = 484.05 + 48{,}41 + 19 + 27{,}5 + 2{,}29$$

$$W_C = 581.7\ tm$$

Displacement estimation

With the values of consumables, light ship and DWT weights obtained, the displacement is calculated as follows:

$$LSW + DWT = \Delta$$

$$LSW = 1831Tn$$

$$DWT = NWT + Consumables$$

$$DWT = 1785Tn$$

$$\Delta = 3616Tn$$

Non-dimensional coefficients calculation

- Block Coefficient

$$CbxHxBxLppx1,03 = \Delta$$
$$Cb = \frac{3616Tn}{5,21mx15,14mx65x0.93x1,03}$$
$$\Rightarrow Cb = 0,736$$

- Midship Section Coefficient (*calculated with an expression from Watson text)*

$$C_m = 0,977 + 0,085 * (Cb - 0,60)$$
$$\rightarrow C_m = 0,9885$$

- Prismatic Coefficient (four methods given at UTN textbook)

$$Cp = Cb / Cm$$
$$Cp = 0,736 / 0,9885$$
$$\Rightarrow Cp = 0,74$$

- Water Plane Area Coefficient

$$Cwl = \frac{1}{3} + \frac{2}{3}Cb$$
$$Cwl = Cb + 0,1$$
$$Cwl = 0,7Cp + 0,3$$
$$Cwl = \sqrt{Cb} - 0,025$$

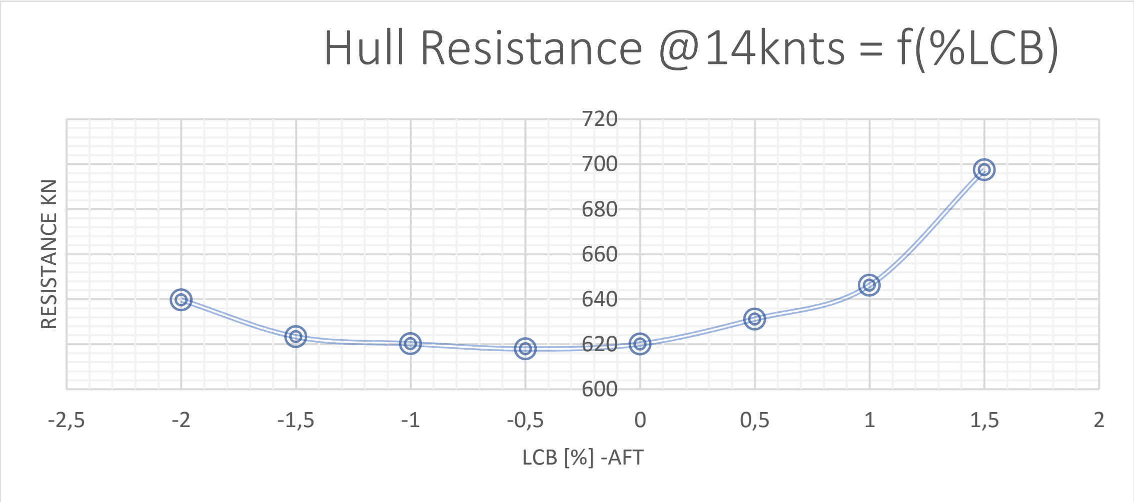
Cwl	**0,77**	**[-]**	0,77
Cwl	0,75	[-]	
Cwl	0,77	[-]	
Cwl	0,78	[-]	

Obtaining an average value of Cwl 0,77

- Longitudinal Center of Bouyancy

No much literature was found about the estimation of the LCB for this type of vessel. With the hull modeled on MaxSurf, with the above coefficient obtained it were generated 8 versions of the hull were the displacement was fixed and the LCB was moved from 1,5% fore from midship section to -2% and the values of resistance were calculated for the service speed of 14 knts using the SLENDER BODY analysis. Although this analysis is not quantitative, it gives a notion of the effect of LCB position in terms of a qualitative analysis. Slender body analysis is not a precise analysis but is good for capture geometry modifications, as is a geometry mesh-based simulation.

LCB [%] AFT IS -	Δ	kN
1,5	3538	697,5
1	3537	646,2
0,5	3530	631,2
0	3533	620,1
-0,5	3534	617,9
-1	3535	620,2
-1,5	3534	623,3
-2	3547	639,7



LCB estimation is of -0,5%LOA, aft from Midship Section.

Summary of dimensions

PRINCIPAL DIMENSIONS

LOA	***65,0 m***
B	***15,14 m***
D	***6,58 m***
H	***5,21 m***
POWER (ESTIMATION)	***7182 BHP***
DISPLACEMENT	***3616 Tn***
BOLLARD PULL	***100 mT***
CB	***0,736***
CM	***0,9885***
CP	***0,74***
CWL	***0,77***
LCB	***0,5% aft from MS***
LSW	***1831 Tn***
DWT	***1785 Tn***
NWT	***1203 Tn***

Hull modelling

Formation and creation

The creation of the forms of a ship is an aspect of significant importance, due to its multiple implications in different projects.

From the hydrodynamic point of view, the optimal forms are those for which the ship can sail at a certain speed using the least amount of power possible and thus spend less fuel and improve autonomy.

Among the current programs for 3D modeling of the hull are MaxSurf and Rhinoceros, both of which work by creating surfaces. NURBS (a non-uniform rational B-spline) is a mathematical model widely used in computer graphics to generate and represent curves and surfaces.

Once we have the 3D shell model, we will be able to carry out different analyses using naval architecture software, CFD, etc., which will allow us to check the validity of the design, implement improvements, which will lead to the modification of the model 3D and which in turn will lead us to the realization of new analyzes, among which we can include the following:

- Calculation of hydrostatic curves, displacements and project draft
- Smoothness of the hull corroboration,
- Study of intact and damaged stability,
- Resistance Prediction
- CFD analysis to quantify the hydrodynamic efficiency of the fairing and of the appendices
- Analysis of behavior at sea and maneuverability.
- Analysis of ways to be beneficial from a constructive point of view (developable and without complex curvatures).

Previous considerations

When designing the forms of a ship, it must first be decided which factors will influence the operation of the ship, and thus try to minimize them. This means that the ship will be projected to minimize as much as possible the resistance in calm waters and the movements of the ship in the sea.

In addition, considering the behavior of the ship at sea, it will be necessary to choose between designing a ship with good platform stability or another that experiences the least reduction of speed in waves hence lower accelerations, since that decision will mark the final form.

To make this decision it is necessary to know in depth the type of operations to which the ship will be dedicated and the characteristics of the sea in which it will sail or operate.

As previously, the main mission of an AHTS vessel is the towing and anchoring of platforms or similar; and these are normally performed at speeds of no more than 6 or 7 knots.

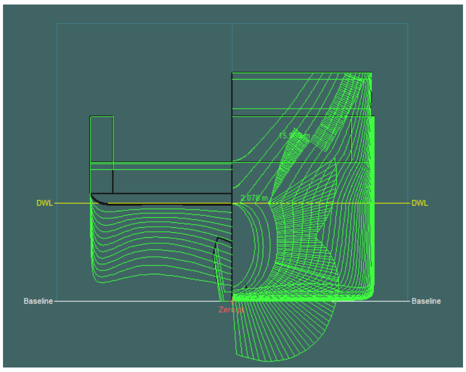
Forms adopted

In consequence, the forms adopted will be those that give the ship a good platform stability, without offering too much wave breaking resistance. This design team, have sought to achieve both objectives, prioritizing platform stability, designing a ship that will be as competitive as possible in all missions. Once the forms are obtained, they will be tried out, and optimize by means of modifications in geometry to reduce the calm water resistance, using CFD (Computational Fluid Dynamics).

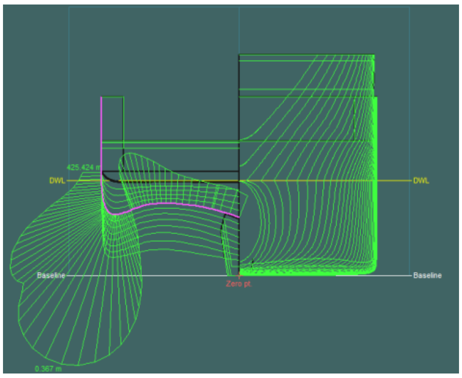
The generation of forms in this case has not been easy, since there is not much information on the forms of these ships in our country. That is why in accordance with our needs, was used the MaxSurf data base and its offshore support vessel, on which the corresponding transformations were applied, looking for our needs.

Fairing, Curvature and Surface Analysis

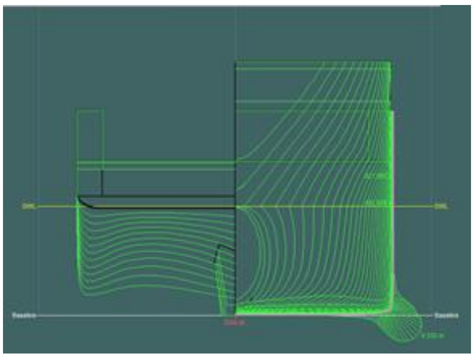
Once the shape of the vessel was constructed and the overall dimensions were determined, the curvature and surface analysis tools were executed to fair the hull. For the hull surface to be smooth, the curves used to construct it must be smooth as well.
In the following pictures, we can verify the first attempt of assessment for the curvature of each section, for brief and self-explanatory reasons is shown three transverse and one longitudinal sections plus the overall ship view applying the Gaussian curvature.

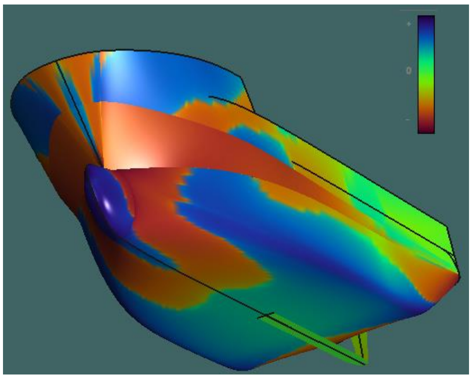


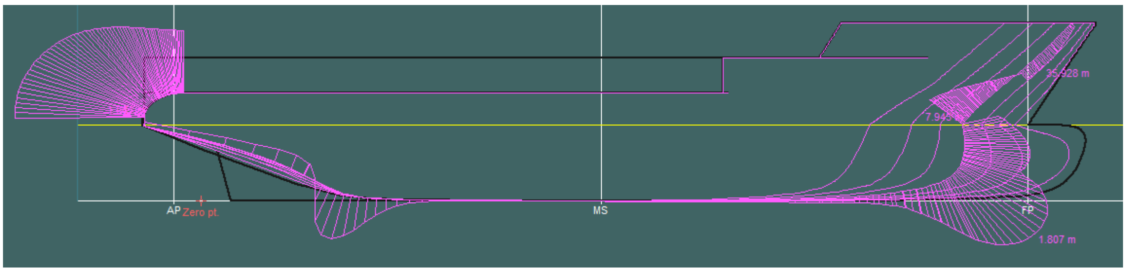
Fore transverse Section



Aft transverse Section


Midship transverse Section


Gaussian Curvature



Longitudinal section

Area/volume summary and floodable length analysis

At this stage of the project, the volumes of the modeled hull will be verified to check if they are suitable to carry the required payload and machinery plus basic outfitting. This will be done obtaining the curve of areas from the hull modeled from MaxSurf software and setting the draught as the depth. Once done the sectional area curves for the whole enclosed volume is obtained. Afterwards the draught is set to the double bottom height of one meter. Done this the double bottom sectional area is plotted over the entire hull curve.

Volumetric contains:

- Fore peak tank bulkhead as "collision bulkhead" position from the reference point according to SOLAS "*This bulkhead is to be located at a distance from the forward perpendicular FPLL of not less than 0,05 Lf or 10 m, whichever is the less, and not more than 0,08 or 0,05 Lf + 3 m, whichever is the greater."*

$$L_{cbMin} = 0.05 * 60{,}45\ m = 3\ m;$$

$$L_{cbMax} = 0.08 * 60{,}45m = 4{,}8m > lppr > 3m$$

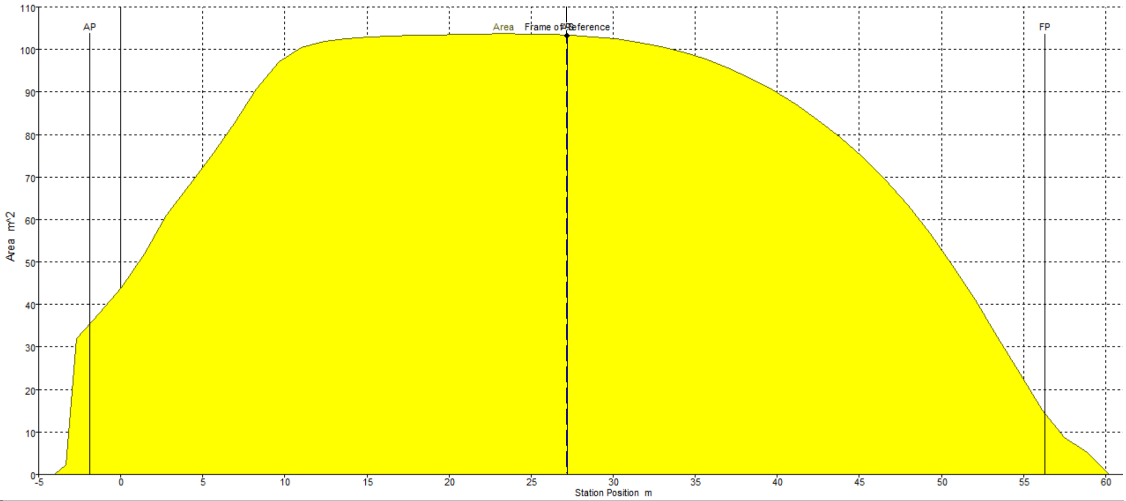
Setting the collision bulkhead position from the reference point is :$\boldsymbol{Lcb = 3\ m}$

The reference point in determining the location of the collision bulkhead is the forward end of L_f except that in the case of vessels having any part of the underwater body, such as bulbous bow, extending forward of the forward end of L_f, the required distances are to be measured from a reference point located a distance forward of the forward end of L_f. This distance *x* (see 3-2-9/Figure 1) is the least of the following:

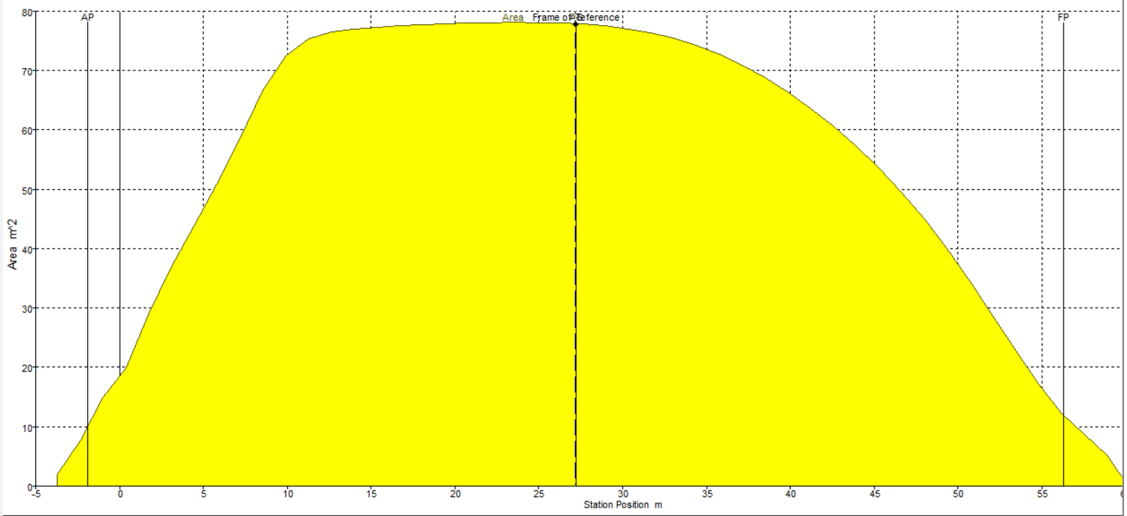
Distance to Reference point	***Obtained***
***i)* Half the distance between the forward end of *L_f* and the extreme forward end of the extension, *p*/2**	*2,2 meter is estimated for the half distance between FP and the extreme of the bulbous*
***ii)* 0.015*L_f* or**	*0,9 meters*
***iii)* 3 m (9.84 ft)**	*3 meters*

The reference point will be at 0,9 meters from the forward *Lf.*

The position for the steering gear bulkhead is also established at 3.9 meter forward of the aft perpendicular.



CURVE OF AREAS UP TO MAXIMUM DEPTH (FORECASTLE HEIGHT)



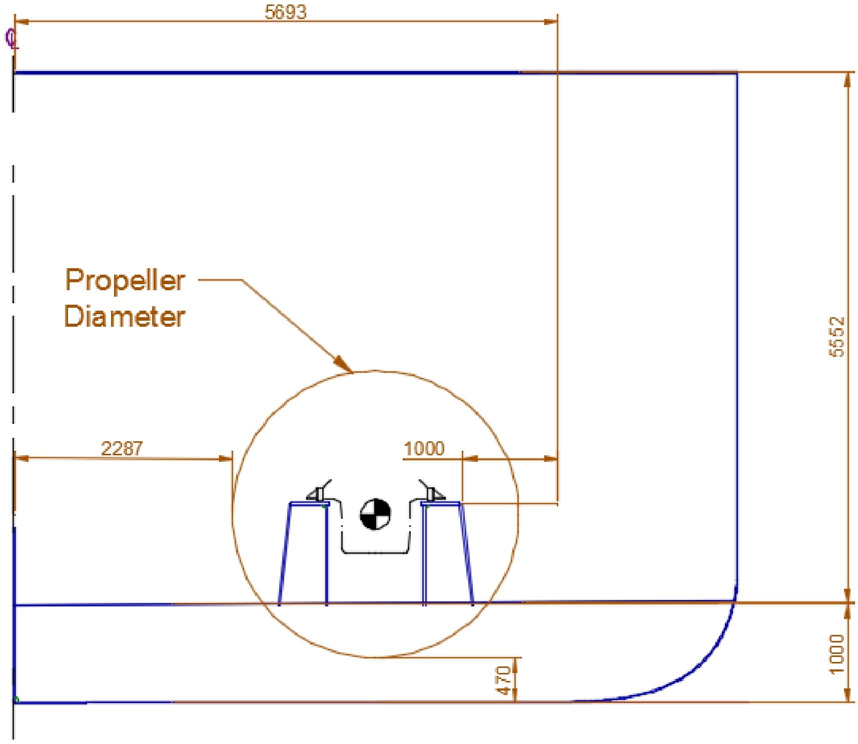
CURVE OF AREAS UP TO MAXIMUM DRAFT

- Engine position

The engine position will affect the position and separation of the propeller from base line. In this stage, a propeller of 3-meter diameter is estimated.

A clearance of 15% is estimated between the base line and propeller tip. This clearance includes the thickness of the nozzle, as the vessel is designed to operate in zones where there is a big chance of grounding. Besides, it also will facilitate the dry dock operation.

To avoid wake interference between both propellers, the engine is situated as far as possible from center line, to maximize the distance between propellers. As is known there is a need of side tanks to full fill the payload requirement as is stated in the curve of areas analysis. This project considers a minimum safety distance of one meter between engine side and tank longitudinal bulkhead of 1 meters that will grant an operative distance to permit the walkway between tank and engine. As a first estimation, the engine is situated in the first quarter from the ship side.



Midship arrangement estimation – for engine positioning

- Longitudinal Bulkheads

From the engine position a double bottom height of 1 (one) meter is at first stage estimated. A safety position for longitudinal bulkhead cargo tanks is delimited at a minimum of 500 mm as per designer's recommendation and a 500 mm extra distance, total of 1 (one) meter, between engine and tank. This would leave sufficient space for transit, pipes and overhaul of the engine. The design team will check the capacity of payload requirement using this first estimation of the side cargo tank longitudinal bulkhead, and working with the curve of areas.

- Area/summary verification

The machinery area over the double bottom and it volume can be estimated. Side cargo tanks, delimited by twice the distance from the safety position of tanks (2 x 5,693 m: 11,386 m) and the height from the double bottom up to deck (5.552 m).

$$D_m x B_m = Area_{machinery}$$

$$Area_{machinery} = 62,2m^2$$

Getting a sectional area of 62.2 $m^{2.}$

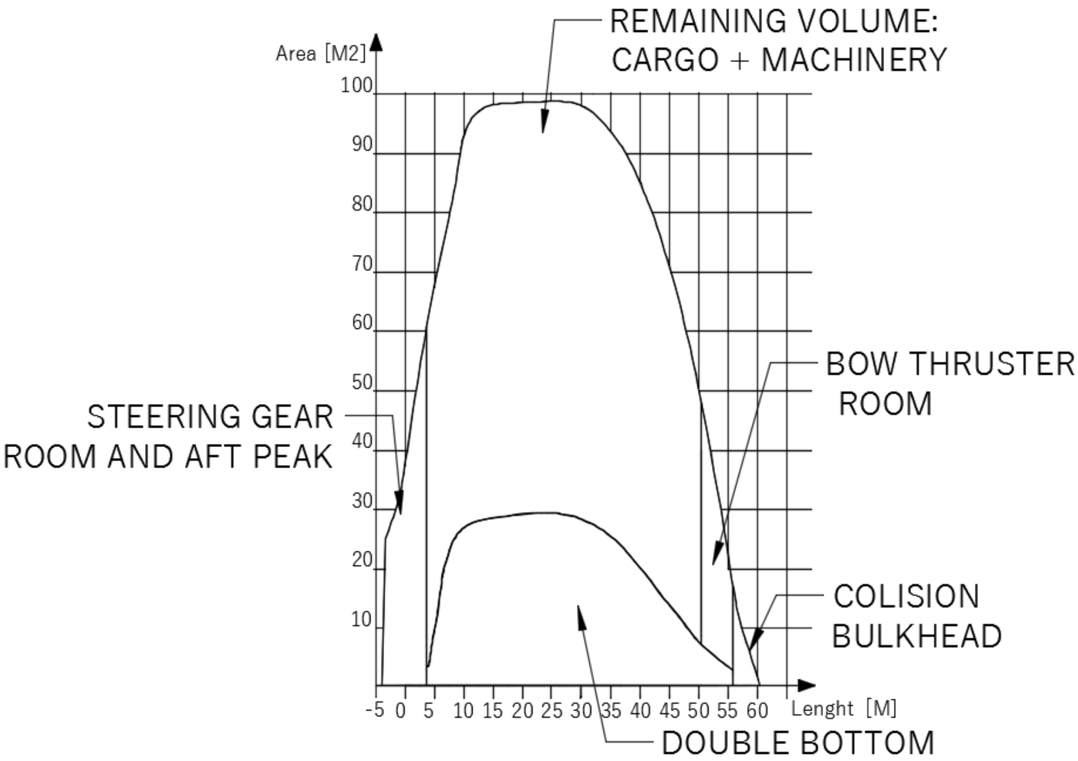
A machinery room length of 18.28 meters is estimated with a similar general arrangement (including the engine control room). An additional 20% is added as estimation for walkways, and of error in estimation of machinery space.

Obtaining a volume suitable for cargo of:

$$Volume_{machinery} = Area_{machinery} x\, L_{machinery} x1,2$$

$$Volume_{machinery} = 1364,4\,m^2$$

Working with the curve of areas.



Area curve delimited by spaces- scaled for integration.

Obtaining the areas from the AUTOCAD, the following summary of volumes is described below:

SPACE	Volume w/permeability [m^3]
STEERING GEAR SPACE + AFT PEAK	289.50
COLISION BULKHEAD	33.03
BOW THRUSTER ROOM	150.58
MACHINERY ROOM VOLUME (CALCULATED)	1364,4
CARGO VOLUME ABLE (REMAINING- ENGINE)	1633,3
CARGO AT DOUBLE BOTTOM	1030.75
CARGO SUBTOTAL	**2664,05**

Permeability of 95% is estimated for cargo tanks

CARGO VOLUME TOTAL: 2664,05 M^3

Payload requirement

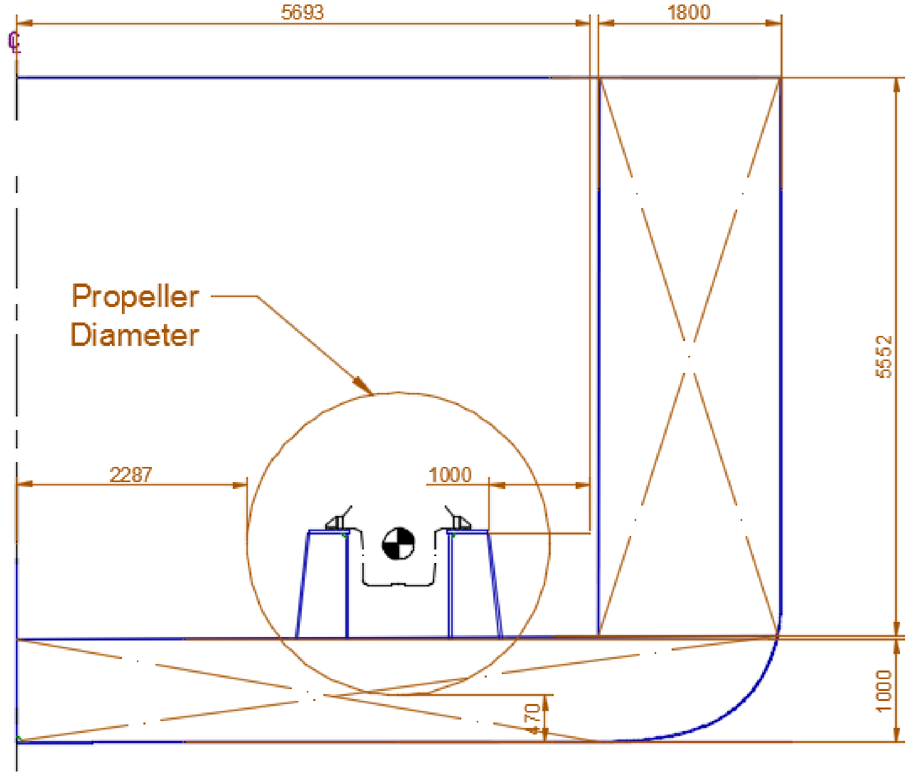
To verify the payload requirement, an initial selection of products to be transported is obtained from the owner´s commercial department, therefore obtaining the densities for the cargo items and relate it to the volume able of being transported as cargo.

CARGO TYPE	*WEIGHT [MT]*	*VOLUME [M^3]*	*S. G*
FUEL OIL (cargo+consumable & L.O.)	470	556	0,8
POTABLE WATER	405	405	1,0
DRILL WATER	635	635	1,0
BRINE	470	190	2,5
DRY CARGO	180	131	1,4
TOTAL WEIGHT/VOLUME REQUIRED WEIGHT	**2160**	**1917**	

To be in accordance with the new regulation of MARPOL (73/78 Annex I. New Regulation 12 A) require double hull protection of fuel oil tanks on any kind of ship, this regulation apply to all ships with an aggregate oil fuel capacity of 600 m3 and above. Fuel Oil amount of less than 600 m^3 should be carried to avoid cofferdam disposition between hull and tanks, and as this is the case in which there is no need of more Fuel Oil transportation. Only the amount to comply with maximum capacity for MARPOL regulations is issued. Even though in the following stages of the project the side damage probability will be mitigated by the use of side reinforcement as is stated in the ABS - OSV rules.

Is realized that the sum of weights of the cargo items exceed the payload. This is because a diversity of specific tanks to be suitable for of any cargo arrangement is preferred. This does not mean that payload will be above the 1785 DWT accorded, or exceeding the load line mark.

For this estimation, a volume of cargo tanks of 1917 m^3 is needed, and at first estimation of the volume able to carry goods is of 2664,05 m^3, having being the areas for this requirement verified. This means a spread between requirement and volume available of 38%.



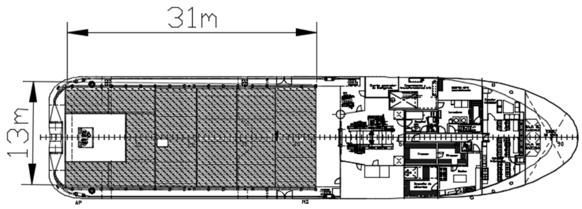
Deck Area estimation

While working with handling duties or supplying containered cargo, the deck area plays a fundamental role in the vessel operation.

When the statistical table was done the deck area number was recollected from each sample, obtaining an average deck area of 430 m^2.

The preliminary deck arrangement gets an area of 403 m^2 that is 7% lower that the statistics. The design team justify this preliminary result, because:

- The handling winch was prefered to be inside the accomodations space, as it is the most expensive machines that the vessel possessed.Being in the sheltered space will grant it a longer life.
- The length of the deck was set to be able to transport oil drilling pipes, that have a maximum length of 14,63 meters each. A lenght of 31 meters permit to sail with a pair (29.26 meters) of pipes per deck position.



Floodable Length

The floodable length was verified by the method of Shirokawa, using the MaxSurf Module Stability.

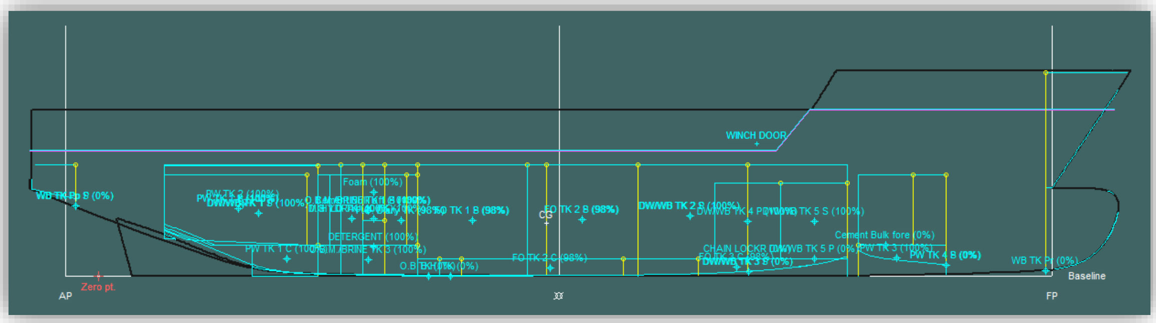
The bulkhead distribution was done by using the recommendation from the ABS code, for collision bulkhead and the other bulkhead were displayed as the engine room dimensions and bow thruster room were obtained.

Name	Location m	Type
AFT PEAK	-1,300	Transverse
STEERING GEAR FIRE	3,900	Transverse
E.R. AFT	18,850	Transverse
E.R.FORE	44,200	Transverse
BOW THRUSTER AFT	50,050	Transverse
COLLISION BLKH	55,900	Transverse

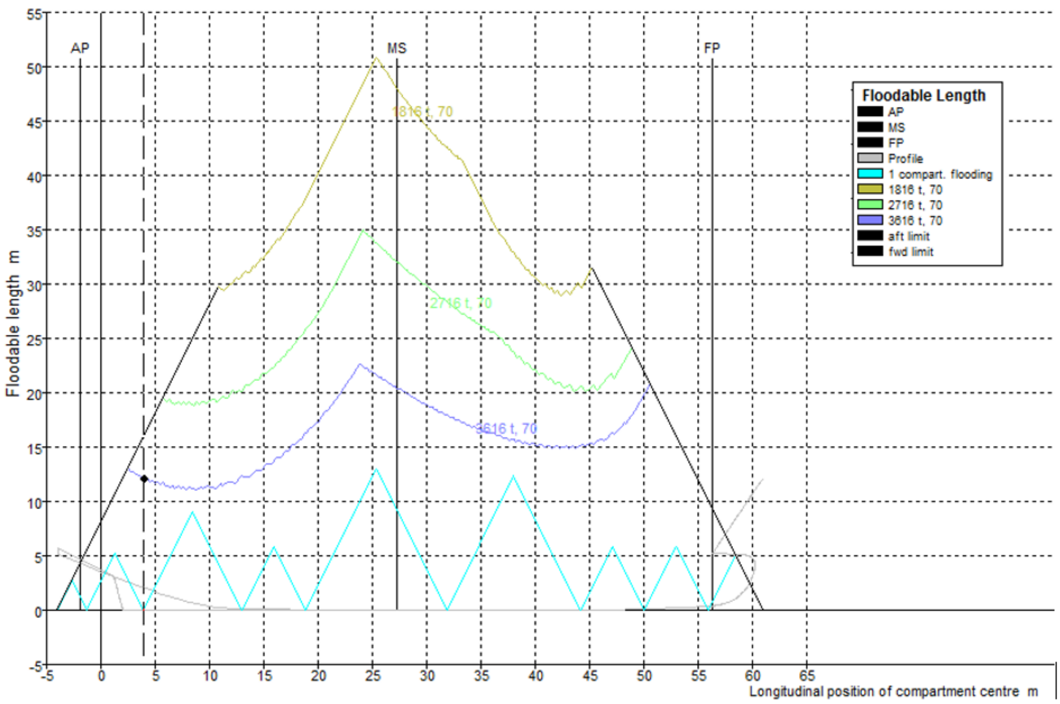
Once the floodable length is determined by the position of the bulkheads, the method of Shirokawa is used to corroborate that the length is suitable. A permeability of 85% is estimated as the volume of the equipment inside the vessel is highly in accordance with the volume of the entire engine room (as per IMO recommendation MSC 82/24).

The tanks watertight division is used as a transverse bulkhead:

MSC 82/24/Add.2 ANNEX 3.2.3 A transverse watertight bulkhead extending from the vessel´s side to a distance inboard of 760 mm or more at the level of the summer load line joining longitudinal watertight bulkheads may be considered as a transverse watertight bulkhead for the damage calculations.



Vessel Margin line



Floodable length verified with Shirokawa Method, as no floodable compartment reach the margin line.

Capacity plan

Tanks capacity and distribution

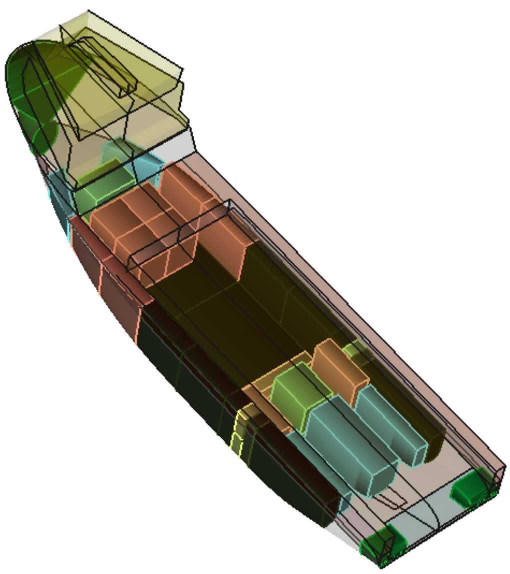
- Tables and Capacity Plan and Center of Gravity of Spaces by Type of Content.

The arrangement of tanks is such that the distribution of the tanks along the ship was made following a series of guidelines:

- It has been tried to reduce, in all conditions, to the least possible free surfaces, and therefore the negative effect they have on transverse stability.
- The limitations and requirements of the ABS have been closely followed, the SOLAS and MARPOL rules; in addition to complying with the project specifications.
- Cofferdams have been arranged separating fresh water from other fuel, waste water or lubricants. In addition, ballast have also separated by means of cofferdams from those of fuel, to avoid future corrosions and possible contaminations.
- The arrangement of tanks has been designed in a symmetrical way about cradle, seeking to avoid undesirable heeling angles.
- The provision of watertight reinforcements and bulkheads has been respected by placing tanks.
- Ballast tanks have been positioned in such a way that they can be corrected hydrostatic balance in all possible operating and operating situations.
- In all the tanks, a permeability of 97% is fixed, considering that 3% of the total volume is occupied by reinforcements, and the peaks and double bottom, where it is considered that the space is much more saturated with reinforcements, was placed 92%. In fuel tanks and oils 98% is considered as maximum filling, allowing a safe distance between air pipe and liquid surface (for WBT) of vapor expansion for cargo tanks.

Next, the table of side bottom and inside tanks are presented, by type of content, showing the capacities and the center of gravity of the tanks totally full and in the annex the capacity plane can be visualized.

NAME	INT. PERM. %	S.G.	FLUID TYPE
FO TK 1 EB	97	0.84	Fuel Oil
FO TK 1 BB	97	0.84	Fuel Oil
FO TK 2 EB	97	0.84	Fuel Oil
FO TK 2 BB	97	0.84	Fuel Oil
FO TK 2 C	92	0.84	Fuel Oil
FO TK 3 C	92	0.84	Fuel Oil
FO TK 3 C	97	0.84	Fuel Oil
F.O. DIARY TK	97	0.84	Fuel Oil
F.O. DIARY TK	97	0.84	Fuel Oil
FOAM	97	1	FOAM
HYDRAULIC TK	97	0.924	Hyd oil
DW TK 1 BB	97	1	Drill Water
DW TK 1 EB	97	1	Drill Water
DW TK 2 EB	97	1	Drill Water
DW TK 2 BB	97	1	Drill Water
PW TK 1 EB	97	1	Fresh Water
PW TK 1 BB	97	1	Fresh Water
PW TK 3	97	1	Fresh Water
PW TK 4	92	1	Fresh Water
PW TK 5 BB	100	1	Fresh Water
PW TK 5 EB	100	1	Fresh Water
O.B.M. TK 1	97	2.5	Oil Base Mud
O.B.M. TK 2	97	2.5	Oil Base Mud
O.B.M. TK 3	92	2.5	Oil Base Mud
M.E. LO TK	97	0.91	Lube Oil
D.G. LO TK	97	0.91	Lube Oil
WB TK PR	97	1.025	Water Ballast
WB TK PP EB	97	1.025	Water Ballast
WB TK PP BB	97	1.025	Water Ballast
O.B.TK	97	0.913	Sludge
DETERGENT	97	0.76	DETERGENT
B.H. TK	97	0.913	Sludge
CEM. BULK AFT	97	1.4	Cement
CEM. BULK FORE	97	1.4	Cement



ARRANGEMENT OF TANKS ON MAXSURF

Structural Design

In this Section, a detailed structural analysis of the mid-ship section is carried out, in order to evaluate if the structural strength of the ship will be able to withstand the primary loads in which it will be seen during its operational life.

The ship resembles as a simple beam loaded, even if the ship has no supports. Therefore, the mid-ship section is supposed to be the most awkward section as it will deal with the highest bending moment.

The structural design calculation on still water conditions comprises the knowledge of:

- ✓ Shear forces
- ✓ Bending moment
- ✓ Local Pressures

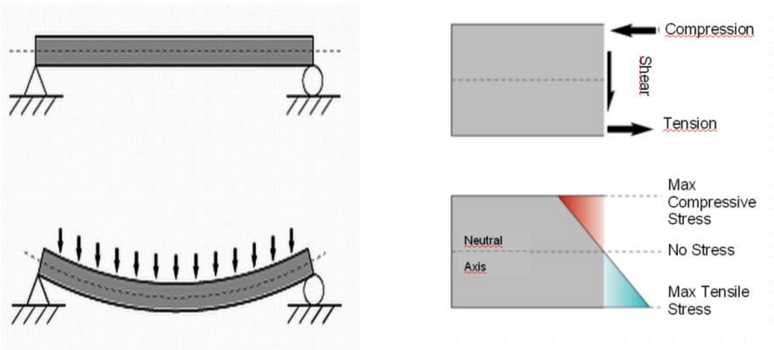


Figure Case of simple beam loaded and the diagrams of shear forces and stress.

This design was made following the guidelines and rules of the ABS RULES FOR BUILDING AND CLASSING OFFSHORE SUPPORT VESSELS, PART 3, as for the structural design of the hull refering to the following Sections:

- ✓ Part 3. Hull construction and equipment Ch.1 General. Sect. 2 General Requirements.
- ✓ Part 3. Hull construction and equipment Ch. 2 Hull structures and arrangements.
- ✓ Part 3. Hull construction and equipment Ch. 3. Subdivision and Stability.

Once the minimum primary loads were defined according to the rules and being supported by the structure, it was proceeded to scantling each structural element of the mid-ship section. Then, the section module of this section was calculated in order to verify if it was greater than the minimum section module agreed on the rule.

After performing this work, the structure of the ship has been established. Therefore, a more accurate estimation of steel weight will be done; the center of gravity and the neutral axis is defined. The table below is a summary of the main structural elements:

Plating	*Required [mm]*	*W/Design margin [mm]*	*Adopted [mm]*
Keel Plating	9.16	9.62	12
Bottom Shell Plating	9.16	9.62	10
Bilge Plating	9.16	9.62	10
Side Shell	8.98	9.43	10
Deck plating	7.53	7.91	10
Inner Bottom	9.43	9.90	12
Inner Side Longitudinal Bulkhead	5.53	5.80	10
Central Girder	7.53	7.91	10
Side Girder	7.53	7.91	10
Profiles			
Inner Deck Longitudinal- L 125 x 75 x 10	103.00	108.15	129
Main Deck Central Girder- L 280 x 14 x 150 x 14	745.00	782.25	853
Side Stringer Web (DLW) SL1-- L 180 x 10 x 75 x 10	216.29	227.10	232

Procedure

To carry out the design, the first assumption the team made, was the definition of the main structural framing to be used. To choose between transversal and longitudinal framing, the requirements of the ship are taking in to account, finding:

1. Longitudinal Strength: as the vessel is less than 90m and the longitudinal strength requirements are low, the vessel does not require to be longitudinally framed since that only shell plating would be enough for reaching the modulus required by the bending moment and yield stress.
2. Shape of the hull in order to improve the construction: a longitudinally framed would mean conform the longitudinal profiles according to the shape of the hull, making the construction more difficult than cutting the frames from plates to the hull section shape.
3. Reinforcement open deck: to fulfill with the Owner Requirement of $5t/m^3$ and $10t/m^3$.

Due to the aforementioned and all the information contained in ABS Rules, it was decided to use transverse framing for the bottom and side and longitudinal framing for the deck.

Next the structural rules and formulas defined by ABS were used to size all the structural components. The section modulus of the mid-ship section was calculated and compared to the required section modulus defined by rules. A summary of the structural calculations is added in the *APPENDIX 2- STRUCTURAL ANALYSIS.*

The value of the Mid-Ship Section modulus represents the vessel structural strength submitted by bending moments. Then, the calculation procedure of this section modulus is:

1. *Still water bending moment calculation*: This value is reached by the ABS Rules formula´s or by direct calculus. In order to do this, on the Stability software was requested to obtain the curve of bending moment and shear force, it was done a change in the distribution of the lightweight ship load, as not to study as a not real point load (instead of being a rectangle, it changes to a triangle) giving a more realistic configuration of loads. Therefore, it was added more load in the fore part, where the superstructure is, and it was considered the shape of the hull where less plating is used at the ends of the ship.

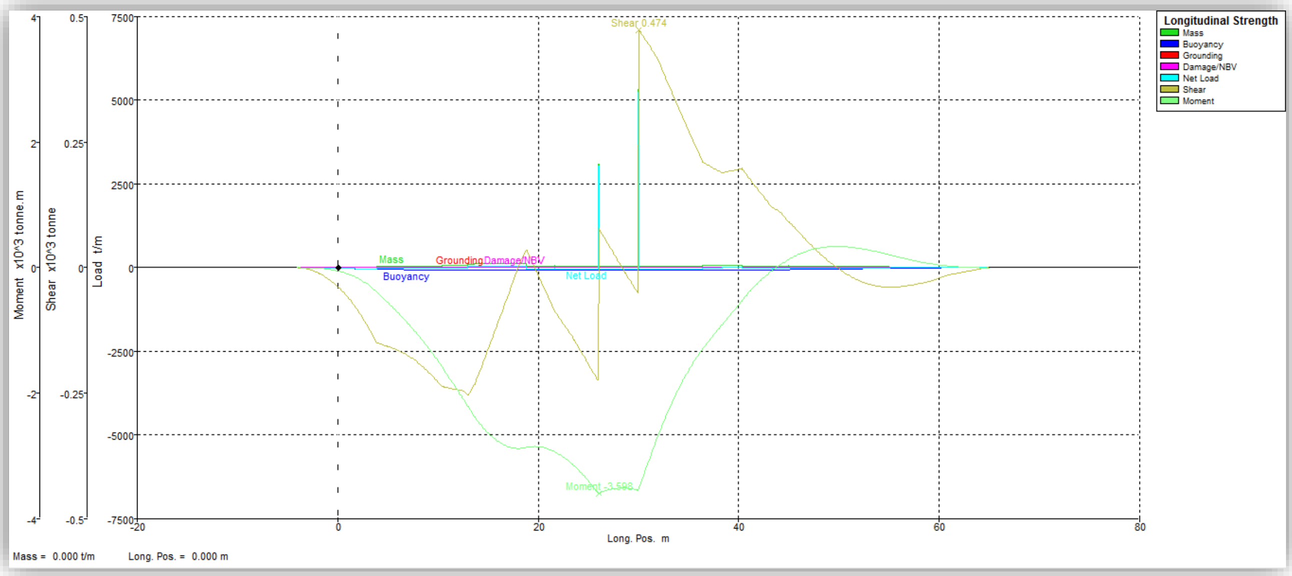


Figure Shear Force and Bending moment at the Scantling draft

2. *Minimum Section Modulus*: To determine the minimum required section modulus the ABS 3-2-1/3.1, gives the following formulae that relates the geometrical aspects of the hull, in order to withstand the bending moment and shear force. This expression states the importance of length in the required modulus as it goes with the square of the length.

$$SM = C_1 * C_2 * L^2 * B * (C_B + 0{,}7) = 4284.96 \text{ m-cm}^2$$

3. *Minimum hull girder moment of inertia*: The ABS 3-2-1/3.7.2 states a expression that relates the inertia of the section with the modulus, in a preliminary stage where there is no information of the neutral axis and the distance up to the extreme material fiber. This moment of inertia must be conformed, as the section modulus with only the longitudinal members as stated in the rules. The minimum midship section moment of inertia from given by the rules is:

$$I = \frac{L*SM}{33.3} = 8572.72 \text{ cm}^2\text{-m}^2$$

As it was stated before, the structural design of this vessel is primarily designed to withstand the local pressures, and will fulfil the requirements for the bending moment and shear force. Also, is noted that the obtained modulus will be far over the required by the ABS. This does not mean that it was over sized in thickness. Is primarily because there are additional longitudinal members that were not needed for longitudinal strength but are placed for operative reasons as longitudinal bulkhead for the boundary of tanks, reinforcement for engine basing, or deck longitudinal reinforcement to withstand the specified load.

Method for section modulus determination	*Section modulus [m-cm²]*
MAXSURF (max bending fromloading curve-σ_{yield})	1534.24 $m\text{-}cm^2$
ABS	4284.96 $m\text{-}cm^2$
DIRECT (from designed midship section)	30584.96 $m\text{-}cm^2$

Therefore, longitudinal reinforcement is considered on the longitudinal strength. And as it is shown, the section modulus verifies the requirements and has a margin to withstand additional loading during operational conditions or extreme weather.

Verifications.

In this project, several verifications were carried out.

- ✓ ABS Rules (Calculation)
- ✓ Soft Calculation (Maxsurf)
- ✓ Soft Calculation (LeoHull)

Finally, the location of the Neutral Axis is calculated by direct method and by LeoHull software, and shown in the table below:

	LeoHull [M]	*Direct calculation [M]*
Location of Neutral Axis in meters from Base Line	3.290	3.256

Propulsion plant trade-off study

General

The following section describes briefly the parameters involved in the analysis and selection of the propulsion plant, main engine and gear box for the vessel in reference.

Propulsion systems concepts

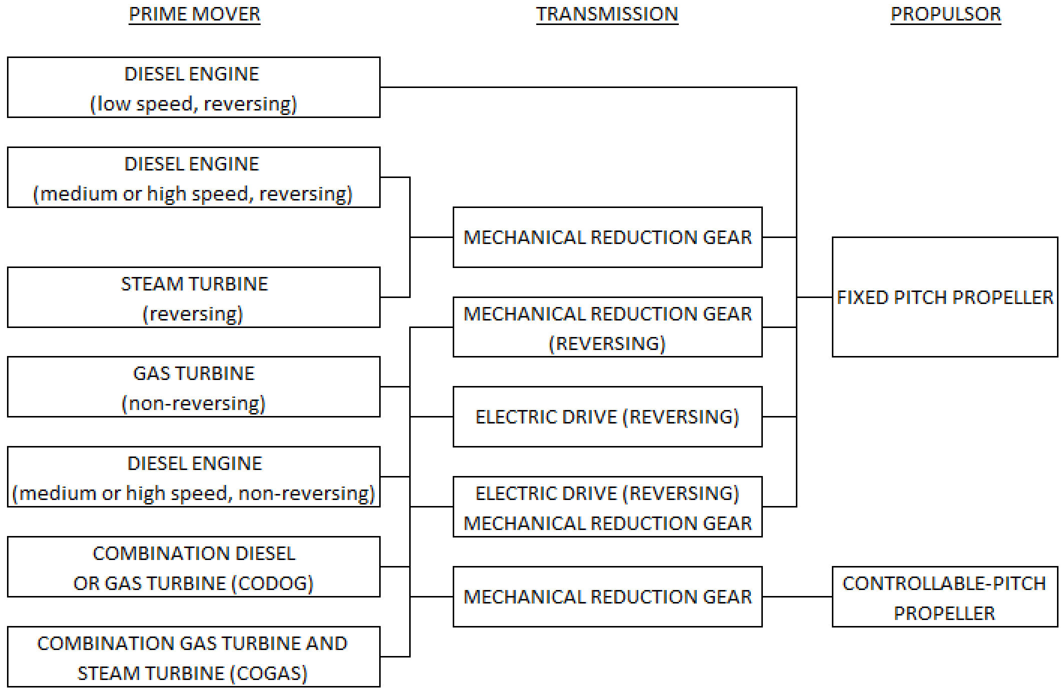
The propulsion plant must reflect the operational profile of the vessel in every sea state condition as well as in every underway situation developing a certain power at a determined fuel oil consumption and maintaining a minimum power in reserve. To establish a the minimum power in reserve the following items must be considered: the fouling, an increased hull roughness, the propeller´s roughness caused by cavitation and the prime mover performance. All of this represent a reduction of the whole propulsion plant performance in time.
The propulsion system and the fuel oil consumption represent a key cost that is studied in the initial stages of ship design.
The design process of the machinery systems of an AHTS vessel focuses on the following basic requirements:

- Payload / mission profile.
- Main dimensions and hull forms coefficients.
- Sustained speed and hull resistance.
- Automation requirements.
- HVAC / Illumination requirements (all spaces).
- Dynamic positioning requirements.
- Mooring, anchoring and maneuver requirements (tug service and anchor handling).
- Reliability and support.

This basic requirement of the propulsion system are necessary for the ship to move at the required design speed and provide maneuver, stopping and reverse capability. These operations musts be performed in a reliable form in accordance with the crew´s capabilities.
In addition, there exists an important interdependent relationship involved in the machinery systems design process: the weight and space requirement of a propulsion plant varies in relation to the rating and might have a significant effect on the vessel´s configuration; the main dimensions and hull forms are needed to estimate the required power.

Alternatives of Propulsion Plant Arrangements

The following table shows the typical propulsion plant arrangement that exists in different classes of vessels according to the project requirements and constraints.



The electric propulsion drives offer many important advantages when compared with other conventional types of propulsion drive alternatives: they have the potential of outweighing the inherently higher first cost, increased weight and space.

Electrical power requirements can be met by one or more generating sets that follow space restrictions, or to alleviate weight and stability problems. Combinations of diverse types of prime movers such as diesels, gas turbines, and steam turbines are easily accommodated once their mechanical output has been converted to the common denominator of electric power. In cases where the development of the desired propeller power requires the use of multiple prime movers, a typical situation in medium and high-speed diesel drives. An electric-drive provides a convenient means of coupling several units to the propeller without the use of mechanical clutches or couplings: for example, a diesel – electric system and conventional screw or a diesel – electric system and Z – Drive.

An electric-drive system is normally arranged so that vessel operation at less than full power can be accomplished with a minimum number of prime movers in service, each operating near peak efficiency. This contributes to more efficient vessel operation and implies downtime for scheduled maintenance. The higher transmission loss of the electric system may in fact be more than offset by a better match between the prime mover capacity and the power demand.

In the case of AHTS, tugs, oil recovery ships and similar ships, in which the changes in speed and in direction of propeller rotation are frequent, D-C machinery, are used because of the superior speed control inherent to such machines. Even with the availability of A-C static power converters, the D-C motor, with its high transitory torque capability, is often the machinery of choice. It is important to note that this type of vessels, often have large electric power requirements that are not coincident with the maximum propulsion power requirements. The nature of the operational requirements for such vessels, permits the generating sets to be applied to supply copious amounts of power for pumping or cargo or anchor handling, when propulsion power demands are low or even nonexistent.

Another alternative is the use of a medium speed diesel electric systems coupled with FPP or Z – Drive.

The use of gas or steam turbines is neglected in this case due to weights and space requirements and constraints, which makes them no technically nor economically feasible.

All this propulsion concepts are evaluated taking into consideration, the following parameters:

- Costs of all machinery, systems and subsystems.
- Size, volume and weight of all machinery, systems and subsystems.
- Complexity of all machinery, systems and subsystems.
- Maintenance and Operation of all machinery, systems and subsystems.
- Fuel consumption of prime movers.
- Redundancy of prime movers, machinery and others.

It is not intended to explain in detail the diesel engine, nor the electrical power system and turbines in this AHTS project report in detail; only the main concepts of the different and typical propulsion plants used in AHTS are mentioned.

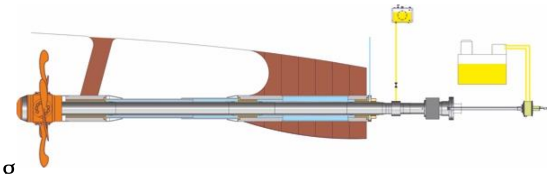
The AHTS uses a propulsion plant confirmed by a medium speed diesel engine, coupled with a mechanical reduction gear and a fixed pitch propeller.

<u>Mechanical Transmission Systems</u>

This section describes the most common types of transmission systems, or configurations. The most important are listed below:

Conventional Transmission

- Cost efficient, simple maintenance and simple to implement.
- Low hull resistance and good seaworthiness
- It may use FPP or CPP in nozzles.
- Engine room at center of the ship.
- High speed and high bollard pull.
- Requires bow and stern thruster for station keeping.
- Not as maneuverable as other systems.



Azimuth Thruster Stern Drive (Azi – Pod)

- Allows greater hydrodynamic and mechanical efficiency when compared to standard z-drive.
- More vessel space in the vessel: engine room towards aft, hence low noise and vibration.
- Good maneuverability, high speed and high bollard pull.
- Low hull resistance and good seaworthiness.
- Inaccessibility to the engine room when under way.
- Expensive system.

Voith Schneider

- High bollard pull and highly maneuverable with instantaneous change in direction capability
- High efficiency
- Significant increase in navigational draft, increase in weight due to the addition of protection guards around the system
- Bottom forms almost flat, decreasing the seaworthiness condition, and typically adding hull resistance

Z Drive

- Low hull resistance and good seaworthiness.
- More reliable than Azi-pod and Voith
- Less expensive than Azi-pod and Voith, although still expensive
- Good maneuverability, high speed and high bollard pull.

A conventional shaft line transmission was adopted for the ATHS. Basically, the conventional shaft and the Z Drive transmission, being the more typical transmission systems, considered the Statistical Data Base; for these kind of vessels were compared, because they are less expensive than Voith Schneider and Azi Pod configurations, and more reliable.

<u>Selected main engine and reduction gear set</u>

Based on the powering and propulsion analysis obtained once the propeller calculation is done (see "Propeller Calculation" in the following sections), there is sufficient information to determine the adequate engine set a reduction gear. As the power needed is dependent on the propeller efficiency.

$$BkW = \frac{EkW}{\eta_h x \eta_o x \eta_{mec} x \eta_{rr}}$$

Once the value of power need is obtained, the team determines the requirement of power and the constrain of the torque to achieve the required bollard pull. Two set of engines were suitable to achieve the requirements, and an analysis was made to select the best option for the project.

TYPE	BKW	SPEED[RPM]	MEP [BAR]	MPS[M/S]	SFOC [G/WH]
6M32C	3000	600	24,9	9,6	177
9M25C	3000	750	26,1	10	184

The engine that was selected is the **6M32C**. After doing some research between the gearbox manufacturers, a good reduction gear was founded. The selected gear permits to match the bollard pull requirement and the use of this engine, as is preferred between the *9M25C* for its low Specific Fuel Oil Consumption (4% less). The lower the SFOC the lower is the daily running cost. The decrease in the Mean Piston Speed is not only an indicator of smaller SFOC, but also of greater times between overhauls as it is supposed to be an indicator of more cylinder liner worn.

Main Engine

Brand & Model Product…...…………………………	MAK 6 M 32 C
Number………………………………………………...	Two (2) Sets
Direction of rotation………………………………...	Port: Clockwise / Starboard: Counte rclock wise
Engine Type…………………………………………	Four stroke diesel engines, non-reversible, turbocharged and intercooled with direct fuel injection
MCR…………………………………………………...	3000 kW (4080 HP) at 600 RPM
Number of cylinders………………………………...	Six (6)
Cylinder configuration……………………………...	6 in – line
Bore………………....……………………………....	320 mm
Stroke…………….…………………………. …..….	480 mm
Stroke / Bore Ratio………………………………….	1.5
BMEP……………………………………………….	25.9 bar
SFOC……………………………………………….	177 g / kWh (1)
Engine length……………………………….………	5946 mm
Engine width……………………………………….	2369 mm
Engine height….……………………………………	3258 mm

Note (1): reference conditions: LCV = 42,700 kJ/kg, ambient temperature 25ºC, charge air coolant temperature 25ºC, tolerance 5%, + 1 % for engine driven pump.

Reduction Gear Set

Brand & Model Product…...……………………….	ZF W63000 NR2
Number……………………………………………...	Two (2) Sets
Maximum Rated Power at 750 RPM………………...	3459Kw
Maximum Rated Torque…………………………...	44047 Nm
Offset……………...………………………………...	Horizontal
Type…………………………………………………	Non – Reversible Reduction
Ratio………………………………………………...	3,16

Electrical Load Analysis

Operational profile

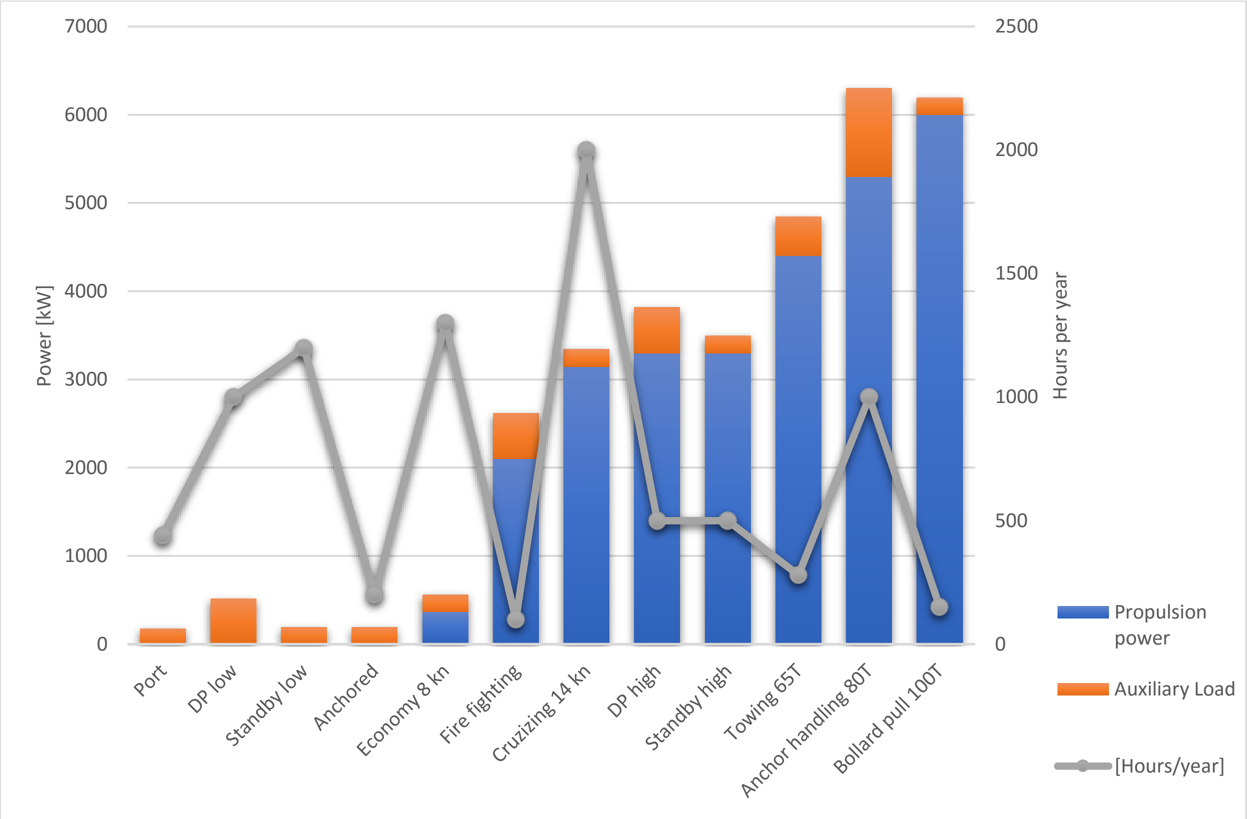
The design team selected a series of service conditions that were considered as the most compromised, that the vessel will would perform, the generators selected must perform according to these demands.

Number of mode	Operational mode	Requirement	Prop. power	Aux. Load	[Hours/year]
			kW	*kW*	*Hours*
1	Port	-	0	177	440
7	DP low	2 kn current, 10kts wind speed, DP2	0	517	1000
9	Standby low	2 kn current, 5 kn wind speed	0	195	1200
12	Anchored	-	0	195	200
2	Economy 8 kn	8 kn	367	195	1300
11	Fire fighting	2 kn current, 5 kn wind speed	2100	517	100
3	Cruzizing 14 kn	14 kn	3147	195	2000
8	DP high	2 kn current, 35kts wind speed, DP2	3300	517	500
10	Standby high	2 kn current, 35k kn wind speed	3300	195	500
5	Towing 65T	6 kn, 65 T pull	4400	445	280
4	Anchor handling 80T	2 kn, 80 T pull, 7.5T tunnel thrusters	4800	1000	1000
6	Bollard pull 100T	100 T	6000	195	150

The bollard pull condition is often considered the most important design condition, as this plays a major role in vessel contract qualification. Looking at below graph ,the grey line, representing the time spent in each mode, we see that the expected time the vessel will spend in this operational condition is very low compared to other modes.

Looking into the above example and how it performs over the entire operational profile, is seen that this vessel would spend less than 4% of the time and 10% of the annual fuel consumption in the full power bollard pull condition. This means 96% of the operational time and 90% of the annual fuel consumption is spent outside of the primary equipment selection mode of operation. This doesn't necessarily mean that the vessel is inefficient in any of these off-design conditions.

The design team decided to evaluate an operative profile of the vessel during all stages of her sailing and harbor life, plotting powering consumptions, electrical an propulsive. It was noted that most of the times where there is a big electrical consumption, hence a big load on the auxiliary engines, there is low demand on the propulsive lines. Leaving them free for electrical generation, maximizing the load of the main engines and moving their work point to a better performance rating (almost 90% of MCR) by plugging a load in the shaft. Because of this technical-economic reason we decided to install two shaft generators (PTO/GCR) coupled after the gear box reduction.



From the Electrical Load Analysis (details are describing on *APPENDIX 1),* the following electric plant is dimensioned.

ELECTRICAL GENERATORS:	*MAKER & MODEL*	*TECH. DATA*	*SFOC[GKW/HR]*
TWO SHAFT GENERATORS:	***Marathon MX-H-630-4***	***630kW-400 v – 50 Hz***	***177***
TWOAUXILIARY GENERATORS:	***Cummins: ECM-750/CCFJ600J***	***600 kW – 400 V – 50 Hz***	***222***
1-EMERGENCY GENERATORS	***Cummins ECM-313/CCFJ250J***	***250 kW – 400 V- 50Hz***	

The following analysis will justify the investment of both shaft generator by analyzing the savings in fuel per year related by the difference between SFOC of the engines. In the analysis is supposed that in the conditions in which the propulsion engine has rest of power (maximum of 6000Kw @ NCR) the auxiliary engines are turned off and all the load is taken by the shaft generator, actioned by the main engines through a PTO.

			Fuel consumption		*Gas Emisions*	
Operational mode	**Propulsion power**	**Auxiliary Load**	**Diesel Main engine**	**Diesel aux machinery**	**Diesel Main engine**	**Diesel aux machinery**
	kW	*kW*	*kg*	*kg*	*g-CO2*	*g-CO2*
Port	0	177	0	17289	0	55326
DP low	0	517	0	114774	0	367277
Standby low	0	195	0	51948	0	166234
Anchored	0	195	0	8658	0	27706
Economy 8 kn	367	195	84447	56277	270229	180086
Fire fighting	2100	517	37170	11477	118944	36728
Cruzizing 14 kn	3147	195	1114038	86580	3564922	277056
DP high	3300	517	292050	57387	934560	183638
Standby high	3300	195	292050	21645	934560	69264
Towing 65T	4400	445	218064	27661	697805	88516
Anchor handling 80T	4800	1000	849600	222000	2718720	710400
Bollard pull 100T	6000	195	159300	6494	509760	20779
			Total fuel consumption per year [ton/year]		**Total CO2 emision per year [ton/year]**	
			3047	**682**	**9,75**	**2,13**
			3729		**11,88**	

LOAD SHARING - WITH PTO + SHAFT GENERATOR

			Fuel consumption		**Gas Emisions**	
Operational mode	**Propulsion power**	**Auxiliary Load**	**Diesel Main engine**	**Diesel aux machinery**	**Diesel Main engine**	**Diesel aux machinery**
	kW	*kW*	*kg*	*kg*	*g-CO2*	*g-CO2*
Port	0	177	0	15576	0	49843
DP low	0	517	0	103400	0	330880
Standby low	0	195	0	46800	0	149760
Anchored	0	195	0	7800	0	24960
Economy 8 kn	562		129316	0	413812	0
Fire fighting	2617		46321	0	148227	0
Cruzizing 14 kn	3342		1183068	0	3785818	0
DP high	3817		337805	0	1080974	0
Standby high	3495		309308	0	989784	0
Towing 65t	4845		240118	0	768378	0
Anchor handling 80t	5800		1026600	0	3285120	0
Bollard pull 100t	6000	195	159300	5850	509760	18720
			Total fuel consumption per year [ton/year]		**Total CO2 emision per year [ton/year]**	
			3432	**179**	**10,98**	**0,52**
			3611		**11,51**	

- ✓ An annual fuel saving of 188 tons of Marine Diesel Oil.
- ✓ Which at a price of 600 USD/Ton, it represents a saving of **U$D 70.800**
- ✓ As less fuel oil is consumed, lower emissions are obtained (0,37 tons of CO_2 will not be released to the atmosphere)

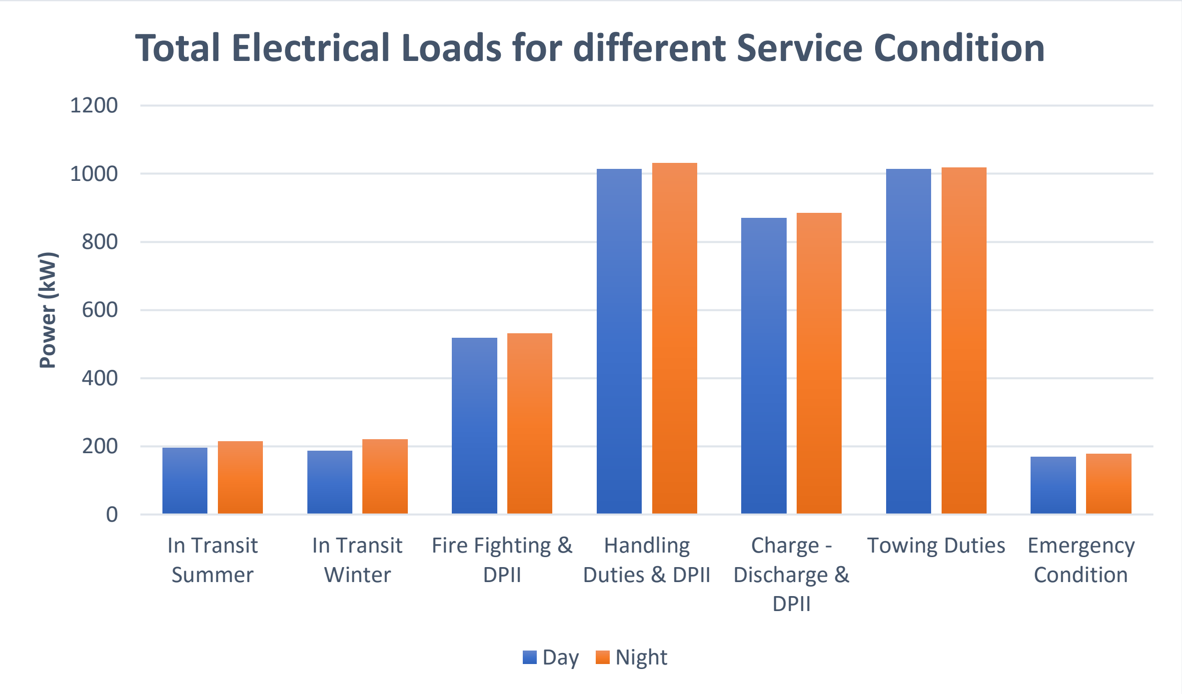
Electrical Balance analysis.

In this section, is to be performed a preliminary electrical load analysis to establish the total demand that the vessel will require in different service conditions.

To realize the electrical load analysis, the design team used information provided from colleagues that work in the marine field, and statistic information from other vessel with similar characteristics.

To determine the equipment on board, power and efficiency data we quest to different manufacturers and colleague vendors. The demand and utilization factors were based on the required equipment and service for all the conditions analyzed.

The following graph summarize the electrical load in different service conditions



Major H, M, & E systems and equipment description

In this section the design team is to inform the basic characteristic of equipments that will be fitted in the vessel in order to perform the tasks for which it was designed and at the same time meet the ABS requirements standards considered for the design of the vessel.

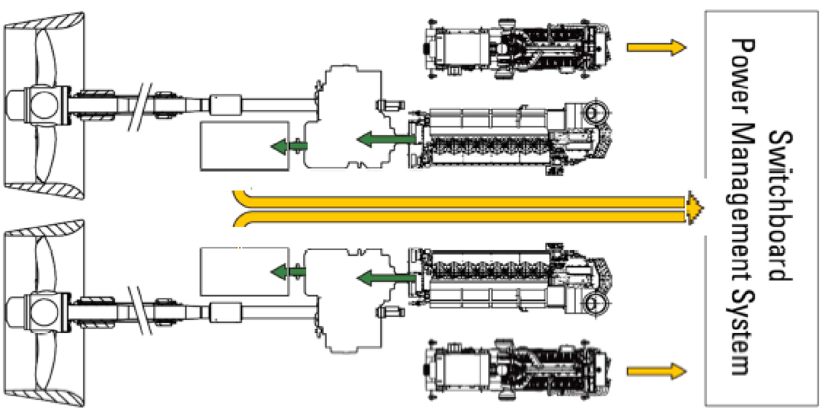
The next table summarize the equipment selected that will be located on the engine room. The design team used statistic information about other similar ship to dimension some equipment's.

ITEM	*QTY*	*TECHNICAL DATA*	*MAKER*
MAIN GENSETS	2	600 kW (400v - 50 Hz)	Cummins
SHAFT GENERATORS	2	600 kW (400v - 50 Hz)	RENK
EMERGENCY GENSET	2	250 kW (400v - 50Hz)	Cummins
GENERAL SERVICE PUMPS	1	75m3/h x 40m head 11 kW	Azcue
BALLAST & BILDGE PUMP	1	75m3/h x 40m head 11 kW	Azcue
FUEL OIL TRANSFER PUMP	2	75m3/h x 40m head 11 kW	Azcue
EMERGENCY FIRE PUMP	1	75m3/h x 40m head 11 kW	Azcue
FUEL OIL CARGO PUMPS	1	150m3/h x 75m head 15 kW	Azcue
FRESH WATER CARGO PUMPS	1	75m3/h x 40m head 11 kW	Azcue
DRILL WATER PUMP	1	100m3/h x 75m head	Azcue
SEWAGE THREATMENT PLANT	1	20 Persons on board	Hamann
DRY BULK AIR COMPRESSOR	1	75kw	MacGregor
FRESH WATER PRESSURE SET	2	1,13kw	Azcue
SEA WATER PRESSURE SET	2	1,13kw	Azcue
DIRTY OIL PUMP	1	2,2 kW 65 m3/h	Azcue
OIL WATER SEPARATOR	1	3 kW	Azcue
HVAC SYSTEM (COMPRESSOR UNIT)	1	25 kW	Carrier
EXTERNAL FIRE FIGHTING SYSTEM CLASS 1	1	1290kw	Hydrodiesel

A brief description of the main equipment where there is a design point of view. The other mandatory equipment's will be also fitted and will comply with regulations and are to full fill owner requirements in this preliminary stage.

<u>Auxiliary & Shaft Generator:</u>

The electrical systems will be powered by two PTO shaft generators, to leverage the remaining power of the main engines during navigation, for the other conditions the AHTS will be provided with two auxiliary generators as a reserve, at the time that full fill with SOLAS requirements.

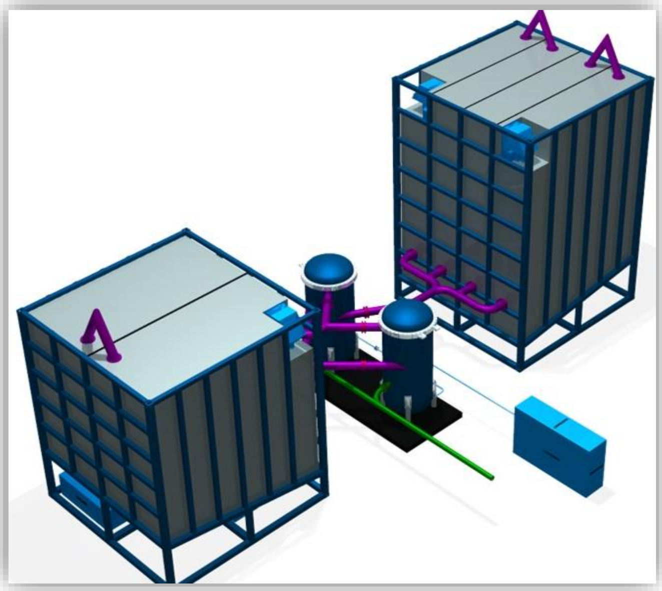


Fuel Oil Cargo System:

The ship will be provided with a high flow fuel oil cargo pump capable to pump cargo to platform in a reduced time. The high flow requirement is because the time spent for discharge operations are, considered as the most dangerous operational time of the vessel. So the lesser the time spent for the operation, the lower are the possibility of risk as is well known that the AHTS will operate in heavy sea, turning the charge and discharge duties dangerous. Also the pump will fulfil with the high head pressure to pump cargo up to the height required (75 meters of pump head output).

Dry Bulk Air Compressor:

The ship will be equipped with a dry bulk tanks to storage the cement that platforms require, the air compressor will be capable to pressurise the tanks and by that pressure pump the dry cement along the piping systems with a reasonable flow that reduce the discharging time. A good sistem of air dryer will be fitted to the compressor in order to avoid water from condensation, that in contact with the cement will make it to solidify.

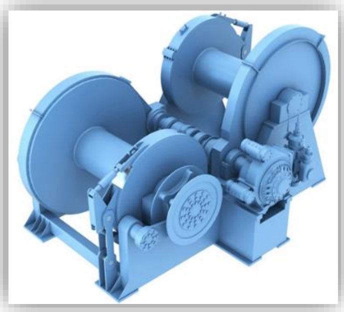


Major mission related systems and equipment description

In this section, we´ll describe the specific equipment's select so that the ship will fulfill the service requirements. The information and characteristics of the equipment have been obtained from calculations, information from vendors and statistic data from other similar ships.

1. *Anchor & Towing Winch*

This is one of the AHTS most important deck equipments. Its two main functions are: the lower drum contains the chains during the lifting of the anchor, the upper drum contains the cable for the towing duties. The winch has an electro-hydraulic system which when at work controls functions such as the constant tension, and the active heave compensation.



To size the anchor handling and towing winch, we used the following expressions:

Reference Load: RL=2BP

RL=2x100T=200T

BL (Breaking Load) = 2BP =2x100T=200T

To determine the power of the electric motor the design team used the following expression:

$$\frac{Pf\ g\ V}{\eta e\ \eta h} = \frac{150\ (Tn)\,.\,9{,}81\ \left(\frac{m}{s^2}\right).\,6\left(\frac{m}{min}\right)}{0{,}98\,.\,0{,}7.60\ \left(\frac{s}{min}\right)} = 215kW$$

- Pf: pull capacity
- ŋe: Electric efficiency
- g: Gravity
- ŋh: Hydraulic efficiency
- V: Speed

Then the design team selected the following equipment that meet all its needs.

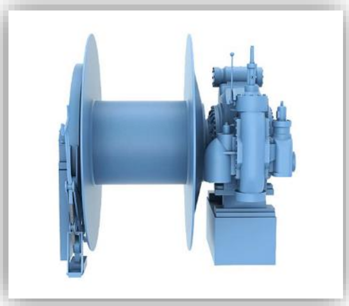
Anchor Handling & Towing Winch	
Model	MG-AHTW
Drum Capacity	1000m x Dia. 56mm SWR @10 Layers
Rated Pull (1st Layer)	150T x 0-6m/min (1st speed)
	71T x 0-12m/min (2nd speed)
	23T x 0-36m/min (3rd speed)
Braking Holding	250T (static, 1st layer)
Rated Power	215 kW
Weight	42T
Quantity	1

2. *Tugger Winch*

This device is often used in AHTS vessels to help the crew during heavy towing gears operations, such as chain bridles, towing plates and large towing wires used in anchor handling or ship handling work. The Tugger winches will be located on both sides of the anchor and towing winch, because of ship stability and operational reasons.

To dimension the electric motor appropriately and select a tugger winch from vendor catalogues, we used the following expression:

$$\frac{Pf\ g\ V}{\eta e\ \eta h} = \frac{10\ (Tn)\ .\ 9{,}81\ \left(\frac{m}{s^2}\right).\ 15\left(\frac{m}{min}\right)}{0{,}98\ .\ 0{,}7\ .\ 60\left(\frac{s}{min}\right)} = 36kW$$



Then the design team selected the following equipment.

Tugger Winch	
Model	MG-HUW-1040UL
Drum Capacity	250m x Dia.22mm SWR@8 Layers
Rated Pull (1st Layer)	10T x 0-15m/min (1st Layer)
Braking Holding	15T (static, 1st layer)
Rated Power	36 kW
Weight	1,8T
Quantity	2

3. *Deck Crane*

This telescopic crane, located on the port side, will have two principal functions: on one hand the crane will develop rescue operations in case of accidents, and on the other hand, it will handle the rescue boat if the situation requires it; the telescopic crane will also help during handling operations, working together with the tugger winches.

According to the SWL required and the necessary distance to operate properly, the team selected the following telescopic deck crane:

Deck Crane	
Model	TRIPLEX KN-50
Capacity	SWL 4T - 12m Max. Distance
Rated Power	75 kW
Weight	5,8 T
Quantity	1

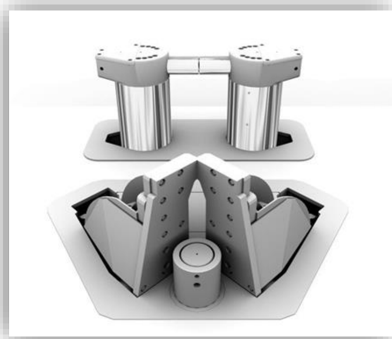
4. *Shark Jaw & Towing Pins*

The shark jaws is a mechanism that works in conjunction with the towing pins. Their function is to guide the cable and chains during the handling duties. The towing pins control and restrict transverse movements of the towline. The shark jaw, on the other hand, holds the towline to reduce the load from the anchor winch or the capstan during the crew operation over the deck.

The shark jaws and towing pins have the additional function of retracting on the deck when these mechanisms aren´t in operation.

These devices also have a security function, because they reduce the risk of the crew by avoiding work with unsecured heavily loaded chains or wires.

The design team selected the following equipment to fulfill the SWL necessary to operate, and the suitable chain and wire size.



SHARK JAW & TOWING PINS

MODEL	MG-STA-200-S
RATED PULL	200T
JAW INSERT	C59769-P-004
CHAIN SIZE/WIRE SIZE	70-83mm / 60-92mm
RATED POWER	15 kW
WEIGHT	6T
QUANTITY	1

5. Capstan

It´s a drum shaped device used to hoist weights, to tight the cables and during anchoring and handle weight over the deck during operations.

To dimension the electric motor and select the appropriate capstans, we used the following expression:

$$\frac{Pf\ g\ V}{\eta e\ \eta h} = \frac{5\,(Tn)\,.\,9{,}81\,\left(\frac{m}{s^2}\right).\,15\left(\frac{m}{min}\right)}{0{,}98\,.\,0{,}7\,.60\left(\frac{s}{min}\right)} = 18kW$$

Capstan

Model	MG-HVC-0540
Rated Pull	5T x 0-15m/min
Warping Head Dia. Size	400mm
Rated Power	18 kW
Weight	0,6T
Quantity	2

6. Anchor and Mooring Windlass

This machine is used to restrains and manipulate the anchoring equipment of the ship. Its other function is to manipulate the equipment during mooring maneuver. The mechanism is composed by three electro-hydraulic driven drums, provided with a gear reduction box, two of the drums will be used for the mooring rope and the other drum to guide the chains to the chain box.

To select the anchor and mooring windlass, the design team must calculate the equipment number, to know the number of anchor, weights, chains and other necessary elements.

According to standard 7/96 from the Argentine Coast Guard, to calculate the equipment number the design team must use the following expression:

$$EN = DE^{2/3} + 2.B.(FB + \sum Hi) + 0,1.\,A$$

DE (t): Displacement corresponding to maximum hull volume.

B (m): Maximum moulded breath

FB (m): Freeboard corresponding to displacement DE

Hi (m): Height in centerline of any superstructure above freeboard deck with breath above B/4

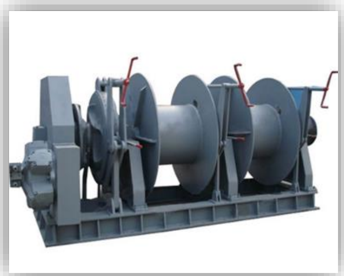
A (m^2): Area of the hull profile and superstructures above maximum load waterline

Equipment Number (EN)= 703.96

The next table summarize all the information about the anchor and mooring necessary equipment.

The equipment selected is the following:

- *Anchors: Two (2) anchors 1710 kg each one (AC-14 HHP)*
- *Chains: Length 467,5 m - Grade 2 - Diameter: 42 mm*
- *Towing Rope: Length 200 m – Breaking Load: 441 kN*
- *Mooring Rope: Four (4) – Length: 170 m – Braking Load: 172 kN*



Anchor and Mooring Windlass

Model	Deyuan DY170306
Working Load	75kN
Speed	9m/min
Supporting Load	442 kN
Chain Diameter	42mm
Weight	4 T
Quantity	2

1. Oil spill recovery:

To develop the oil spill recovery duties, the AHTS will be provided with a V-shaped multibarrier Moss Sweeper. This type of oil spill recovery system is one of the most efficient, because the V-shaped barrier routes the oil on the surface of the water towards the floating tank located at the end of the barrier. Later, the recovered oil will be pumped and stored in specific tanks.

In addition, Moss Sweeper systems allow higher oil recovery speeds and better maneuverability compared to other systems. This is essential because the oil spill recovery time will be lower and wildlife risk will be reduced in catastrophe cases.

The Oil Spill Recovery system selected:

"MOS Sweeper 25"

- Maker: Egersund Group (Norway)
- Towing speed: up to 4,5 knts
- Wave Height: 0-3m
- Sweeper width: 25m
- Housed within a single 20ft container

V-Shape multibarrier system

AHTS during Oil Spill Recovery duties

7. Fire Fighting System

The fire fighting systems is one of the principal systems on board, it provides the AHTS with the capability to extinguish huge fires in platforms or on other ships, reducing potential disasters.

The AHTS will be provided with FIFI Class I, with a flow rate of 2400m^3/h and two (2) monitors, to fulfill standards requirement.

In addition, the ship will be equipped with a water spray system that offers the possibility to sail close to the fire tolerating the heat during firefighting duties.

To dimension the FIFI system, the design team selected the following equipment configuration:

- *One (1) Diesel driven Pump – Rated Flow:2400m^3/h*
- *Two (2) FIFI monitors – Rated Flow:1200 m^3/h*

FIFI I System

FIFI pack model	SKID MOUNTED FIREPAK 2400
Maker	Maker: HYDRODIESEL
Engine Model	Cummins KTA50-M2
Rated Power	1268 kW
Speed	1800 RPM
Fire Water Pump	Nijhuis Venus1 - 350.650
Capacity	2400 m3/h
Discharge head	130 mwc
Quantity	1
Weight	14000 kg
Monitor Model	FWM-8-EL INNOVFOAM
Capacity	1200 m3/h - 16 Bar
Throw distance (elevation 30º)	>120 meters
Throw Height	>70 meters
Quantity	2
Weight	136 kg

FIFI Monitor
Model FWM-8-EL

Sample of a monitor in operation

AHTS water spray systems in operation

Dynamic Positioning

The ship will be equipped with a computer-controlled system that automatically maintain the vessel position by using the bow and stern thruster, the main engines and manoeuvring system. The dynamic positioning system is based on a mathematical model of the vessel and a complex system of position reference sensors that reference to a fixed point such as seabed, a platform, or a mobile point like other ships, also wind sensors, gyrocompasses and current drag of the vessel, in order to control the bow and stern thruster speed, the angle of the rudders and the pitch of the propellers to maintain the position during charge and discharge duties, handling duties and FIFI operations.

This system one of the most important on board, because the AHTS is a ship that must realize dangerous duties near platforms and it shouldn´t loss his position, for this reason the vessel will have dynamic positioning II (DPII).

The dynamic positioning II has redundancy, this involve that no single fault in the system will cause that all the system fail, for example, if one generator, switchboard, or bow thruster fails, the ship will have other as a reserve instead of maintain the position.

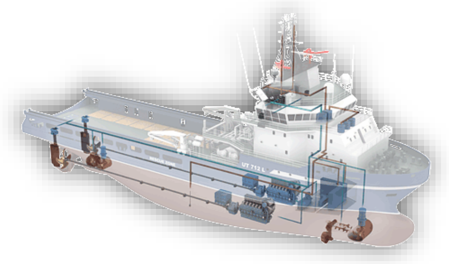


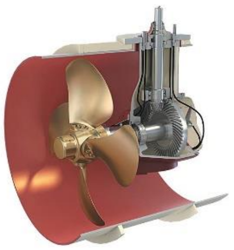
Diagram of a dynamic positioning system

Inclusive in bad conditions of the sea, de DP II will maintain the position

The Bow and Stern thruster selected are the following:

Bow Thruster:

- *Maker: Rolls Royce – TT1300*
- *Propulsion: Electro-hydraulic system*
- *Rated Power: 500 kW*
- *Diameter:1300mm*
- *Controllable Pitch*
- *Quantity: 2*



Stern Thruster:

- *Maker: Rolls Royce – TT1100*
- *Propulsion: Electro-hydraulic system*
- *Rated Power: 300 kW*
- *Diameter:1100mm*
- *Controllable Pitch*
- *Quantity: 1*

Weight estimation

In this section, the precise estimation of the weight will be done. This is one of the fundamental aspects that must be of maximum precision in the first stage of the project. An initial estimation was done, just to obtain the basic sizing of the vessel. Next, a new weight calculus is done, once the basic size and some other determinations, such as engine selection or equipment needs, have already been solved.

The technical paper "Estimation of Machinery Weights" – S.C. Powell. and the T&R Bulletin No.7-8 -SNAME was used for some determinations.

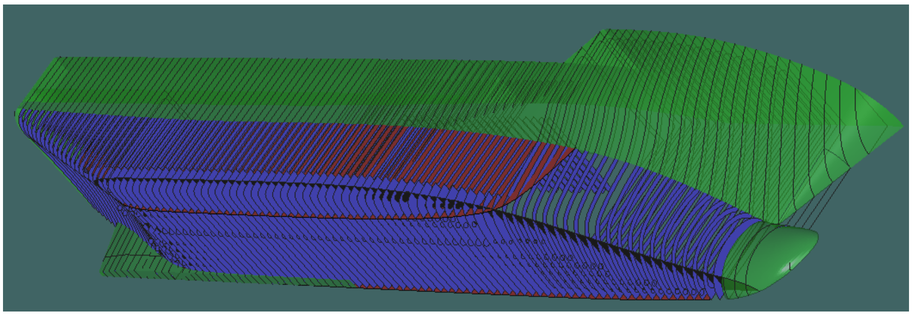
Steel Weight

A very hard task is to obtain the hull´s steel weight, that includes hull steel, reinforcements and inner structure, longitudinal and vertical bulkhead. In the structural design stage, the frame spacing and type of construction was determinate. Using these data and the modeled hull, the MAXSURF package STRUCTURE can be used for the steel weight estimation. Once the station grid design is done and the midship section arrangement scantling have been calculated, this software allows, to project that information in a first estimation along the entire length of the vessel. One hundred frames and their arrangement are estimated. Clearly, the aim is not to obtain a final figure of steel weight, but this estimations, will enable the team to get closer than it was to the weight real value, than it was when the first estimation was done with the parametric and statistical formulas.

Although in this stage, only preliminary technical information is available, some assumptions can be done to obtain, from the collected data, as much as posible.

- Plate thickness in bow and stern was increased for local stress concentration
- Inner Structure scantling was almost kept almost equivalent to that of the midship, up to the bow and stern, for as the parallel body is expected to withstand identical pressure components.

Steel Item	*Weight [MT]*	*LCG[m]*	*VCG[M]*
Hull Steel	415	26,70	6,10
Inner Structure	307	26,08	5,10
Long and horizontal Bulkhead	151	26,69	2,33
Total Steel Weight	**873**	**26,55**	**5,05**



STRUCTURE modeling

Machinery Items

For the determination of the machinery items, a market research was conducted with the real main machinery items estimated to be carried. Some of this were determine by calculus, shown in the following table. Others were selected by suggestions made by experienced crew contacted by this project team, and not by direct calculus. Minimal deviation in weight is expected.

Ítem/System	*Qty.*	*Capacity*	*Weight (kg)/unit*	*Maker*	*Total, Weight (kg)*
Main Engine	2	3000 KW	39500	MAK	79000
Gear Box	2	-	9900	ZF	19800
Main Gensets	4	825 kW (400v - 50 Hz)	7000	Cummins	28000
Shaft Generators	2	-	1500	Renk	3000
Emergency Genset	2	400 kW (400v - 50Hz)	3850	Cummins	7700
Steering Gear	2	-	500	RIQ	1000
Bow Thruster	2	500 KW	2000	Rolls Royce	4000
Anchors	2	-	1440	Sotra	2880
Anchor chain	2	-	9466	Sotra	18932
Controllable Pitch Propellers	2	-	1400	Shipyard	2800
Kort Noozle	2	-	300	Shipyard	600
Rudder	2	-	1100	Shipyard	2200
Stern Tube	2	-	700	Shipyard	1400
Hydraulic Anchor Windlass	2	75kn - 9m/min	4000	DEYUAN	8000
Hydraulic Anchor/Towing Winch	1	250T (static, 1st layer)	42000	CARGOTEC	42000
Hydraulic Capstans	2	5T x 0-15m/min	600	CARGOTEC	1200
Hydraulic Tugger Winch	2	15T (static, 1st layer)	1800	CARGOTEC	3600
Hydraulic Shark Jaw & Towing Pins	1	200T	6000	CARGOTEC	6000
Stern Roller	1	250 MT 1.6 m x 3.5 m Wide SWL 200tn	14000	CARGOTEC	14000
Deck Crane	1	SWL 4T - 12m Max. Distance	5800	TRIPLEX	5800
Fire & General Service Pumps	1	75m3/h x 40m head 17 kW	130	AZCUE	130
Ballast & Bildge Pump	1	75m3/h x 40m head 17 kW	130	AZCUE	130
Fuel Oil Transfer Pump	2	10m3/h x 20m	25	AZCUE	50
Hot Water Circulating Pump	1	2m3/h x 40m head 1,3kW	23	AZCUE	23
Dirty Oil / Sludge Pump	1	2m3/h x 40m head 1,3 kW	23	AZCUE	23
Emergency Fire Pump	1	25m3/h x 45m head	80	AZCUE	80
Fuel Oil Cargo Pumps	1	150m3/h x 75m head	300	AZCUE	300
Fresh Water Cargo Pumps	1	75m3/h x 40m head 17 kW	130	AZCUE	130
Drill Water/Ballast Pump	1	100m3/h x 75m head	150	AZCUE	150
Liquid Mud Pump	2	70 m3/h x 75m head 86 kW	115	AZCUE	230
Cement Compressor Pump	1	75kw	100		100
Fresh Water Pressure Set	2	1.13kw	300	-	600
Sea Water Pressure Set	2	1.13kw	300	-	600
Dirty oil pump	1	2,2 kW	20	AZCUE	20
Oil Water Separator	1	3 kW	25	AZCUE	25
Rescue Boat	1	6,8m LOA - 150 HP	2200	BIM Shipyard	2200
External Fire Fighting System Class 1	2	1290kw	14000	Csh	28000
Fire Pumps	1	18,5kw	80	AZCUE	80
Monitors Control	2	1200 m3/h @ 16bar	136	Innovfoam	272
HVAC System (Compressor unit)	1	25kw	90	CARRIER	90
		TOTAL, MACHINERY WEIGHT (KG)			285145
		TOTAL MACHINERY WEIGHT (mT)			**285,15**

Remainign Weight

Clearly, an extra weight for additional items, like pipes, foundings, electrical wires and electrical components, ventilation pipes…, non-structural tanks, etc, that will be carried for the operation of the machinery room, must be considered. This value will be estimated by a regression line that matches this "remainder weight" with the MCR of the main engine (time 2). This regression is obtained from the Watson and Gilfillan, Paper for Tanker ships. The AHTS is classifid as a tanker because of the substantial number of pumps; and additional items, that are of regulatory need for the notation of the vessel. It is recommended to increase the weight by no more than 30% between the machinery weight and the remaining weight. This project team agrees with this percentage, that will be used in search of other reliable figure.

Remainign Weight 85,5 ton

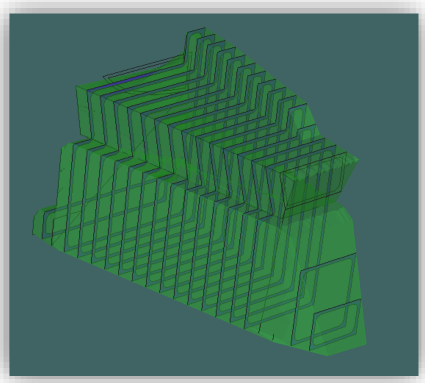
Superestructure

The software STRUCTURE was used for obtaining a preliminary steel weight of the superstructure. A preliminary structure was obtained, with twice the framing of the hull, but with the same scantling as the hull in the inner structure, as is known by experience of the model vessel, that such reinforcement is needed cause the big acceleration and wave slamming that can cause important deformations.

Although in this stage there is only preliminary technical information, some assumptions were done to obtain, as much as possible, from the known data.

- Plate thickness was estimated as 6mm, as seen in some arrangements
- Inner Structure scantling was almost kept equal thoughtout the length of the superstructure.

Steel Item	*Weight [MT]*
Superstructure Steel	52,6
Inner Structure	56,07
Horizontal decks	18,4
Total, Superstructure Weight	**127**



<u>Outfitting</u>

Estimating the outfitting is one of the inaccurate task in the calculation of the LWS. To estimate the outfitting this design team will use the Watson & Gilligan technical paper as it was done in the initial LWS estimation. As this design team lacks of detailed information, selecting a suitable outfit weight in relation to the square number (L x B), is the best method to be used. Such relation is obtained from the following graph. An Outfit relation of 0,33 is obtained for our length and working with an average of the three samples plotted for supply vessel.

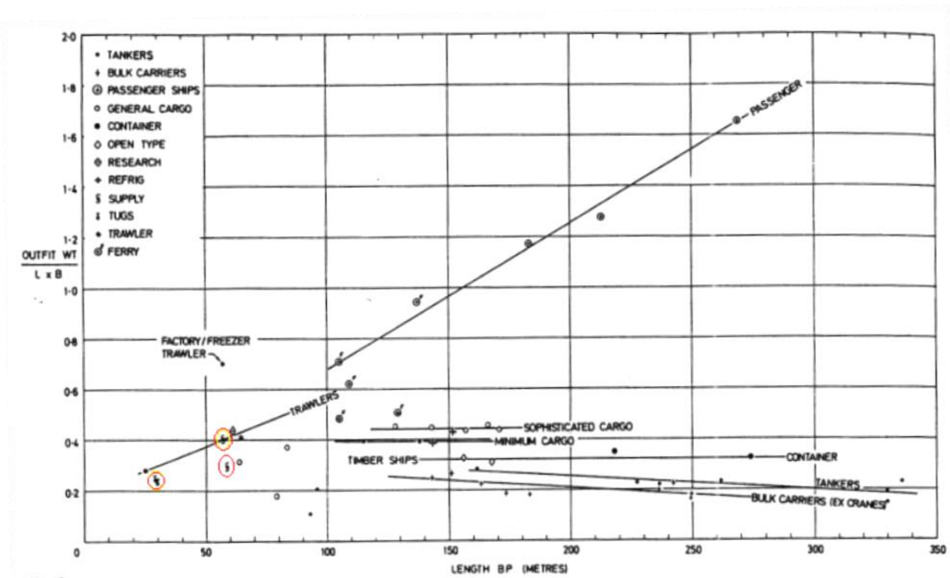


Fig. 9

$$Woutfitting[mT] = 0{,}33x\ (LxB)$$

$$Woutfitting[mT] = 0{,}33x\ (65mx15{,}14m)$$

$$Woutfitting[mT] = 324{,}75mT$$

LSW estimation

LWS ITEM	WEIGHT [MT]
HULL STEEL	873
MACHINERY	285
REMAINIG MACHINERY	86
SUPERSTRUCTURE	127
OUTFITTING	325
MARGIN 4%	68
LWS W/MARGIN 4%	**1763**

This design team will keep the initial LSW estimation as it is less than a 4% of difference between the initial/parametrical calculations. The LWS will be kept as 1831 mT

Center of gravity position:

In the completed total Light weight ship estimate list, the corresponding positions for each item that was not calculated by the use of STRUCTURE, was determinate in the preliminary general arrangement. The position of the transverse center of gravity is supposed as a resultant in the center line. This design team decides not to determinate the transverse position at this stage of the project, minimal deviation from center line that can be found will be corrected in a following stage of project. An estimated position of the LSW center of gravity is obtained. Positions are measured from aft perpendicular.

Steel Item	*Weight [MT]*	*LCG[m]*	*VCG[M]*	*Vertical M [mT-m]*	*Long Mt [mT-m]*
Hull Steel	415	26,7	6,1	11080,5	2531,5
Inner Structure	307	26,08	5,1	8006,6	1565,7
Long and horizontal Bulkhead	151	26,69	2,33	4030,2	351,8
Main Engine	79	23,03	2,54	1819,4	200,7
Gear Box	19,8	18,215	2	360,7	39,6
Main Gensets	28	28	2,2	784,0	61,6
Shaft Generators	3	18,215	2,54	54,6	7,6
Emergency Genset	7,7	37,4	11,1	288,0	85,5
Steering Gear	1	1,6	4,7	1,6	4,7
Bow Thruster	4	51,07	2,88	204,3	11,5
Anchors	2,88	55,6	9,5	160,1	27,4
Anchor chain	18,932	30,6	4,7	579,3	89,0
Controllable Pitch Propellers	2,8	-0,3	1,85	-0,8	5,2
Kort Noozle	0,6	-0,3	1,85	-0,2	1,1
Rudder	2,2	2,33	1,698	5,1	3,7
Stern Tube	1,4	7,415	1,65	10,4	2,3
Hydraulic Anchor Windlass	8	52,17	13,3	417,4	106,4
Hydraulic Anchor/Towing Winch	42	31,58	8,173	1326,4	343,3
Hydraulic Capstans	1,2	-0,4	7,2	-0,5	8,6
Hydraulic Tugger Winch	3,6	30,45	10,7	109,6	38,5
Hydraulic Shark Jaw & Towing Pins	6	-1,8	7,03	-10,8	42,2
Stern Roller	14	-5,03	5,8	-70,4	81,2
Deck Crane	5,8	28,11	11,7	163,0	67,9
Fire & General Service Pumps	0,13	27,63	1,4	3,6	0,2
Ballast & Bildge Pump	0,13	53,4	1,4	6,9	0,2
Fuel Oil Transfer Pump	0,05	30,2	1,4	1,5	0,1
Hot Water Circulating Pump	0,023	31	1,4	0,7	0,0
Dirty Oil / Sludge Pump	0,023	30,6	1,4	0,7	0,0
Emergency Fire Pump	0,08	32	1,4	2,6	0,1
Fuel Oil Cargo Pumps	0,3	30	1,4	9,0	0,4
Fresh Water Cargo Pumps	0,13	30	1,4	3,9	0,2
Drill Water/Ballast Pump	0,15	30	1,4	4,5	0,2
Liquid Mud Pump	0,23	30,5	1,4	7,0	0,3
Cement Compressor Pump	0,1	45	1,4	4,5	0,1
Fresh Water Pressure Set	0,6	45	2,4	27,0	1,4
Sea Water Pressure Set	0,6	45	2,5	27,0	1,5
Dirty oil pump	0,02	30	1,4	0,6	0,0
Oil Water Separator	0,025	30	1,8	0,8	0,0
Rescue Boat	2,2	32,73	10,9	72,0	24,0
External Fire Fighting System Class 1	28	34	2,5	952,0	70,0
Fire Pumps	0,08	33	1,4	2,6	0,1
Monitors Control	0,272	42	11	11,4	3,0
HVAC System (Compressor unit)	0,09	30,4	11,2	2,7	1,0
Remaingin weight	85,5	47	6,4	4018,5	547,2
Superstructure steel	52,6	43,45	11,8	2285,5	620,7
Inner Structure	56,07	43,45	12,3	2436,2	689,7
Horizontal Decks	18,4	43,45	11,8	799,5	217,1
outfitting	324,75	43	7,8	13964,3	2533,1
Margin as per initial LWS	136	41	7,8	5576,0	1060,8
				59539,4	11448,4
LIGHT SHIP CONDITION	**1831,465**	**32,5**	**6,3**		

Loading conditions

In this stage the design team will test the vessel up to the most stability demanding conditions that the vessel could encounter, in its their operational life. The ABS rules are to be precisely verified, as stability assessment in Offshore vessel is task of serious importance, as it is designed to support the most adverse conditions.

From the ABS OSV Part 4, chapter 3/7 Standard Loading conditions are descripted:

The following conditions of loading are to be examined in the Trim and Stability Booklet:

CODE	DESCRIPTION
I)	Vessel at the maximum Load Line draft, with full stores and fuel and fully loaded with all liquid and dry cargo distributed below deck and with remaining deadweight distributed as above deck cargo (specified by weight, LCG, VCG and total height above deck) corresponding to the worst service departure condition in which all the relevant stability criteria are met.
II)	Vessel with 10% stores and fuel and fully loaded cargoes of *i)* above, arrival condition.
III)	Vessel with full stores and fuel and loaded with the maximum design deck cargo (specified by weight, LCG, VCG and total height above deck) and with remaining deadweight distributed below deck in liquid and dry cargo spaces corresponding to the worst service departure condition in which all the relevant stability criteria are met.
IV)	Vessel with 10% stores and fuel and fully loaded cargoes of *iii)* above, arrival condition.
V)	Vessel with full stores and fuel in ballast departure condition.
VI)	Vessel with 10% stores and fuel in ballast arrival condition.
VII)	Vessel in the worst anticipated operating condition (i.e., arrival condition with deck cargo only – 100% deck cargo with 10% stores and fuel).

The above loading conditions were created to later, verify the stability of the vessel.

As already defined in the Capacity Plan Section, the tanks were assumed as, 98% as full tank for highly volatile liquid, and the permeability of the double bottom was considerated to be of 92% and of 97% for the rest off compartments. In each case, the most effective loading condition, was sought, trying to carry the least possible amount of ballast water possible, so that the heel and the trim are the most nearest to zero.In condition VII) the worst loading condition is to be fulfil the ballast arrival with full deck cargo is used.

Note that the Fuel Oil tanks are shared between cargo and endurance fuel of the vessel. As stated in the endurance calculation 333 Mt for Main engine and auxiliary generators. So for arrival condition a consumption of 300 mT (90%) is assumed has been done during the voyage of the vessel from a total of 470 mT capacity of tank.

Also is noted that Drill Water and Ballast tank can be used for the same purpose.

Drinkable water is correspondent to one estimated in the initial dimensions of the vessel (27,5 mT), but also is used as a cargo to be delivered at platform. So for arrival conditions a consumption of 24,7mT from a total of 406,16 mT capacity of tank is assumed.

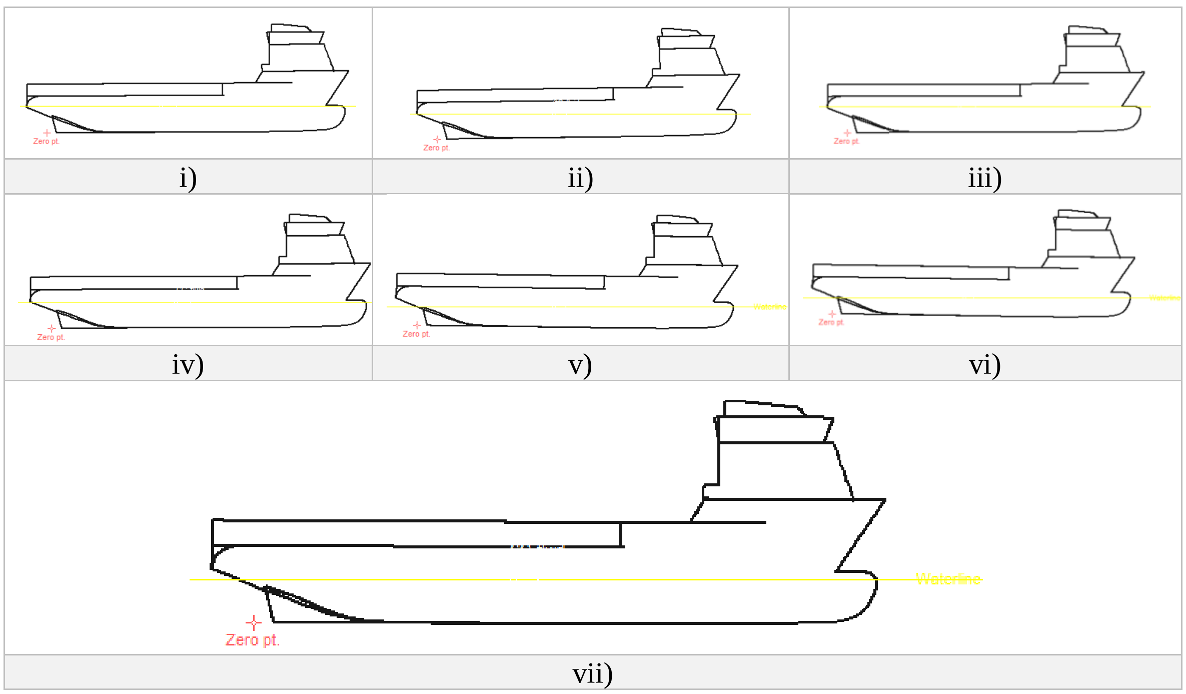
CODE	CONFIGURATION				DWT
	STORES	***DWT**ON-TANKS*		***CARGO**ON-DECK*	***[mtT]***
I)FULL DRAFT (FULL TANKS AND REMAINING AT DECK)	100%	F.O.: LUB.OIL.: POTABLE W.: BILGE: DRILL W.: BRINE: BALLAST W.: CEMENT: FIFI.:	460 mT (98%) 25 mT (100%) 297 mT(73%) 0mT(0%) 130mT(0%) 471Mt(100%) 0mT(0%) 0mT(0%) 28mT(100%)	6 anchors:120mT 6 bouys:8mT 3000m chain:242mT	1782 (100%)
II)ARRIVAL OF I)	10%	F.O.: LUB.OIL.: POTABLE W.: BILGE: DRILL W.: BRINE: BALLAST W.: CEMENT: FIFI.:	160 mT (34%) 2,5 mT (10%) 272 mT(67%) 12mT(50%) 130mT(21%) 471Mt(100%) 0mT(0%) 0mT(0%) 28mT(100%)	6 anchors:120mT 6 bouys:8mT 3000m chain:242mT	1450 (81%)
III)FULL DECK CARGO AND REMAINING AT TANKS	100%	F.O.: LUB.OIL.: POTABLE W.: BILGE: DRILL W.: BRINE: BALLAST W.: CEMENT: FIFI.:	366 mT (78%) 25 mT (100%) 91 mT(22%) 0mT(0%) 173mT(30%) 471Mt(100%) 0mT(0%) 135mT(74%) 28mT(100%)	6 anchors:120mT 6 bouys:8mT 3000m chain:242mT 133 Pipes on deck: 93mT	1757 (98%)
IV)ARRIVAL OF III)	10%	F.O.: LUB.OIL.: POTABLE W.: BILGE: DRILL W.: BRINE: BALLAST W.: CEMENT: FIFI.:	160 mT (34%) 2,5mT (10%) 67 mT(17%) 12mT(50%) 173mT(29%) 471Mt(100%) 0mT(0%) 135mT(74%) 28mT(100%)	6 anchors:120mT 6 bouys:8mT 3000m chain:242mT 133 Pipes on deck: 93mT	1517 (85%)
V)BALLAST DEPARTURE	100%	F.O.: LUB.OIL.: POTABLE W.: DRILL: BALLAST W.: FIFI.:	368mT(78%) 25mT(100%) 91mT(22%) 173mT(29%) 28,24(19%) 28mT(100%)	-	714(40%)
VI)BALLAST ARRIVAL	10%	F.O.: LUB.OIL.: POTABLE W.: BILGE: DRILL: BALLAST W.: FIFI.:	160mT(34%) 2,5mT (10%) 67mT(17%) 24mT(100%) 173mT(29%) 28mT(19%) 28mT(100%)	-	486(27%)
VII)WORST CONDITION	10%	F.O.: LUB.OIL.: POTABLE W.: BILGE: DRILL: BALLAST W.: FIFI.:	160mT(34%) 2,5mT (10%) 67mT(17%) 24mT(100%) 173mT(29%) 28mT(19%) 28mT(100%)	6 anchors:120mT 6 bouys:8mT 3000m chain:242mT 133 Pipes on deck: 93mT	1042 (58%)

Trim and intact stability analysis

In this stage a hydrostatic study of the above seven conditions is to be conducted. As previously mentioned, all the conditions for rational loading arrangement in which minimum heel, ballast and trim was desired were calculated.

CASE	TRIM [M]	HEEL [DEG]	DRAUGHT AMIDSHIP[M]	GMT [M]	DISPLACEMENT [MT]	DWT	%DWT
I)	***0,316***	***0***	***5,2***	***2***	3616	1782	100%
II)	***0,55***	***0***	***4,81***	***1,02***	3283	1450	81%
III)	***0,169***	***0***	***5,2***	***1,74***	3588	1757	98%
IV)	***0,02***	***0***	***4,92***	***0,9***	3349	1517	85%
V)	***-0,78***	***0***	***4,32***	***1,75***	2546	714	40%
VI)	***-0,87***	***0***	***3,61***	***1,68***	2320	486	27%
VII)	***-0,308***	***0***	***4,45***	***1,16***	2873	1042	58%

Trim positive is by stern.



As a conclusion of this assessment of the trim for the seven conditions, in the following stage of the project a reorganization of “ballast condition “ items should be done in order to place them to the as close as possible to the aft part of the ship. Although trim by bow are obtained for ballast condition and worst condition, trim values that are not excessive for the equilibrium waterline, as it was consulted with a operational manager from the offshore market and told that it was normal for those conditions because the significant weight at the fore because the superstructure position..

Intact Stability Requirements for Offshore Support Vessels

At this stage, the vessel is proved to support the proposed operational loading conditions as well as to comply with the stability requirements for offshore vessels. A study of the towing and FI-FI operation and her ability to meet stability requirements for such situation in each towing condition is carried out.

To fulfil the requirements for ABS Stability assessment for OSV, is for every above loading condition, the righting arm curve (GZ curve) to be plotted using the VCG corrected for the free surface effects of liquid in tanks.

General Criteria
The following stability criteria are to be complied with:

i) The area under the righting lever curve (GZ curve) should not be less than 0.055 meter-radians (10.3 ft-degrees) up to θ = 30° angle of heel and not less than 0.09 meter-radians (16.9 ft-degrees) up to θ = 40° or the angle of flooding, if this angle is less than 40°. Additionally, the area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40° or between 30° and θf*, if this angle (θf) is less than 40°, is not to be less than 0.03 meter-radians (5.6 ft-degrees).

ii) The righting lever GZ is to be at least 0.20 m (0.66 ft) at an angle of heel equal to or greater than 30°.

iii) The maximum righting arm is to occur at an angle of heel not less than 25°.

iv) The initial metacentric height, GM0, is not to be less than 0.15 m (0.49 ft).

Downflooding points
According to the regulations, the weathertight door of the winch compartment is set as the first flooding point.

Down flooding points	***LCG [m]***	***TCG [m]***	***VCG [m]***
Machine Room Access	38,9 m	-3.5 m	7.822 m

Free surface considerations
The free surface is calculated by MAXSURF for each tank as the maximum free surface effect that can be found for a determined ullage.

Carriage of Pipe as Deck Cargo
Where pipes are carried on deck, a quantity of trapped water equal to a certain percentage of the net volume of the pipe deck cargo should be assumed in and around the pipes. The net volume is to be taken as the internal volume of the pipes, plus the volume between the pipes. This percentage is to be 30% . When the pipes were added an amount of water inside was added as rule states. Also a FSM was conducted by MaxSurf.

Hydrostatics & curves of form

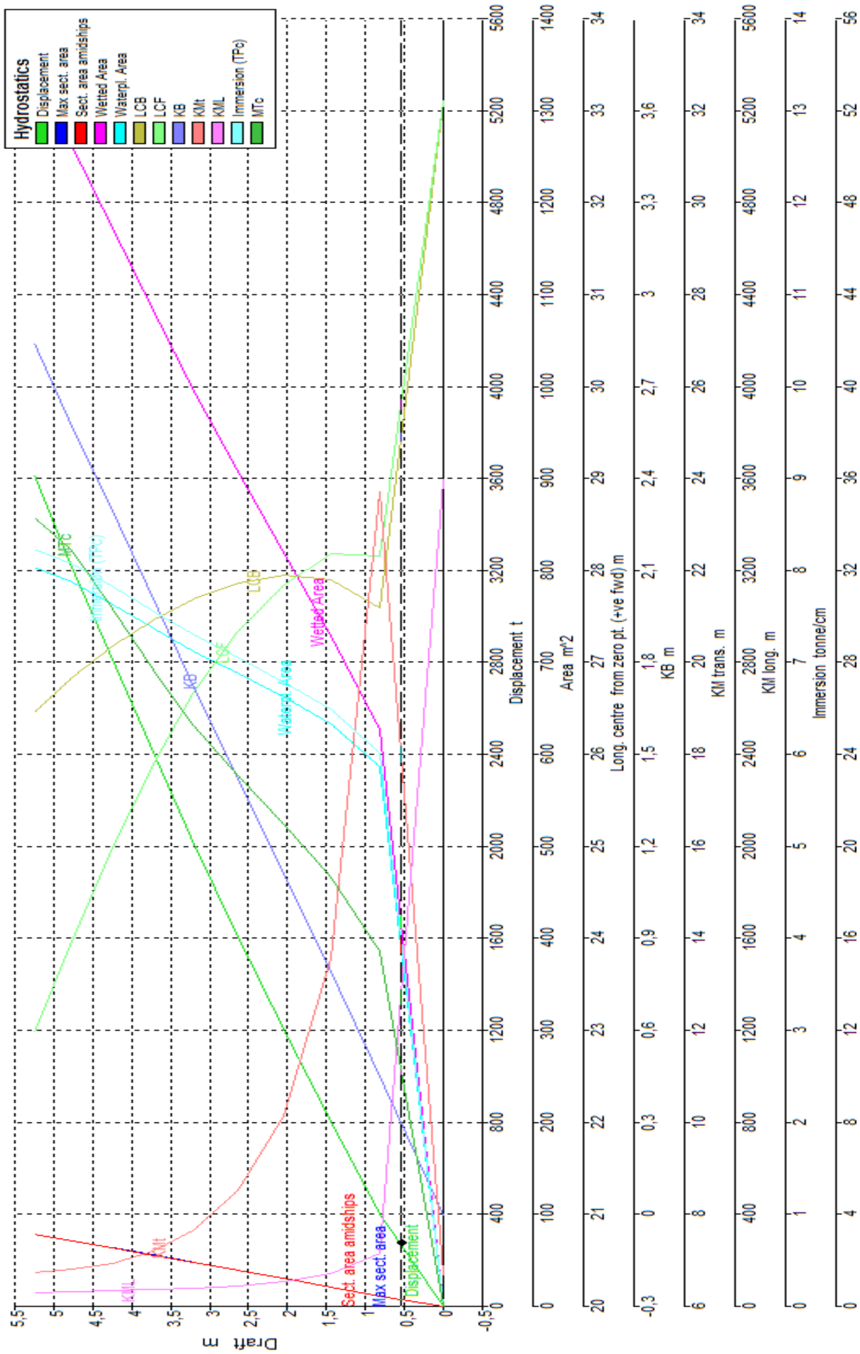


Table N°1: Hydrostatics curves, max draft and trim zero

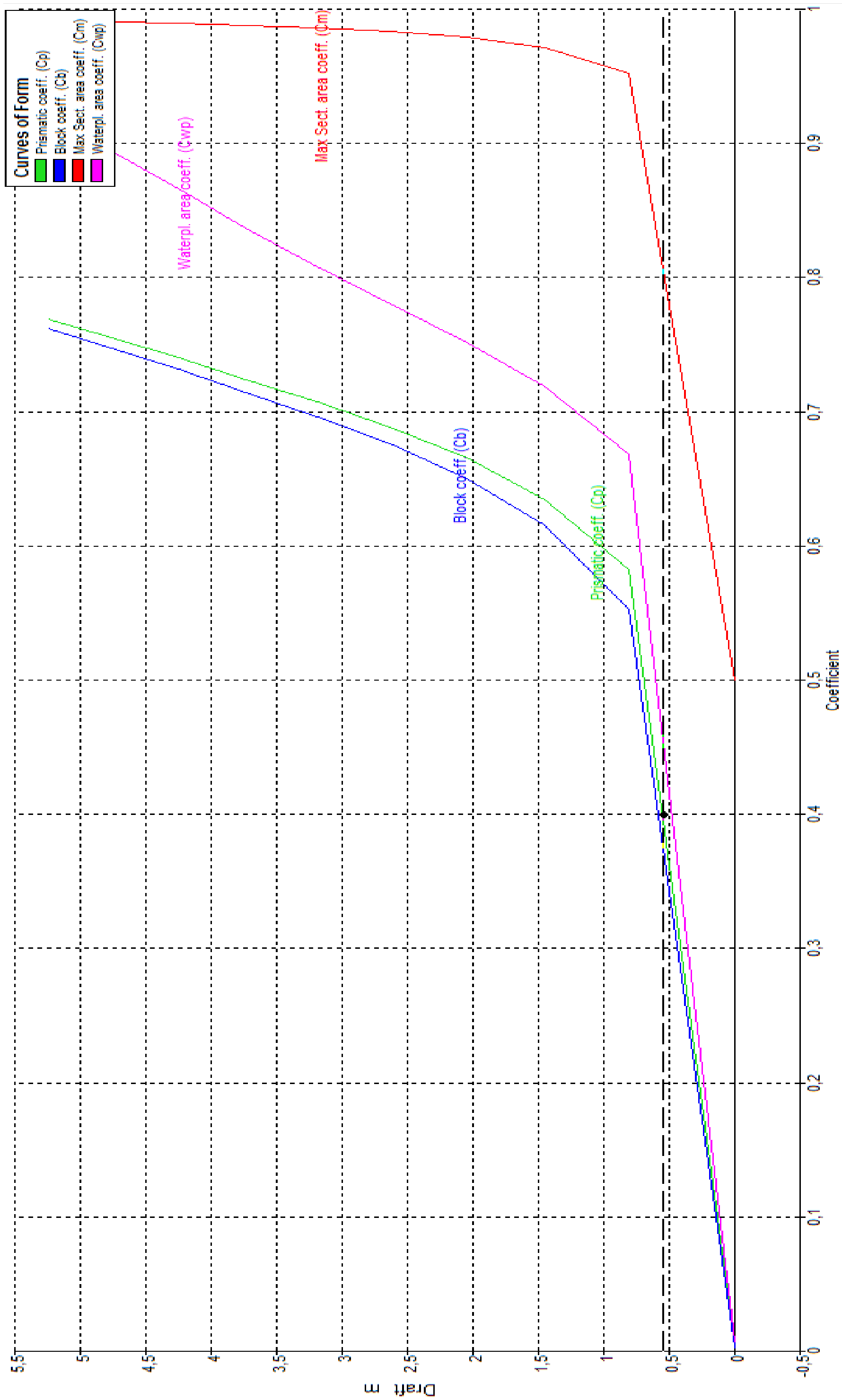


Table N°2: Form curves, max draft and trim 0

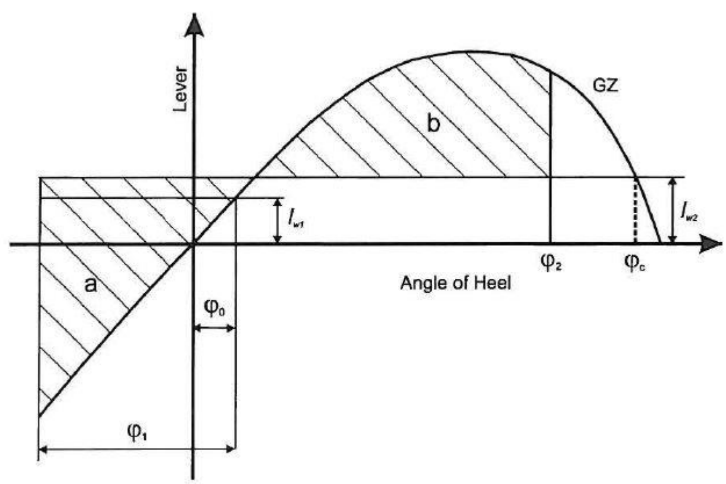
Severe Wind and Rolling Criterion

In addition to 3-3-A1/3.1, The Severe Wind and Rolling Criterion in Part A, Section 2.3 of the 2008 Intact Stability Code is to be complied with. Where the vessel's characteristics render compliance with this criteria impracticable, consideration will be given for compliance with another published weather criteria.

Intact Stability Code criteria:

2.3.1 The ability of a ship to withstand the combined effects of beam wind and rolling shall be demonstrated, with reference to figure 2.3.1 as follows:

- The ship is subjected to a steady wind pressure acting perpendicular to the ship's centreline which results in a steady wind heeling lever (l_{wl})
- from the resultant angle of equilibrium (ϕ_0) the ship is assumed to roll owing to wave action to an angle of roll (ϕ_1) to windward. The angle of heel under action of steady wind (ϕ_0) should not exceed 16° or 80%, of the angle of deck edge immersion, whichever is less;
- the ship is then subjected to a gust wind pressure which results in a gust wind heeling lever (l_{w2}); and
- under these circumstances, area *b* shall be equal to or greater than area *a*, as indicated in figure 2.3.1 below:



where the angles in figure 2.3.1 are defined as follows:

- ϕ_0 = angle of heel under action of steady wind
- ϕ_1= angle of roll to windward due to wave action (see 2.3.1.2, 2.3.4)
- ϕ_2=angle of down-flooding (ϕ_f) or 50° or ϕ_c , whichever is less,

Where:

ϕ_f= angle of heel at which openings in the hull, superstructures or deckhouses which cannot be closed weathertight immerse. In applying this criterion, small openings through which progressive flooding cannot take place need not be considered as open.

ϕ_c= angle of second interccpt between wind heeling lever (l_{wl}) and GZ curves.

The wind heeling levers (l_{wl}), and (l_{w2}) referred to in 2.3.1.1 and 2.3.1.3 are constant values at all angles of inclination and shall be calculated as follows:

$$l_{w1} = \frac{PxAxZ}{1000xgx\Delta}\ [m]$$

$$l_{w2} = l_{w1}x1{,}5\ [m]$$

Where:

P= wind pressure of 504 Pa. The value of P used for ships in restricted service may be reduced subject to the approval of the Administration

A=projected lateral area of the portion of the ship and deck cargo above the waterline (m2)

Z=vertical distance from the center of A to the center of the underwater lateral area or approximately to a point at one half the mean draught (m)

Δ=displacement (t)

g= gravitational acceleration of 9,81 m/s^2

2.3.3 The wind velocity used in the tests shall be 26 m/s in full scale with uniform velocity profile. The value of wind velocity used for ships in restricted services may be reduced to the satisfaction of the Administration.

Weather stability analysis procedure:

The weather criteria will be calculated with the use of MaxSurf Stability software. The following assumptions will be made.

- The velocity will be kept as 26m/s as for the owner requirement is to be verified the seakeeping at 35 knts (18 m/s)
- The dynamic pressure will be kept as 504 Pa
- As the MaxSurf software has recently installed the roll-back angle calculator, and this type of vessel may exceed the typical dimensions relations. This design team will calculate with the procedures from de IS Code to check the angle ϕ_1

The angle of roll ϕ_1 is to be calculated as follows:

$$\varphi_1 = 109 * k * X_1 * X_2 * \sqrt{r * s} \quad (degrees)$$

Where:

- X_1= factor as shown in table 2.3.4-1
- X_2=factor as shown in table 2.3.4-2
- k = factor as shown in table 2.3.4-3
- r $=0{,}73 + 0{,}6\frac{OG}{d}$ OG=KG-d
- s = factor as shown in table 2.3.4-4 , where T is the ship roll natural period. Aproximation will be done with the following formula.
  - Rolling period
    - $T = \frac{2xCxB}{\sqrt{GM}}\ (s)$
    - $C = 0.373 + 0.023(B/d) - 0.043(L_{wl}/100).$

B/d	X_1
≤ 2.4	1.0
2.5	0.98
2.6	0.96
2.7	0.95
2.8	0.93
2.9	0.91
3.0	0.90
3.1	0.88
3.2	0.86
3.4	0.82
≥ 3.5	0.80

Table 2.3.4-1

C_B	X_2
≤ 0.45	0.75
0.50	0.82
0.55	0.89
0.60	0.95
0.65	0.97
≥ 0.70	1.00

Table 2.3.4-2

$\frac{A_k \times 100}{L_{WL} \times B}$	k
0	1.0
1.0	0.98
1.5	0.95
2.0	0.88
2.5	0.79
3.0	0.74
3.5	0.72
≥ 4.0	0.70

Table 2.3.4-3

T	s
≤ 6	0.100
7	0.098
8	0.093
12	0.065
14	0.053
16	0.044
18	0.038
≥ 20	0.035

Table 2.3.4-4

- B/d smaller than 3.5
- (KG/d-l) between - 0.3 and 0.5
- T smaller than 20 s.
- B = 15,14m ; d = 5,21 m B/d = 2.9059 From Table 2.3.4-1 → **X1 =0,91**
- Cb = 0,74 from table 2.3.4-2 → **X2 = 1.00**
- A bilge keel is considered of a web height of 200 mm and a parallel bilge body of 20 meters $A_k = 8\ m^2\ \frac{A_k x100}{L_{wl} xB} = 0{,}87$. From Table 2.3.4-3 → k=1 (no diminution of angle)
- → C = 0.4139
- T = 2*(0.4139)*15.14/ $\sqrt{0{,}9}$ T = 13.21 [s] s→0,053 (for the worst GM-> bigger period->bigger roll->worst condition kept for all loading conditions)
- →r=0,67

$$\varphi_1 = 109 * k * X_1 * X_2 * \sqrt{r * s} \quad (degrees)$$

ϕ_1 = 18,7 degrees vs. 25 degrees from MaxSurf Software.

Towing operation

In order to verify stability during towing operation the ABS criteria is satisfy with a Thrust of 100 mT of bollard pull. Although the ABS permit a reduction of the Bollard pull, is used the max bollard pull available, as it might be a scenario in which dynamic bollard pull may exceed the diminished bollard pull.

Heeling due to towing or bollard-pull

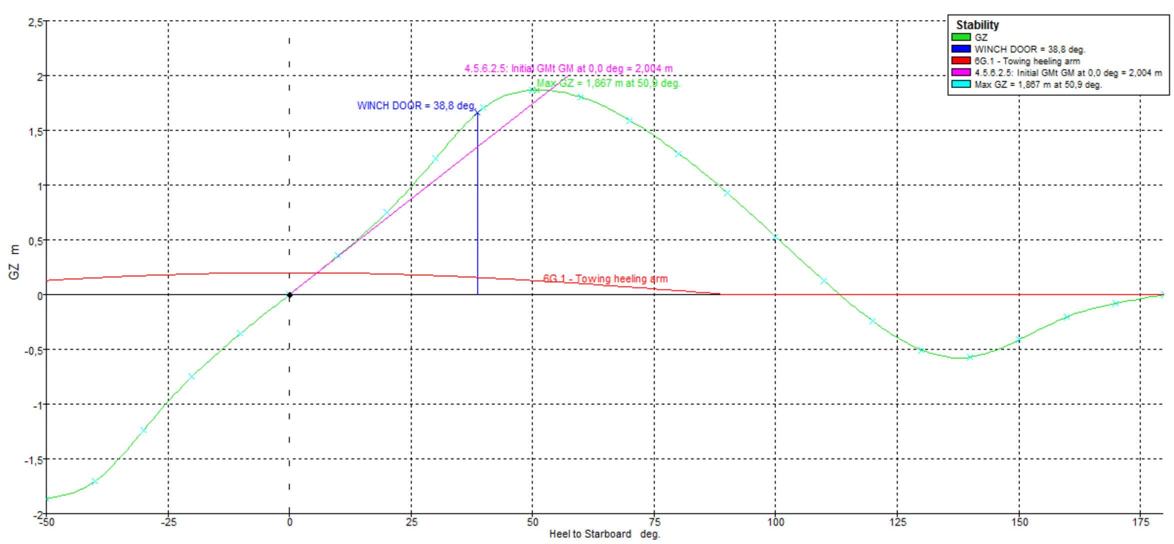
The magnitude of the heel arm is given by:

$$H_{tow}(\phi) = \frac{T}{g\Delta}\left[v\cos^{n}(\phi+\tau) + h\sin(\phi+\tau)\right]$$

where:

T is the tension in the towline or vessel thrust, expressed as a force.
h is horizontal offset of the tow attachment position from the vessel centreline
v is vertical separation tow attachment position from the vessel's vertical centre of thrust
Δ is the vessel mass
n is the power index for the cosine term which may be used to change the shape of the heeling arm curve
τ is the (constant) angle of the towline above the horizontal. It is assumed that the towline is sufficiently long that this angle remains constant and does not vary as the vessel is heeled.

Towing condition in full load



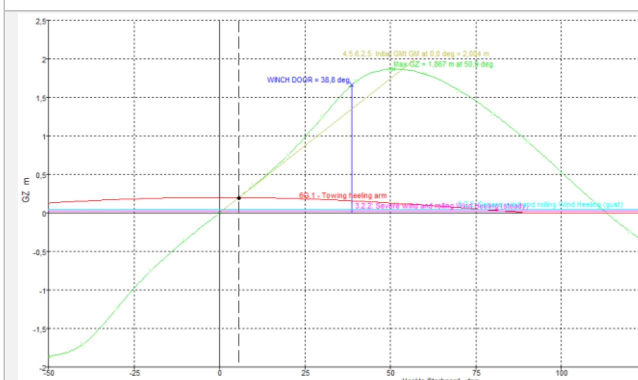
First Interception at 5,5 deg

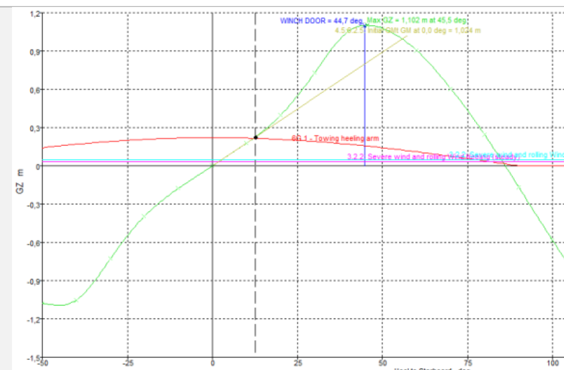
Results:

Every condition is assessed for large angle stability, with the MaxSurf package STABILITY.

		Unit	(I)	(II)	(III)	(IV)	(V)	(VI)	(VII)
			Obtained						
6g.1 - Towing heeling arm			Pass	Pass	Pass	Pass	Pass	Pass	Pass
heel of equilibrium shall be less than 15°			5,70	12,10	6,60	12,30	9,00	10,10	12,30
6g.1a&b -Towing heeling - GZ area between limits type 2			Pass	Pass	Pass	Pass	Pass	Pass	Pass
area1 shall be greater than (>) 0 + 0,09 area2	0,05	m.rad	0,41	0,20	0,35	0,20	0,34	0,29	0,21
4.5.6.2.1: GZ area between 0 and angle of maximum gz			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall not be less than (>=)	0,06	m.rad	0,90	0,42	0,78	0,43	0,86	0,76	0,51
4.5.6.2.2: Area 30 to 40			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall not be less than (>=)	0,03	m.rad	0,22	0,16	0,20	0,16	0,23	0,20	0,17
4.5.6.2.3: Maximum GZ at 30 or greater			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall not be less than (>=)	0,20	m	1,87	1,10	1,67	1,10	1,59	1,38	1,17
4.5.6.2.4: Angle of maximum GZ			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall not be less than (>=)	15,0	deg	50,90	45,50	50,0	46,40	53,6	52,70	48,20
4.5.6.2.5: Initial GMT			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall be greater than (>)	0,15	m	2,00	1,02	1,75	0,95	1,75	1,69	1,08
3.2.2: Severe wind and rolling			Pass	Pass	Pass	Pass	Pass	Pass	Pass
angle of steady heel shall not be greater than (<=)	16	deg	0,8	1,9	1	2	1,5	1,7	2,1
angle of steady heel / deck edge immersion angle shall not be greater than (<=)	80	%	5,38	10,56	5,93	10,59	6,18	6,7	9,33
area1 / area2 shall not be less than (>=)	100	%	259,94	285,4	260	289,45	260	245,2	275,91

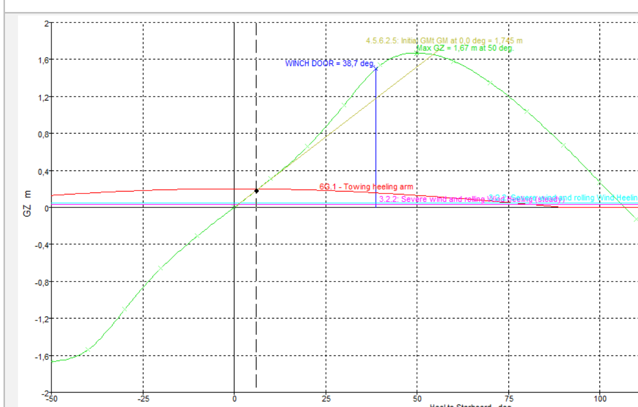
GZ curves with Towing heel angle intersection plotted

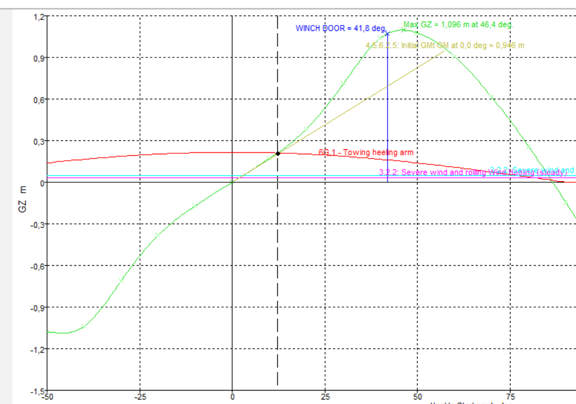


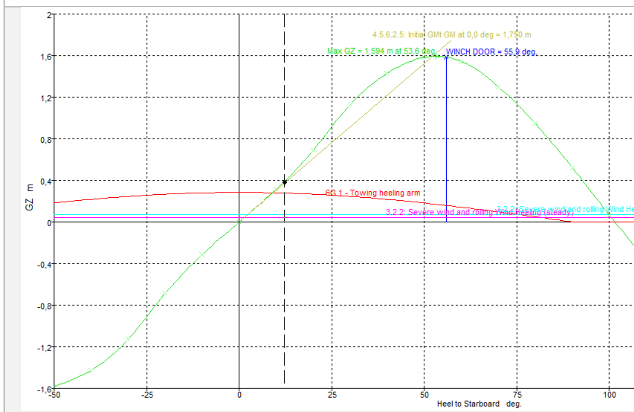
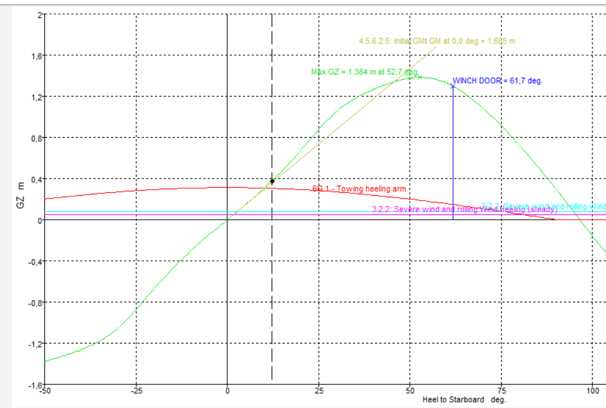
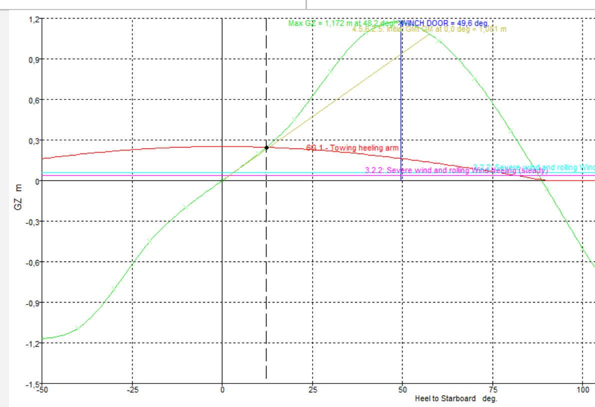


i)FULL DRAFT (FULL TANKS AND REMAINING AT DECK)

ii)ARRIVAL OF I)





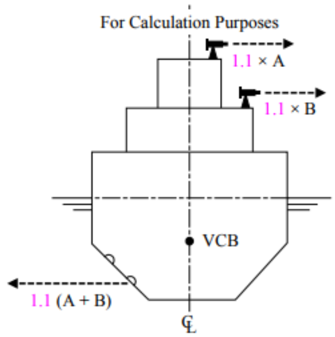
iii)FULL DECK CARGO AND REMAINING AT TANKS	iv)ARRIVAL OF III)
	
v)BALLAST DEPARTURE	vi)BALLAST ARRIVAL
	
vii)WORST CONDITION	

Fire Fighting Stability

The intact stability of each vessel receiving a fire fighting notation is to be evaluated for the loading conditions indicated for compliance with the intact stability criteria.

Intact Stability Criteria

Each vessel is to have adequate stability for all loading conditions, with all fire fighting monitors operating at maximum output multiplied by a factor of 1.1 in the direction most unfavorable to the stability of the vessel. The thruster(s) are to be considered operating at the power needed to counter-act that force. For the calculation purposes, the total thruster force should be vertically located at the location of the lowest available Thruster.



The heeling moment due to the operation of all fire fighting monitors and thrusters is to be converted to a heeling arm, and superimposed on the righting arm curve of each loading condition. The first intercept must occur before half of the freeboard is submerged. The area of the residual stability (area between the righting arm and heeling arm curves beyond the angle of the first intercept) up to an angle of heel 40° beyond the angle of the first intercept; or the angle of downflooding if this angle is less than 40° beyond the angle of the first intercept, should not be less than 0.09 meter-radians.

Each monitor receives a pressure of 16 Bar , and a flow of 1200 m^3/hr

The force produces by each monitor is calculated by:

$$F[N] = V\ \left[\frac{m}{s}\right] x\ \frac{dm}{dt}$$

Obtaining the velocity of the water at the monitor as:

$$\Delta P = \frac{1}{2}\rho V^2$$

- For the given pressure a is obtained a velocity of 56,56 m/s
- A monitor force of 18,86 kN is obtained.
- The total force for the two monitors is 37,33 kN.
- The Thrusters location above base line is estimated as 1,5m.
- Monitors height above baseline is of 21 meters.
- KB for loading condition is of 2,81 m

Obtaining a moment of:

$$M_{FI-FI} = 2\ x\ F\ x\ (21m - 2{,}81m) - 2\ x\ F\ x(1{,}5m - 2{,}81m)\text{=73 mT-m}$$

For such displacement of example 2320mT (minimum displacement), a heeling arm of 0,03 meters is obtained. Intersection of heeling arm with GZcurve is at 0,93 deg and gives just a decrease in freeboard of 0,13 m, that is not the half of the freeboard.

Damage stability

A Damage Stability analysis is carried out with the deterministic concept. This method is based on damage assumptions such as damage length, transverse extent and vertical extent. The potential risk to the environment resulting from the type of cargo carried, compliance with a required compartment status must be proved. The deterministic concept to offshore supply vessels.

From the ABS OSV 3.3.2.-3

Damage Assumptions

The following damage assumptions are to be applied:

i) Damage is to be assumed to occur anywhere in the vessel's length between transverse watertight bulkheads. The longitudinal extent of damage is:

  i For a vessel the keel of which is laid or which is at a similar stage of construction on or after 22 November 2012:

    with length (L_f) greater than 43 m and less than 80 m :
    3 m plus 3% of L_f => 4,812 meters

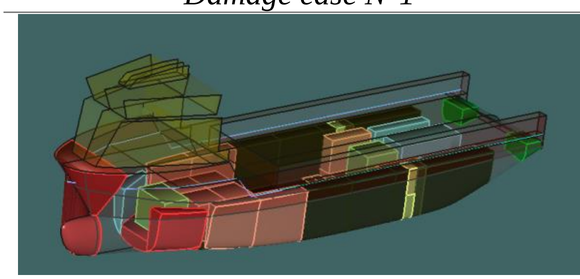
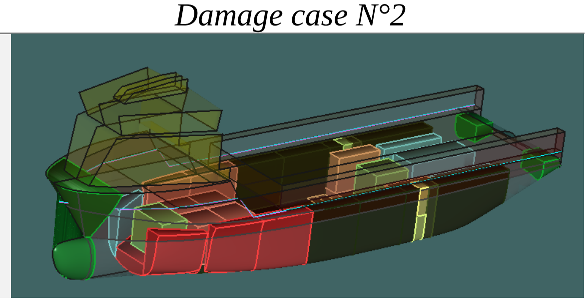
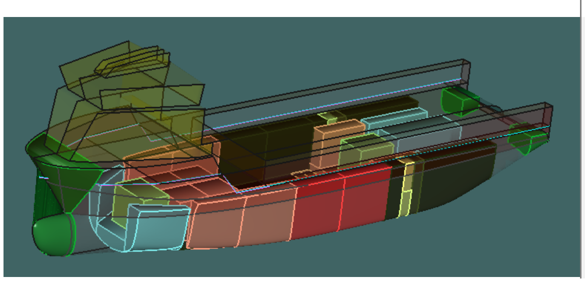
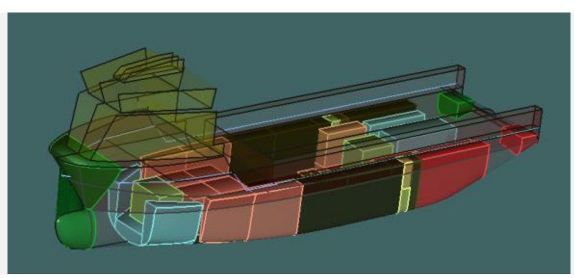
ii) The vertical extent of damage is to be assumed from the underside of the cargo deck, or the continuation thereof, for the full depth of the vessel.

iii) The transverse extent of damage is:

  with length (L_f) less than 80 m (262.5 ft): 760 mm (30 in.)

With the damage length calculated the following 4 damage cases are simulated to cover all damage cases

Damage cases

Damage case N°1	*Damage case N°2*
	
Damage case N°3	*Damage case N°4*
	

Criteria

The following damage stability criteria are to be satisfied:

i) The final waterline, taking into account sinkage, heel and trim, is to be below the lower edge of any opening through which progressive flooding may take place. Such openings are to include air pipes and those openings which are capable of being closed by means of weather-tight doors or hatch covers and exclude those openings closed by means of watertight manhole covers and flush scuttles, small watertight cargo tank hatch covers which maintain the high integrity of the deck, remotely operated watertight sliding doors, and side scuttles of the non-opening type.

ii) In the final stage of flooding, the angle of heel due to unsymmetrical flooding is not to exceed 15°. This angle may be increased up to 17° if no deck immersion occurs.

iii) The stability in the final stage of flooding is to be investigated and may be regarded as sufficient if the righting lever curve has a positive range of at least 20° beyond the position of equilibrium in association with a maximum residual righting lever of at least 100 mm (3.9 in.) within this range. Unprotected openings are not to become immersed at an angle of heel within the prescribed minimum range of residual stability unless the space in question has been included as a floodable space in calculations for damage stability. Within this range, immersion of any of the openings referred to in 3-3-A2/5i) and any other openings capable of being closed weather-tight may be authorized.

iv) The vessel shall maintain sufficient stability during intermediate stages of flooding.

Results

The results of the damage stability are summarized in the following table. Every condition surpass the requirements for the four damage cases presented.

	EQUILIBRIUM HEEL ANGLE LESS THAT 15 DEG				**RANGE OF POSITIVE STABILITY > 20 DEG**			
	Damage Case				Damage Case			
LOADING CONDITION	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
I)FULL DRAFT (FULL TANKS AND REMAINING AT DECK)	-1	-5,24	1	-1	110	107,76	112	112
II)ARRIVAL OF I)	-2	-10,5	-10	-3	84	96	96	88
III)FULL DECK CARGO AND REMAINING AT TANKS	-1,5	-5,6	0	0	104	100	106	106
IV)ARRIVAL OF III)	-2	-11	-11	2	86	97	96	82
V)BALLAST DEPARTURE	1	-6,8	3,5	5,7	99	110	97	98
VI)BALLAST ARRIVAL	-1,5	-7,5	-2,8	7,4	97	105	98	90
VII)WORST CONDITION	-1,6	-11	-6,5	7,3	90	100	93,5	80

Speed/power analysis

Resistance Analisys

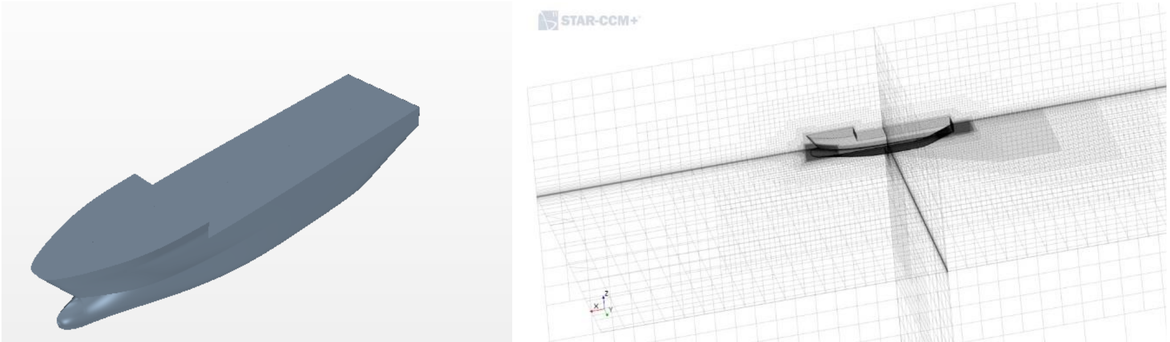
To determine the effective resistance of the hull, it was done a deep research of technical papers that talked about hull resistance studies for AHTS/OSV/PSV vessels. A big lack of information was found. The problem was that this type of vessel does not fit in the small tug series as the classic statistical series *van Oortmerssen*, neither in the series for big displacement vessels, as they are commonly used in the preliminary project stage. Knowing about problem, and its magnitude, as it will be a great deal to match vessel speed requirements, the design team proposed to conduct an analytic study with the use of Computational Fluid Dynamics "*CFD"*. And as there also was a requirement for energy efficiency, as in this stage a whole study of hull forms and it optimization will not be done, a precise estimation of the EHP is needed for a good preliminary propeller design, and critical for obtaining a high propeller performance, thus a high-energy efficiency. With the preliminary MaxSurf hull forms and the trim and heel calculation from the capacity plan, and the displacement obtained, the hull was set to a series of CFD simulations in several speeds.

CFD Configuration

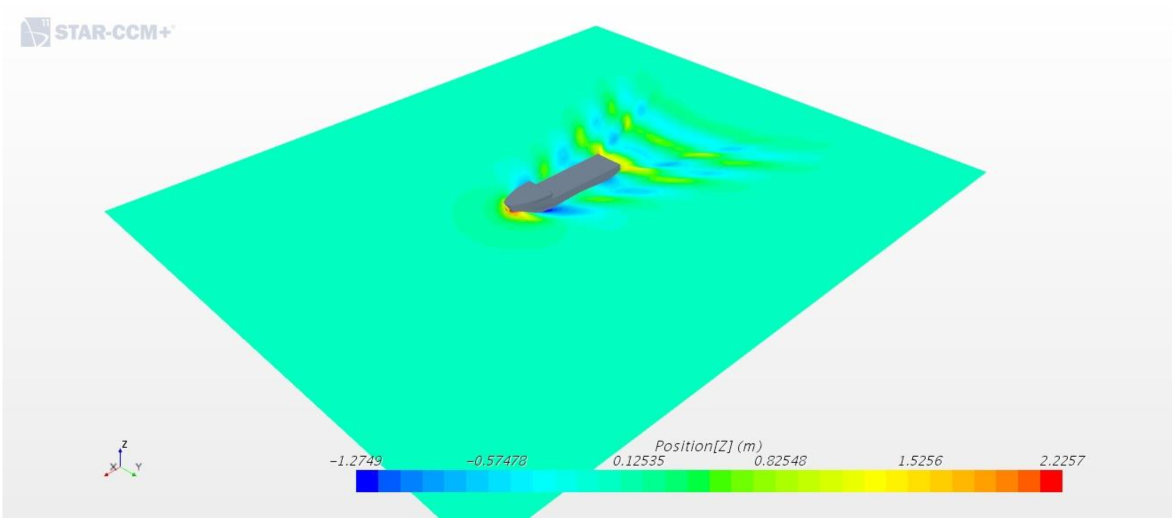
The simulation was set in the commercial code STAR-CCM+, as the design team has an Academic License for a partnership between UTN and SIEMENS. For computational time saving, half of the hull was modeled as is a best practice in CFD. A mesh of 3.5 million of cells was set. The type of CFD method used was Reynolds Average Navier Stokes (RANS). The turbulence model used was K-epsilon as is recommended for fair hull forms. The time step was set at 0,017 second to full fill with the Courant Number. A free surface as was solved by the Volume of Fluid method (VOF), setting as a coordinate the fill of the volume 0,5 to establish the free surface. The fluid was modeled as tourboulent near the hull. A refinement was set with a Prism Layer near the hull up to 0,07 meters from the hull in order to obtain a good caption of boundary layer effect (y+ Wall treatment applied). The Mesh was based in a prism layer mesher, a surfaces remesher and finally a trimmer. A Volume change of 0,0% was obtained giving a good confidence in the mesh structure and helping the simulation to obtain the convergence.

A set of refinements were made in the bow and the stern, and also in the supposed wake pattern. It is well known that there is a need for good density of mesh where the biggest water elevetions will be found avoid discrepancies in the Volume of Fluid interface.

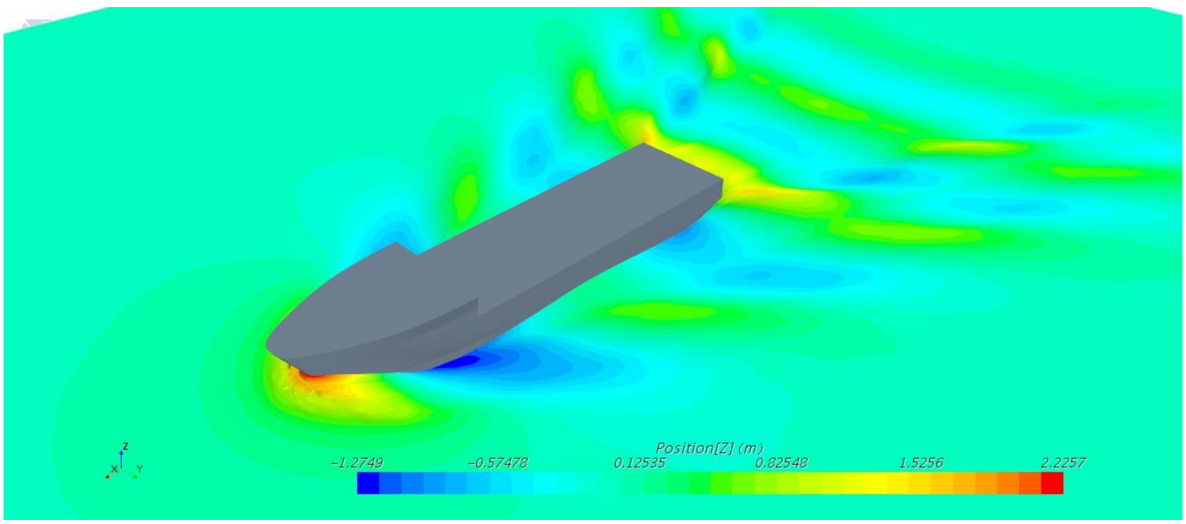
The simulation was run on a server with four XEON processors with 32 GB of RAM



Mesh configuration – 3.5 Million of cells



AHTS 100 – Sailing at 14 knots on the CFD domain



AHTS 100 – Sailing at 14 knots

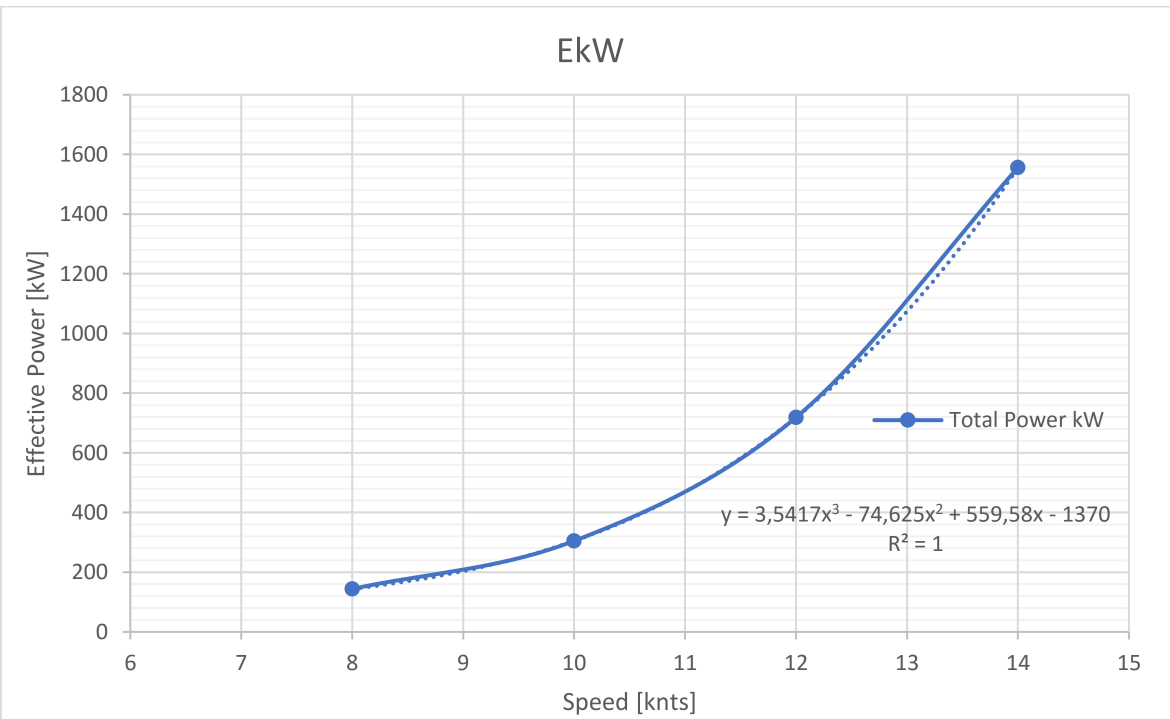
Resistance result

The simulation was set to run until the convergence of the result was obtained. The resistance values from the whole simulation were exported to EXCEL and the average results of the tail of the curve, obtaining a mean result, for each speed.

Speed [knts]	*Half resistance [N]*	*TOTAL EKW*
8	1.76E+05	144
10	2.97E+04	305
12	5.82E+05	719
14	1.08E+05	1556

Power/Speed curve

With the set of simulations above described the curve was plotted. A trendline of third order was created with minimum quadratic error. The team concluded that the equation of the polynomial function is suitable for use, for example in the speed prediction for each propeller P/D.

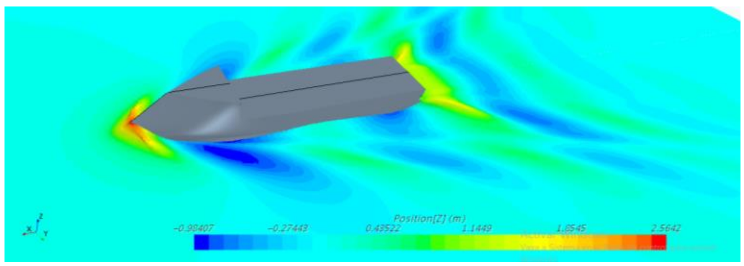


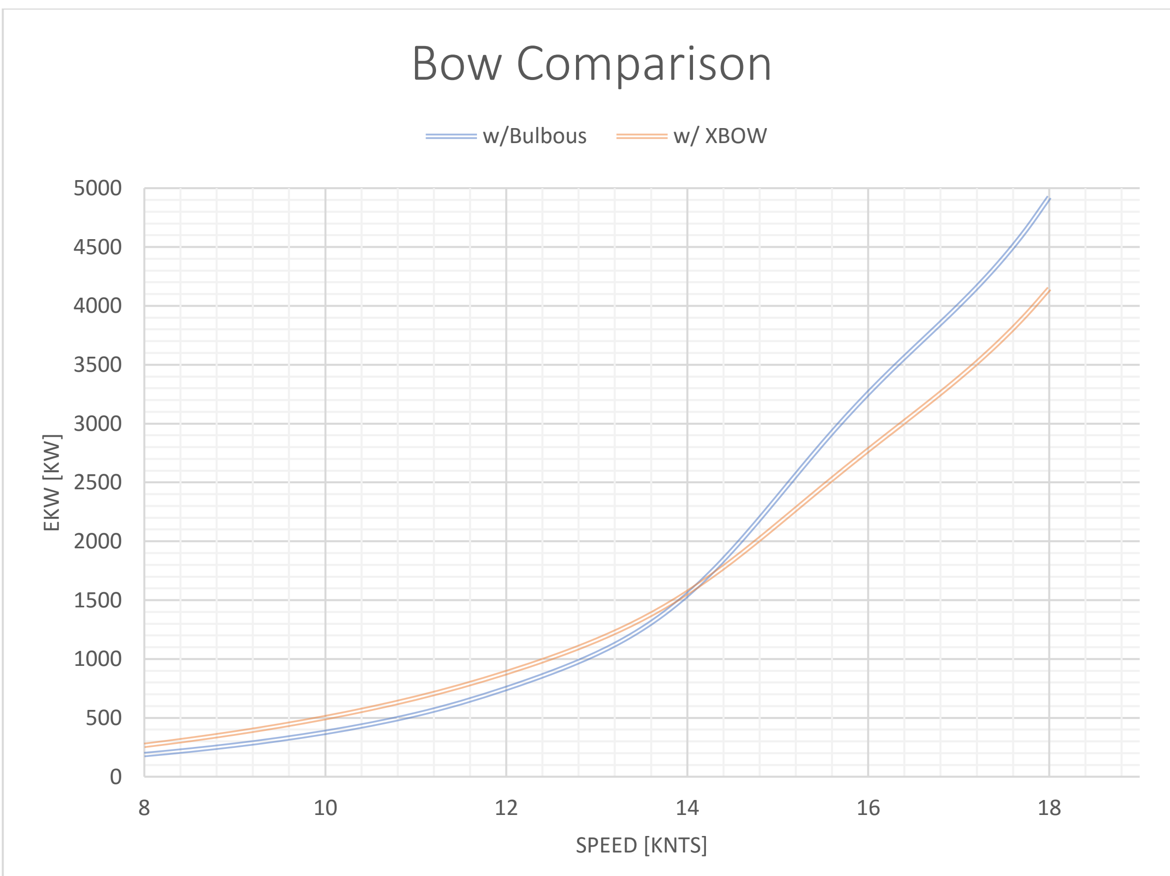
Obtaining that for the speed required 14 knots an amount of 1556 EKW of effective power is required.

Bulbous Bow vs. X-Bow discussion

An analysis is done between bulbous bow and X-bow. A similar hull is modeled with the same displacement and position of LCB. The analysis is validated by CFD use.

On the right the Bulbous bow hull, and on the left the X-Bow Hull.





From the result the team concluded that for speeds below 14 knts a bulbous bow is desired. Henceforth, an X-Bow for this length and Fn is not desired, as it will have a benefit effect just in speeds over the service speed. A bigger benefit will be obtained using a Bulbous bow for all range of speeds. In a future stage, should be analyzed the benefit of seakeeping and motion of the vessel in sea state.

Propeller Selection

Discussion of type of propeller

The series to be used must be selected, and once the series has been obtained, the Ae / Ao necessary to satisfy the cavitation requirements must be calculated. For the selection of the propeller will looked for the series that is estimated that will give a maximum performance in free waters. An estimated Bp value is calculated as:

$$Bp = \frac{\sqrt{DHP_0}\,N}{Sa^{2,5}}$$

$$Bp = \frac{\sqrt{BHP\eta_{rr}\eta_{mec}}\,N}{S(1-w)^{2,5}}$$

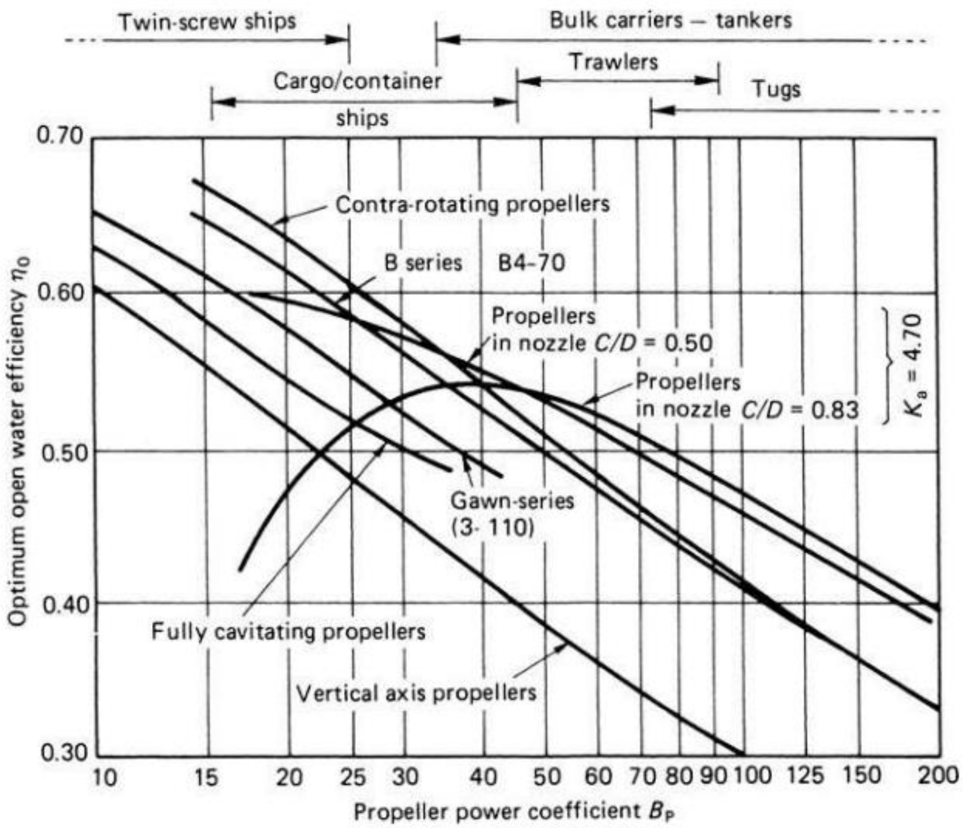
Where:

- BHP=7182 HP
- N= Estimated as 200 RPM
- S= 11knts
- Sa=Speed of advance= $Sa = S(1-w)$ = 7,7knts
- W= Wake coefficient determined by Taylor's expression

  $$w = 0,5Cb - 0,05$$

  $$w = 0,5x0,7 - 0,05$$
- $w = 0,3$
- η_{rr} = Relative rotative performance: limit value between 0.95 and 1.05 It is estimated 1
- η_{mec} = Being a vessel with reducer box is estimated 0.96

$$Bp = \frac{\sqrt{\frac{(7182x1x0,96)}{2}}\,200RPM}{11knts(1-0,3)^{2,5}} = 71$$



In the graph it is observed that for a Bp of 71 the maximum performance is in the propeller with nozzle, and good for series K_a 4.70

<u>Selection of Ae / Ao</u>

To select the correct propeller series for the project, it must be verified at its Ae / Ao ratio influencing the cavitation. The cavitation study will be taken for the service-free speed. Increased 0,1 of Ae / Ao according to cover cavitation in the position of towing.

$$\frac{Ae}{Ao} = \frac{(1{,}3 + 0{,}3Z)T}{(Po - Pv)D^2} + k$$

Where :

Z= Number of blades, estimated number of blades. (It will be sought not to be multiple of number of cylinders, to avoid torsional vibrations)

T= Thrust produced by the propeller in maximum speed condition (14 knots), divided 2 by being double-line axis.

$$T = \frac{Rt}{(1-t)} = \frac{277108N}{2} = 138554\,N$$

t= Thrust deduction coefficient: Estimated as 0.5W according to Taylor or according to Holtrop's expression

$$t = 0.325CB - 0.18885D/\sqrt{(BT)} = 0{,}17$$

- Rtb is the towing resistance obtained from the calculation carried out by Holtrop at 14 knots of Rt= 231KN
- K = vessel shape value, between 0.2 and 0.1, it is estimated 0.1
- Po = Hydrostatic pressure up to shaft line
- Pv = Estimated vapor pressure at sea of 17000 pascals
- D = Propeller diameter, estimated from an arrangement of 2.58 m
- H = Depth to axis line = 4.26 m

$$Po = P_{atm} + \rho gh = 143115{,}6Pa$$

$$\frac{Ae}{Ao} = \left(\frac{(1{,}3 + 0{,}3x4)138554N}{(125115{,}6Pa)2{,}58m^2} + 0{,}2 \right) x1{,}2 = 0{,}64$$

Added 20% for towing condition as recommended in Gozan's work, an Ae / Ao of 0.69 is obtained.

Dimensioning of the propeller from hull resistance.

Calculation procedure

The optimum propeller is calculated for the given conditions. This is done by automating the selection using the EXCEL program and solved by SOLVER and automated using MACROS. In which the tests of free waters of the selected series are loaded, by polynomials of sixth grade.

The coefficients for the selected series are obtained from the bibliography "Marine Propulsion and Propellers" Carlton.

Thrust coefficient

$$Kt = \frac{T}{\rho n^2 D^4}$$

Torque coefficient

$$Kq = \frac{Q}{\rho n^2 D^5}$$

Advance coefficient

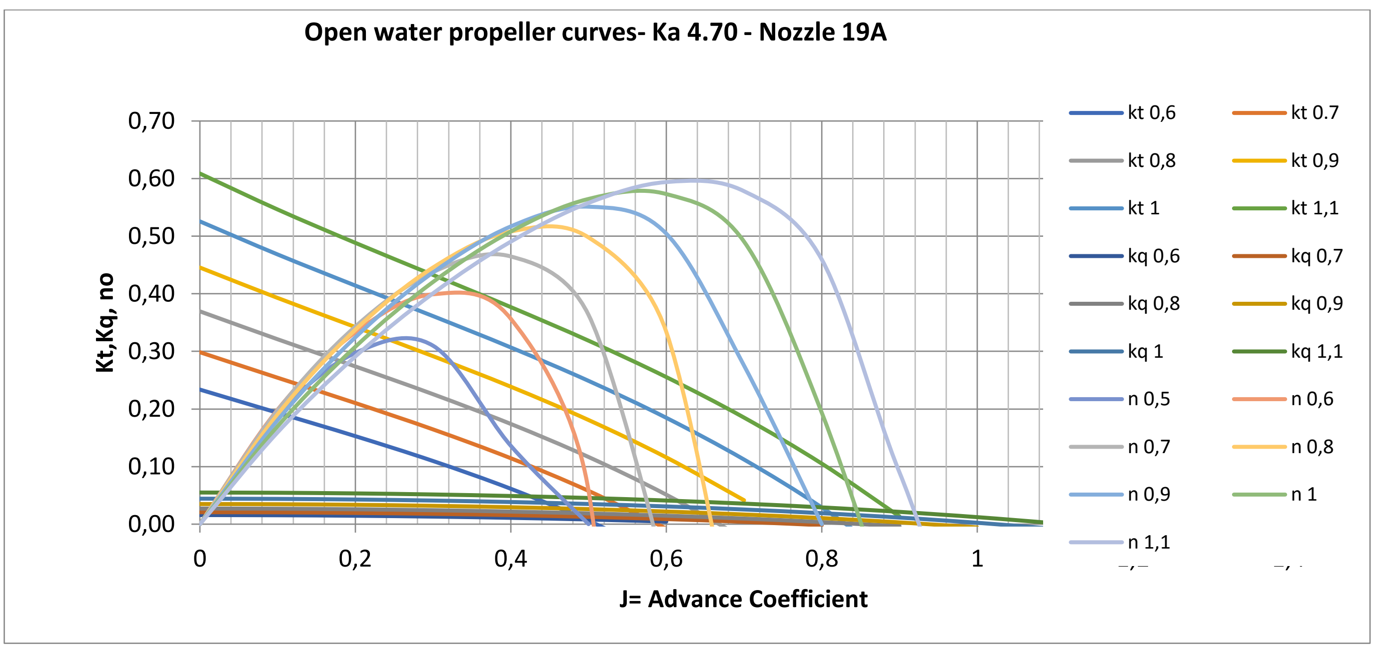
$$J = \frac{S_a}{nD}$$

$$Kt = A_{0,0} + A_{0,1}J + A_{0,6}J^6 + A_{1,0}\left(\frac{P}{D}\right) + A_{1,1}\left(\frac{P}{D}\right)J + ... +$$

$$A_{1,6}\left(\frac{P}{D}\right)^2 J^6 + A_{2,0}\left(\frac{P}{D}\right)^2 + A_{2,1}\left(\frac{P}{D}\right)^2 J + A_{2,6}\left(\frac{P}{D}\right)^2 J^6$$

$$K_Q = B_{0,0} + B_{0,1}J + B_{0,6}J^6 + B_{1,0}\left(\frac{P}{D}\right) + B_{1,1}\left(\frac{P}{D}\right)J + ... +$$

$$B_{1,6}\left(\frac{P}{D}\right)^2 J^6 + B_{2,0}\left(\frac{P}{D}\right)^2 + B_{2,1}\left(\frac{P}{D}\right)^2 J + B_{2,6}\left(\frac{P}{D}\right)^2 J^6$$



Nozzle No. 19A

	x	*y*	*Axy*	*Bxy*	*Cxy*
0	0	0	+0.030550	+0.076594	+0.006735
1		1	−0.148687	+0.075223	
2		2		−0.061881	−0.016306
3		3	−0.391137	−0.138094	
4		4			−0.007244
5		5		−0.370620	
6		6		+0.323447	
7	1	0		−0.271337	
8		1	−0.432612	−0.687921	
9		2		+0.225189	−0.024012
10		3			
11		4			
12		5			
13		6		−0.081101	
14	2	0	+0.667657	+0.666028	
15		1			
16		2	+0.285076	+0.734285	+0.005193
17		3			
18		4			
19		5			
20		6			
21	3	0	−0.172529	−0.202467	+0.046605
22		1			
23		2		−0.542490	
24		3			
25		4			
26		5			
27		6		−0.016149	
28	4	0			−0.007366
29		1			
30		2			
31		3		+0.099819	
32		4			
33		5			
34		6			
35	5	0			
36		1		+0.030084	
37		2			
38		3			
39		4			
40		5			
41		6			
42	6	0			−0.001730
43		1	−0.017283		−0.000337
44		2		−0.001876	+0.000861
45		3			
46		4			
47		5			
48		6			
49	0	7			

Solving the proposed polynomial yields the characteristic curves for the selected series.

P/D	***0,5***	***0,6***	***0,7***	***0,8***	***0,9***	***1***	***1,1***	***1,2***	***1,3***	***1,4***	***J***
	0,18	0,23	0,30	0,37	0,45	0,53	0,61	0,69	0,78	0,87	**0,0**
	0,14	0,19	0,25	0,32	0,39	0,47	0,55	0,63	0,70	0,78	**0,1**
	0,10	0,15	0,21	0,27	0,34	0,41	0,49	0,56	0,64	0,71	**0,2**
	0,06	0,11	0,16	0,23	0,29	0,36	0,43	0,50	0,57	0,64	**0,3**
	0,02	0,06	0,11	0,17	0,24	0,31	0,38	0,45	0,51	0,58	**0,4**
		0,01	0,06	0,12	0,18	0,25	0,32	0,39	0,45	0,51	**0,5**
		0,06	0,01	0,05	0,12	0,18	0,26	0,33	0,39	0,45	**0,6**
Kt				0,02	0,04	0,11	0,19	0,26	0,33	0,39	**0,7**
						0,03	0,11	0,18	0,25	0,32	**0,8**
						0,07	0,01	0,09	0,17	0,24	**0,9**
								0,01	0,08	0,15	**1**
										0,05	**1,1**
										0,07	**1,2**
											1,3

P/D	***0,5***	***0,6***	***0,7***	***0,8***	***0,9***	***1***	***1,1***	***1,2***	***1,3***	***1,4***	***J***
	0,01	0,02	0,02	0,03	0,03	0,04	0,05	0,07	0,08	0,09	**0,0**
	0,01	0,02	0,02	0,03	0,03	0,04	0,05	0,07	0,08	0,09	**0,1**
	0,01	0,01	0,02	0,03	0,03	0,04	0,05	0,07	0,08	0,09	**0,2**
	0,01	0,01	0,02	0,02	0,03	0,04	0,05	0,06	0,08	0,09	**0,3**
	0,01	0,01	0,02	0,02	0,03	0,04	0,05	0,06	0,07	0,09	**0,4**
	0,00	0,01	0,01	0,02	0,03	0,04	0,05	0,06	0,07	0,08	**0,5**
	0,00	0,00	0,01	0,01	0,02	0,03	0,04	0,05	0,07	0,08	**0,6**
Kq			0,00	0,01	0,02	0,03	0,04	0,05	0,06	0,07	**0,7**
			0,00	0,00	0,01	0,02	0,03	0,04	0,05	0,07	**0,8**
				0,00	0,00	0,01	0,02	0,03	0,05	0,06	**0,9**
					0,01	0,00	0,01	0,02	0,04	0,05	**1**
						0,01	0,00	0,01	0,03	0,04	**1,1**
							0,01	0,00	0,01	0,03	**1,2**
							0,03	0,01	0,00	0,01	**1,3**

P/D	0,5	0,6	0,7	0,8	0,9	1	1,1	1,2	1,3	J
	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	**0,0**
	0,19	0,20	0,20	0,19	0,18	0,17	0,16	0,15	0,14	**0,1**
	0,30	0,33	0,34	0,34	0,32	0,31	0,29	0,27	0,26	**0,2**
	0,31	0,40	0,44	0,45	0,44	0,42	0,40	0,38	0,36	**0,3**
	0,14	0,36	0,46	0,51	0,52	0,51	0,49	0,47	0,45	**0,4**
	0,00	0,06	0,36	0,50	0,55	0,56	0,56	0,54	0,52	**0,5**
no		1,27	0,08	0,33	0,50	0,57	0,59	0,59	0,57	**0,6**
				0,29	0,28	0,49	0,58	0,61	0,61	**0,7**
					0,00	0,19	0,46	0,57	0,60	**0,8**
						0,20	0,09	0,41	0,53	**0,9**
							0,20	0,20	0,20	**1,0**
							0,00	0,00	0,00	**1,1**
							0,00	0,00	0,00	**1,2**
										1,3

The obtained values for J are evaluated in the corresponding functions.

The maximum value of performance obtained is selected, from which the optimum propellant will be derived from this value, for the evaluated condition and its characteristics.

The optimum propeller is designed from four points of view as there is a big lack of contrains.

- K_{tD}: The thrust coeficient is obtained from a known diameter, in this case from the maximum diameter permited in the General Arragement. It is well known that the bigger the diameter the higher the performance of the propeller.
- K_{tN}:The Thrust coefficient is obteinted from the known RPM from the ones obteined form K_{tD} and by the selection of a commerciable reduction gear ratio. The RPM are adjusted to those that delivered by the gear box.
- K_{qD}: The torque coefficient is obtainted from a known diameter.
- K_{qN}:The torque coefficient is obtainted from the known RPM known from the ones obtained from K_{tD} and the gear box selection.

$$Kt_D = \frac{Kt}{J^2} = \frac{EHP_{serv}}{V^3(1-t)(1-w)^2 \rho D^2}$$

$$Kt_N = \frac{Kt}{J^4} = \frac{EHP_{serv} N^2}{V^5(1-t)(1-w)^4 \rho}$$

$$Kq_D = \frac{Kq}{J^3} = \frac{DHP_o}{2\pi\rho D^2 V^3 (1-w)^3}$$

$$K_{QN} = \frac{K_Q}{J^5} = \frac{DHP_o N^2}{2\pi\rho V_a^{\,5}}$$

By using any of them and multipling by the corresponding J^{power}, the optimum curve of propeller correspondant coefficient J is plotted for the given diameter/RPM and delivered torque/thrust. The intersection of those curve are found by doing equal both expressions of the curves (for example kq and kqD), this is done by founding the root of a sixth-degree polynomial. It is performed by using the SOLVER tool, where is assigned to find the J that gives a null difference between the curve and the propeller curve, the whole EXCEL is automated by MACRO tool

Intesection =

$$Kq = f(J)$$

$$KqD = g(J)$$

$$Kq - KqD = 0$$

In this way the values of J are obtained where both curves intersect, and those point are the optimum propeller for given J coefficient.

Below are the EXCEL results.

INPUT DATA

Propeller diameter estimated [m]	2,9
EKW CFD@14knots per shaft w/Sea Margin	1037
No. Of shafts	2
Depth of shaft [m]	3,474
Sea water vapor pressure [Pa]	17000
Service speed [knts]	14
Service speed [m/s]	7,2016
Block coefficient	0,736
Number of blades	4
Wake coefficient	0,318
Thrust deduction coefficient	0,159
No. Of engines	2
Maker: MAK	6M32C
BKW	3000
RPM @ NCR	600
Reduction ratio	3,16
RPM propeller	190
Max. Torque [N-m]	137119
Mechanical performance	0,96
Relative rotative performance	0,95
Density of service water	1025
Sea Margin+Appendage	25%
Derating	10%
Hull performance	1,10

OUTPUT DATA

Speed of advance [m/s]	4,91
Ae/Ao for cavitation limit	0,53
KqDiameter known	0,38
KqN Rev known	1,38
KtDiameter known	0,82
KtN RPM known	2,16

Propeller selection

From	KqD	KqN	KtD	KtN	Optimum Propeller
Diameter	2,9	2,9	2,9	2,9	**2,9**
Pitch/Diameter	1,2	1,2	1,2	1,2	**1,2**
Open water efficiency	0,56	0,51	0,60	0,60	**0,60**
N [rpm]	193	193	165	165	**165**
Bollard Pull	100	98	100	100	**100**

Propeller selection using KqD

J	KqD*J3	J´	Kq-KqD	P/D
0,1	0,00	0,25	4,4E-03	0,5
0,2	0,00	0,32	9,5E-11	0,6
0,4	0,02	0,35	3,5E-11	0,7
0,5	0,05	0,39	7,6E-11	0,8
0,6	0,08	0,42	7,4E-12	0,9
0,7	0,13	0,46	7,0E-11	1
0,8	0,20	0,49	1,5E-11	1,1
0,9	0,28	0,53	2,6E-11	1,2
1,1	0,51	0,56	1,2E-11	1,3
1,2	0,66	0,59	1,3E-11	1,4

Diameter	2,90
Pitch/Diameter	1,20
Open water propeller efficiency	0,56
N [rpm]	193
J	0,53
Ae/Ao	0,70
Bollard Pull [Tn]	100

P/D	J´	Kt	Kq	no	N[rpm]	T [N]	Q [N-m]	DKW	BkW	RPM@BP	BP[N]	Q@BP	BkW@BP
0,5	0,25	0,08	0,01	0,319	406	275901	99922	4253	4430	441	127701	137119	2989
0,6	0,32	0,10	0,01	0,402	316	201360	74320	2462	2565	386	169622	137119	2989
0,7	0,35	0,14	0,02	0,463	288	232024	81610	2462	2565	336	216728	137119	2989
0,8	0,39	0,18	0,02	0,503	263	252239	89437	2462	2565	294	268268	137119	2989
0,9	0,42	0,23	0,03	0,529	241	265203	97546	2462	2565	259	323490	137119	2989
1	0,46	0,27	0,04	0,545	222	273183	105745	2462	2565	230	381642	137119	2989
1,1	0,49	0,32	0,05	0,554	206	277519	113884	2462	2565	207	441974	137119	2989
1,2	0,53	0,37	0,06	0,556	193	278818	121843	2462	2565	187	490903	137119	2989
1,3	0,56	0,42	0,07	0,553	182	277135	129515	2462	2565	172	462422	137119	2989
1,4	0,59	0,46	0,08	0,543	172	272088	136801	2462	2565	159	438753	137119	2989

Propeller selection using KtD

J	KtD*J2	J´	Kt-KtD	P/D
0,1	0,01	0,29	-6,7E-12	0,5
0,2	0,03	0,34	-1,1E-11	0,6
0,4	0,13	0,39	-1,6E-11	0,7
0,5	0,21	0,43	-2,2E-11	0,8
0,6	0,30	0,48	-3E-11	0,9
0,7	0,40	0,53	-3,8E-11	1
0,8	0,53	0,57	-4,5E-11	1,1
0,9	0,67	0,62	-5E-11	1,2
1,1	1,00	0,66	-5,2E-11	1,3
1,2	1,19	0,69	-4,7E-11	1,4

Diameter	2,90
Pitch/Diameter	1,20
Open water propeller efficiency	0,60
N [rpm]	165
J	0,62
Ae/Ao	0,70
Bollard Pull [Tn]	100

P/D	J´	Kt	Kq	no	N[rpm]	T [N]	Q [N-m]	DKW	BkW	RPM@BP	BP[N]	Q@BP	BkW@BP
0,5	0,3	0,1	0,0	0,316	354	171275	71843	2665	2776	441	127701	137119	2989
0,6	0,3	0,1	0,0	0,400	302	171275	66346	2101	2189	386	169622	137119	2989
0,7	0,4	0,1	0,0	0,467	264	171275	65251	1803	1878	336	216728	137119	2989
0,8	0,4	0,2	0,0	0,515	234	171275	66603	1633	1701	294	268268	137119	2989
0,9	0,5	0,2	0,0	0,550	211	171275	69363	1531	1594	259	323490	137119	2989
1	0,5	0,2	0,0	0,573	192	171275	72974	1467	1528	230	381642	137119	2989
1,1	0,6	0,3	0,0	0,589	177	171275	77171	1429	1489	207	441974	137119	2989
1,2	0,6	0,3	0,1	0,596	165	171275	81899	1411	1470	187	490903	137119	2989
1,3	0,7	0,4	0,1	0,595	155	171275	87286	1415	1473	172	462422	137119	2989
1,4	0,7	0,4	0,1	0,583	147	171275	93656	1443	1504	159	438753	137119	2989

Propeller selection using KqN

J	KqN*J5	J´	Kq-KqD	P/D
0,1	0,00	0,36	8,1E-11	0,5
0,2	0,00	0,38	2,9E-11	0,6
0,4	0,01	0,41	2,5E-11	0,7
0,5	0,04	0,43	3,4E-11	0,8
0,6	0,11	0,46	1,3E-11	0,9
0,7	0,23	0,48	3,1E-11	1
0,8	0,45	0,50	8,8E-11	1,1
0,9	0,82	0,53	2,0E-11	1,2
1,1	2,23	0,55	2,3E-11	1,3
1,2	3,44	0,57	7,6E-11	1,4

Diameter	2,90
Pitch/Diame	1,20
Open water propeller efficiency	0,51
Diameter	2,90
J	0,53
Ae/Ao	0,70
Bollard Pull [Tn]	98

P/D	J´	Kt	Kq	no	N[rpm]	T [N]	Q [N-m]	DKW	BkW	RPM@BP	BP[N]	Q@BP	BkW@BP
0,50	0,36	0,04	0,01	0,17	4,23	115902	168285	3401	3543	441	580583	137119	6943
0,60	0,38	0,07	0,02	0,27	3,99	182176	161879	3272	3408	386	606933	137119	6076
0,70	0,41	0,11	0,02	0,35	3,75	224690	155172	3136	3267	336	606318	137119	5296
0,80	0,43	0,16	0,03	0,41	3,53	249949	148822	3008	3133	294	591152	137119	4632
0,90	0,46	0,21	0,03	0,45	3,34	263824	143055	2891	3012	259	569691	137119	4080
1,00	0,48	0,26	0,04	0,48	3,17	270334	137906	2787	2903	230	546577	137119	3627
1,10	0,50	0,32	0,05	0,50	3,03	271909	133360	2695	2807	207	524201	137119	3256
1,20	0,53	0,37	0,06	0,51	2,90	269892	129419	2616	2724	187	490903	137119	2951
1,30	0,55	0,43	0,07	0,51	2,79	264914	126124	2549	2655	172	396723	137119	2702
1,40	0,57	0,47	0,08	0,51	2,70	257129	123556	2497	2601	159	328423	137119	2498

Propeller selection using KtN

J	KtN*J4	J´	Kt-KtN	P/D
0,1	0,0	0,4	8,3E-12	0,5
0,2	0,0	0,4	4,9E-11	0,6
0,4	0,1	0,4	-1,3E-11	0,7
0,5	0,1	0,5	-4,3E-11	0,8
0,6	0,3	0,5	9,9E-12	0,9
0,7	0,5	0,6	2,3E-11	1
0,8	0,9	0,6	4,5E-11	1,1
0,9	1,4	0,6	7,6E-11	1,2
1,1	3,2	0,6	-1,3E-11	1,3
1,2	4,5	0,7	-1,7E-11	1,4

Diameter	2,90
Pitch/Diamete	1,20
Open water propeller efficiency	0,60
Diameter	2,90
J	0,59
Ae/Ao	0,70
Bollard Pull [Tn]	100

P/D	J´	Kt	Kq	no	N[rpm]	T [N]	Q [N-m]	DKW	BkW	RPM@BP	BP[N]	Q@BP	BkW@BP
0,50	0,36	0,04	0,01	0,242	4,99	171275	201788	6955	7245	441	1118025	137119	6943
0,60	0,41	0,06	0,01	0,349	4,41	171275	139928	4823	5024	386	910764	137119	6076
0,70	0,45	0,09	0,01	0,438	3,99	171275	111382	3839	3999	336	776044	137119	5296
0,80	0,49	0,12	0,02	0,504	3,66	171275	96801	3336	3475	294	683014	137119	4632
0,90	0,53	0,16	0,03	0,549	3,41	171275	88879	3063	3191	259	615982	137119	4080
1,00	0,56	0,21	0,03	0,577	3,20	171275	84542	2914	3035	230	566519	137119	3627
1,10	0,59	0,26	0,04	0,592	3,03	171275	82416	2841	2959	207	529950	137119	3256
1,20	0,62	0,31	0,05	0,596	2,90	171275	81899	2823	2940	187	490903	137119	2951
1,30	0,64	0,37	0,06	0,590	2,79	171275	82798	2854	2973	172	397516	137119	2702
1,40	0,66	0,41	0,08	0,573	2,71	171275	85204	2937	3059	159	334202	137119	2498

Optimum propeller selection

From the propeller selection process the optimum Kaplan 4.70 with nozell 19A was obtained.

	OPTIMUM PROPELLER
DIAMETER	**2,9**
PITCH/DIAMETER	**1,2**
OPEN WATER PROPELLER EFFICIENCY	**0,60**
N [RPM]	**165**
BOLLARD PULL [MT]	**100**
SERIES	**Ka 4.70 +19A**

Main engine selection

The optimum RPMs to which the selected propeller will rotate, the assumed torque, and the power to be delivered was obtained. The design team proceeded to the selection of the main engines (double axis line)

Engine selected: MAK MARINE ENGINES

A 4-stroke engine is selected. (Reduced machinery space, and well-known reliability with MDO)

- 6000 kW total power (3000 kW per engine)
- It will work with a 6M32C engine that develops at 3000KW @ 600 RPM
- A reduction ZF W93300 NC2: Reduction ratio selected= 3,19

The design team proceeded to size the propeller from the known motor parameters according to their statistical power.

Number of engines	**2**
Type	MAK 6M32C
BKW	3000
RPM @ NCR	600
Reduction gear	ZF W93300 NC2/ Ratio 3,16:1
RPM propeller	190

Bollard Pull verification

The assessment of the propeller for reach the bollard pull requirement is estimated as follow, the thrust coefficient and torque coefficient are obtained for J zero, as in bollard pull condition:

$$DHP_o = 2\pi N Q_o$$
$$Q_o = \frac{DHP_o}{2\pi \frac{190RPM}{60s}}$$
$$Q_o = 137119N - m$$
$$Q_o = K_q \rho N^2 D^5$$
$$N = \sqrt{\frac{DHP_o}{2\pi N K_q \rho D^5}}$$
$$N = 187,4RPM$$
$$BP_{shaft} = K_t \rho N^2 D^4 => 490,903kN$$
$$BP = BP_{shaft} x 2 = 100 Tn$$

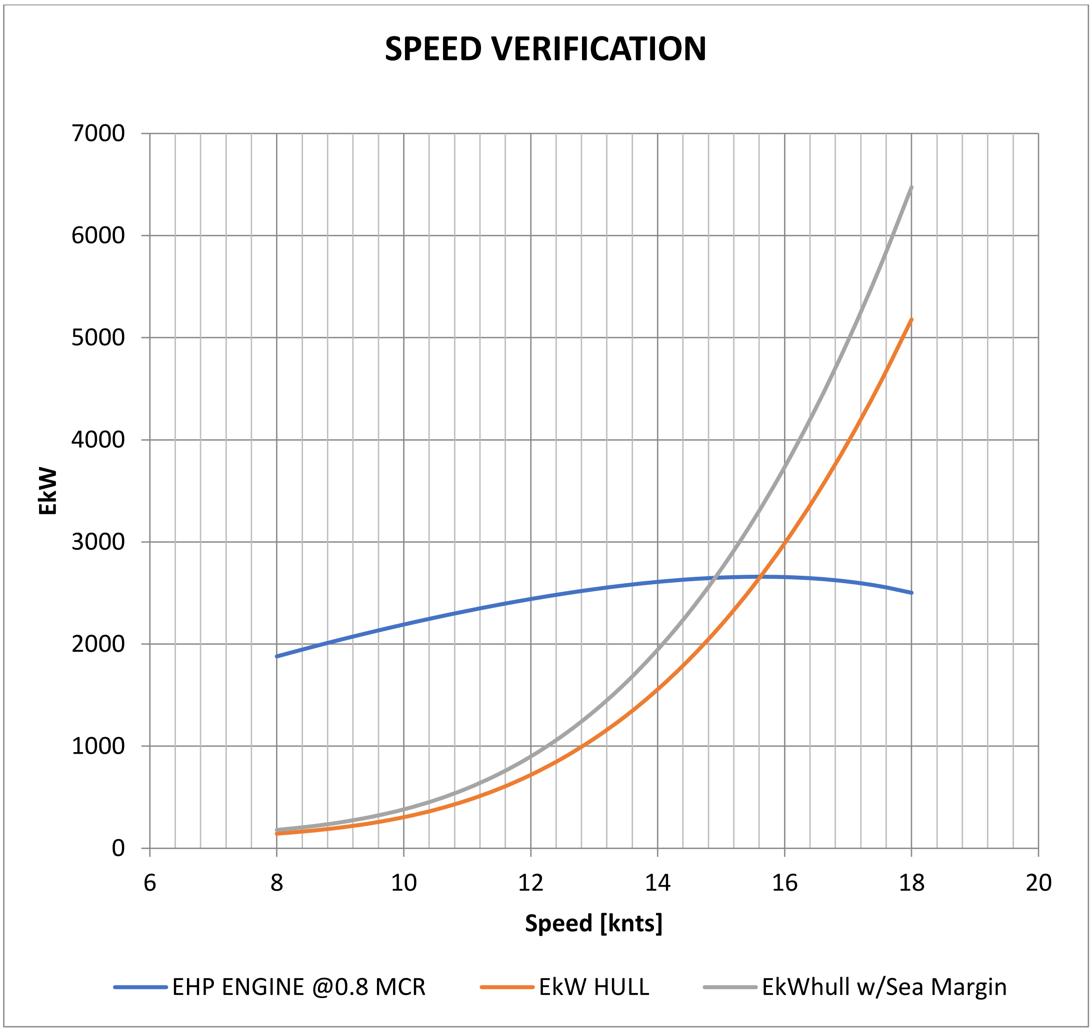
Although the RPM for bollard pull are by little percentage below the max RPM, this is not translated as an overdemand of the engine as in less than 2 % of RPM decrease. Bollard Pull for the designed propeller at NCR is 100 Tn, accomplishing the required Bollard Pull. Also, the maximum toque delivered Qo, was obtained with a derate of the engine of 10%.

Speed verification

The speed requirement is of 14 knts in trial condition and at 80% of MCR. For this verification is found a point where the power required by the hull for that speed(EkW) is equal to the power delivered by the engine and the efficiency factors with the deraeting percentage of engines MCR.

$$BkW = \frac{EkW}{\eta_h x \eta_o x \eta_{mec} x \eta_{rr} x \%MCR}$$

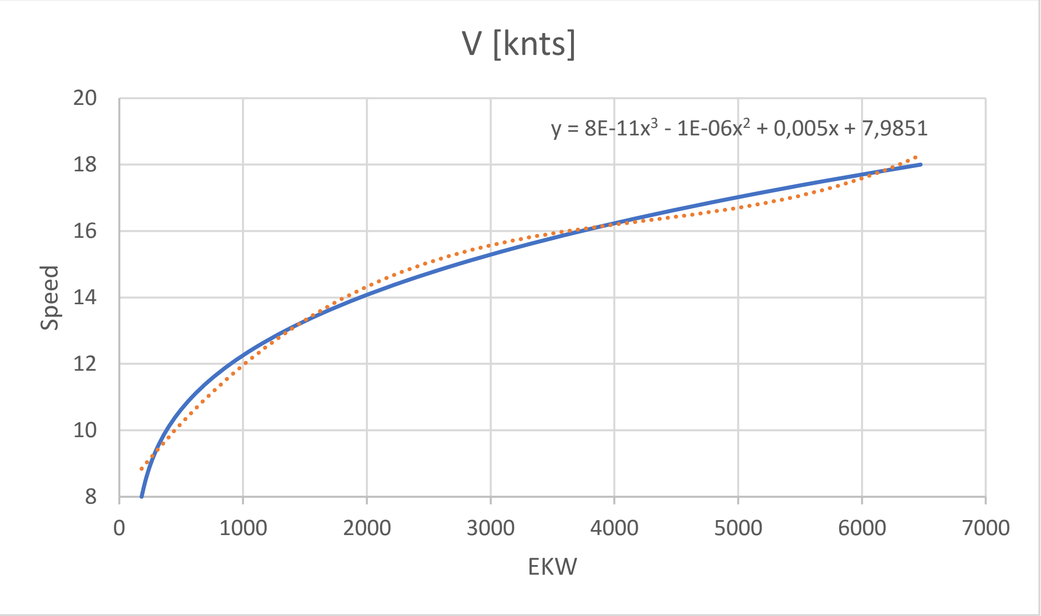
V [knts]	*J*	*no*	*EHP ENGINE @0.8 MCR*	*EkW HULL*	*EkWhull w/Sea Margin*
8	0,35	0,429	1879	144	180
9	0,40	0,467	2043	203	254
10	0,44	0,501	2192	305	381
11	0,49	0,531	2325	470	587
12	0,53	0,558	2441	719	899
13	0,57	0,580	2537	1074	1343
14	0,62	0,596	2609	1556	1945
15	0,66	0,606	2651	2186	2733
16	0,71	0,607	2656	2986	3733
17	0,75	0,597	2612	3977	4971
18	0,79	0,572	2502	5179	6474



Speed requirement	*Speed*
Trial condition	15.6 knts,
Sea margin of 25%	14.8 knts

Speed calculation for each P/D for the CCP

For the determination of sailing speed in function of the P/D at constant RPM, the thrust per shaft was obtained for each P/D and consequently obtaining the Useful power by Thrust times Speed. For a given speed the useful power delivered by the propeller must be equal to the effective power required by the hull. Obtaining the function that governs the power required for a given speed, such Analisis is performed. As a CPP propeller is used the Thrust is decresead by a 5% due to the loss of efficieny because of the increace in the hub diameter.



P/D	J´	KT	KQ	THRUST [N] PER SHAFT	UKW	S[KNOTS]
0,8	0,62	0,04	0,01	21095	303	**8,86**
0,9	0,62	0,10	0,02	56520	814	**10,89**
1	0,62	0,17	0,03	94172	1356	**12,58**
1,1	0,62	0,24	0,04	132883	1913	**13,90**
1,2	0,62	0,31	0,05	171274	2466	**14,89**
1,3	0,62	0,38	0,06	207713	2991	**15,59**
1,4	0,62	0,44	0,08	240264	3460	**16,08**

Endurance Calculation

An autonomy assessment is carried out in order to support the owner's requirement, 4000 mn, or it should be modified due to vessel's activities. The following is regarded:

- The distance from *Punta Quilla* Port to the operation area is 160 mn.
- The distance from *Puerto Deseado* Port to the operation area is 300 mn.
- The distance from *Operation area* to *Rio de Janeiro, Brazil* is 2500 mn.

Situations considered:

1. Once a week, the vessel arrives to Punta Quilla Port and once a month to Puerto Deseado Port (were bunker operations are carried out). It gives a total of 1880 mn only for own consumption. If the DP is activated because any regular activity or even because the weather, and considering the fuel supply to platforms, a fuel consumption equivalent to 1600 mn is estimated. Total autonomy estimated: 3500 mn.
2. At least every six month, the vessel arrives to Rio de Janeiro Port in order to tow the drilling units to the operation area, giving 2500 mn. Because of harsh environment conditions, fifteen days of placement of the drilling unit is estimated, and seven days of drilling works. Total autonomy estimated: 3700 mn.

Therefore, an autonomy of 4000mn will be considered.

From the aforementioned, the following will be considered in the project:

- The vessel will have lashing points in the exterior deck in order to transport spare parts,
- A restriction in LOA, maximum 70 m, is applicable due to the capability of the Ports,
- The propeller shall be above the base line because low depth in Ports zone and a huge difference between tides.

General

The following section describes the endurance calculation for the vessel in reference.

Calculation

The endurance calculation is based principally in the main engine specific fuel oil consumption, set from the engine product guide, at the rated power for a given range and service speed.

Fuel Oil Consumable

As stated in the first paragraph, it depends primarily on the following parameters

$$\mathrm{Wfo} = \left(\mathrm{g}.\frac{\mathrm{A}}{\mathrm{Ss}}.\mathrm{BHP}\right).1{,}1$$

- g: specific fuel oil consumption[g/kWh] of main engine, set form technical product guide; SFOC = 177 g/kW hs.
- A: range, set form owner requirements at 4000nm
- Ss: service peed of the vessel 14 kts (Nm/hs)
- BHP: obtained from main engine product guide: 3000 kW → 6M32C
- Relative density δ = 0,9443 Ton /m^3

$$Wfo = \left(177 \ * 6000 * \frac{4000}{14*1000}\right).1,1 = 303,42 \text{ Tons}$$

The vessel requires the following amount of fuel oil capacity:

$$V_{Fo} = \frac{W_{FO}}{\delta} = \frac{303,42}{0,84} = 361,21\, m^3$$

<u>Diesel Oil Consumable</u>

$$W_{DO} = 10\,\%\, W_{FO}$$

Estimated as 10% of the fuel oil calculated and is meant for use while maneuvering, and on port maneuvers. $\text{Wdo} = 10\%\ \text{Wfo} = 30,3\ \text{Ton}$

Relative density δ = 0,84 Ton /m^3

The vessel requires the following amount of diesel oil capacity:

$$V_{DO} = \frac{W_{DO}}{\delta} = \frac{30,3}{0,84} = 36,07\, m^3$$

<u>Lubricant Oil Consumable</u>

From literature is known the following relation for oil calculation: 2,5 BHP/1000 [Tn]

Relative density δ = 0,92 Ton /m^3

$$\text{Woil} = 19\text{tm}$$

The vessel requires the following amount of lube oil capacity:

$$V_{LO} = \frac{W_{LO}}{\delta} = \frac{19}{0,92} = 20,652\, m^3$$

It must be noted that, fuel oil consumable, diesel oil consumable and lubricant oil consumable depends in machinery systems and the vessels endurance depends in them.

Seakeeping analysis

The AHTS may offer stand-by service for offshore units. The vessel must offer conditions in which the crew can live with, and that even in harsh conditions, the accelerations and motions will not have a severe effect in the comfort of the crew. In this section of the document the seakeeping of the vessel in the worst sea conditions is to be evaluated.

- Wind velocity = 35 knts
- Significant Wave Height= 2.5m
- Current velocity= 2.0 knts
- Wave Period= 10 sec

To evaluate this condition the vessel is to be simulated in the MAXSURF – MOTIONS. A preliminary analysis is done with the STRIP METHOD, as no RAO from the vessel is obtained from any towing tank test of CFD simulations. For this method a mapped of 5th degree will be consider in order to map correctly the semi-tunnel at aft. The vessel loading condition analyzed is ballast condition at arrival with 10% of consumables and with not cargo- condition (V). That is supposed to be the worst condition to live with the periods of roll and big accelerations, as has one of the biggest GM and lowest displacement (dependent of coefficient C)

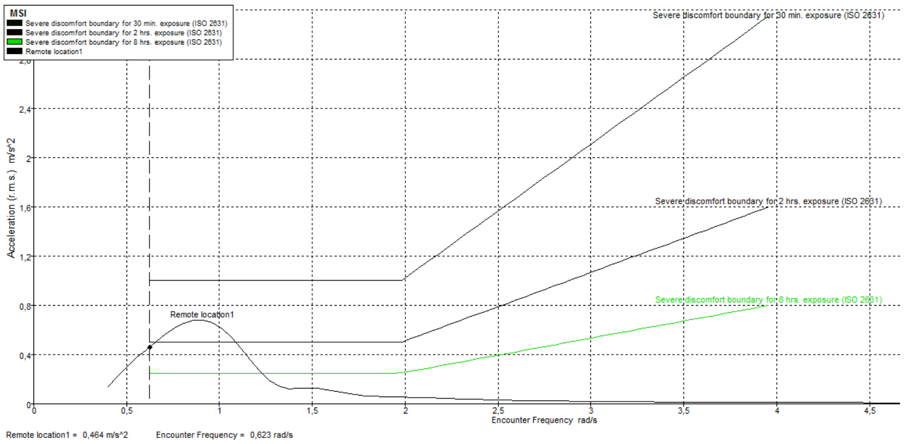
$$T = \frac{2xCxB}{\sqrt{GM}}\ (s)$$

The SPECTRA used is the Pierson Moskowitz, well known for having good results in simulating the south Argentina seas, and calculated for a 35 knts wind speed that has a output an average period of 10,16 seg and a characteristic wave height of 6,921 m, a wave higher than the proposed by the owner.

The MSI is calculated to know how much time the crew will be able to keep the heading against each course. From the analysis, a family of curves for each heading is obtained. Showing that at the intersection with each curve of severe discomfort boundary, a limit in time exposure will be stablished for such encounter frequency. A location at the wheelhouse is calculated for the analysis purpose. An analysis for headings against sea of 0°,45°,90°,135° and 180° degrees is carried out. The worst condition found is the one for head sea. In which there is a condition in which the discomfort is reached below the 2 hrs. of exposure. From the period (T) of 10 seconds, an angular frequency of:

$$\omega = \frac{2\pi}{T} = 0{,}628\ \frac{rad}{seg}$$

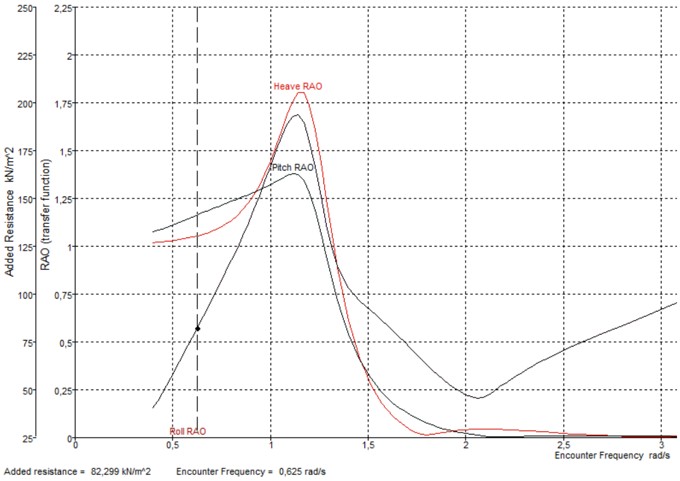
From the analysis a operator on the wheelhouse and sailing in the mentioned conditions, will have severe discomfort when sailing for head sea at more time than two hours. This was mentioned with sailors and was concluded that the vessel has a good sea motion characteristics. As it those conditions are suffered. The vessel can change course and establish less demanding and discomfortable situation.



For an encounter frequency of [0,7 – 1,2] the crew will suffer discomfort since 2 hrs. of exposure with head sea.

<u>Response Amplitude Operators – Added Resistance</u>

The MOTIONS software is able to output the added resistance. With a accuracy between 20-30% as stated in the manual, as the calculations are second order with respect to wave amplitude. The method of Salvesen is purported to be more accurate than those of Gerritsma and Beukelman for a wider range of hull shapes. That is why this design team decide to choose this method. The added resistance calculated is due only to the motion of the vessel in the waves. It does not account for speed loss due to wind; reduction of propeller efficiency or voluntary speed loss to reduce motions.



For period of 10 seconds= Added Resistance coefficient of 82,3 kN/m²

The added resistance is obtained automaticaly by integrating the added resistance spectral density funtion over the frecuency range.

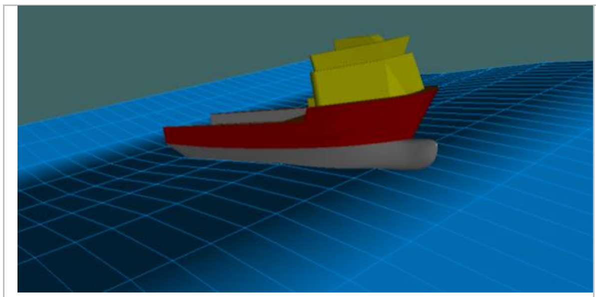
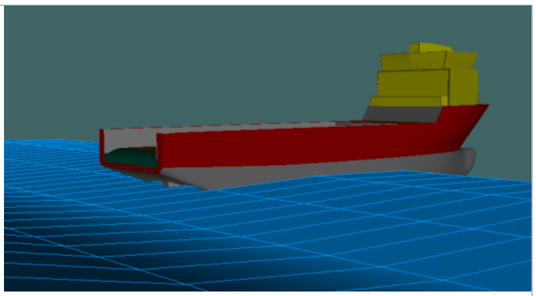
$$\overline{R_{aw}} = 2\int_0^\infty C_{aw} S_\varsigma(\omega_e)\, d\omega_e$$

Speed [knts]	*Half resistance [N]*	*TOTAL EKW*	*Added Resistance [kN]*	*EKw w/Sea*	*BHP [kW]*
8	1.76E+05	144	651	3058	5831
10	2.97E+04	305	648	3957	8383
12	5.82E+05	719	645	5119	10847
14	1.08E+05	1556	643	6720	14238

As a conclusion is noted that the vessel will only be able to sail in those conditions up to 8 knts. It include the air resistance with the data shown in the following section.

Motion of the vessel in the sea

With the use of the MOTIONS software, a simulation of the motions of the vessel in the sea is shown, and gives a idea of the dynamics that the vessel will encounter. The simulation was configured at the resonance frecuency of 1,057 rad/seg

	
Severe structural slamming is predicted. Big ventilation of Bow Thruster is expected	Regular propeller ventilation is estimated for the condition.- No water on deck detected

Station keeping performance

For the assessment of the station keeping performance of the vessel, the ABS *Guide for Dynamic Positioning Systems* will be followed in order to comply with the requiermenst for dynamic positioning.

DPS-2 *For vessels, which are fitted with a dynamic positioning system which is capable of automatically maintaining the position and heading of the vessel within a specified operating envelope under specified maximum environmental conditions during and following any single fault, excluding a loss of compartment or compartments.*

During the proyect the vessel and it equipment was designes with the redundancy concept required by the class notation DPS-2. The station keeping capability after a single fault is to be achieved by providing control, electric power and thrust. For the DPS-2 notation, a single fault includes: Any active component or system (generators, thrusters, switchboards, DP control computers, sensors, remote controlled valves, etc.)

The ABS guide is used to dimension the Thruster Capacity

Thruster Capacity

The thruster system is to provide adequate thrust in longitudinal and lateral directions and yawing moment for heading control.

- Vessel with DPS-2 or DPS-3 notation. The vessel is to have thrusters in number and of capacity sufficient to maintain position and heading, in the event of any single fault, under the specified maximum environmental conditions. This includes the failure of any one or more thrusters

From the equipment selection the thrust from the Bow Thruster and Stern Thurster is obtained.

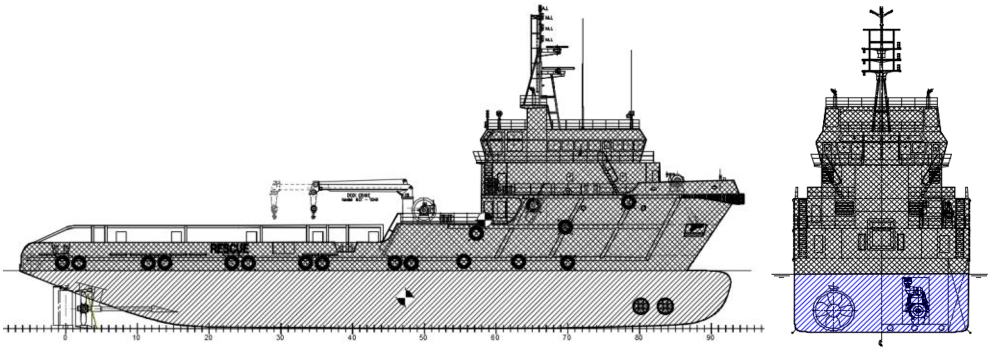
	Thrust [mT]
Bow Thruster	7,5
Stern Thruster	5
Each Propeller Thruster	50

Importance of DPS in the transfer of staff

Station Keeping equilibrium state

For the verification of station keeping the following situation is supposed:

	Direction
Wind velocity = 35 knts	From Starboard
Current velocity= 2.0 knts	From Starboard



From Autocad Software Areas are obtained.

	Long. Area [m^2]	*Trans. Area [m^2]*	*Longitudinal centroid [m]*	*Vertical Centroid [m]*
Windage	367 m^2	189	37,89	9,82
Underwater	288 m^2	77	30,69	2,78

For this preliminary analysis, the following procedure is done and only for the transversal scenario:

Y-axis is defines as transversal- Distance from force application measured from Fr.0

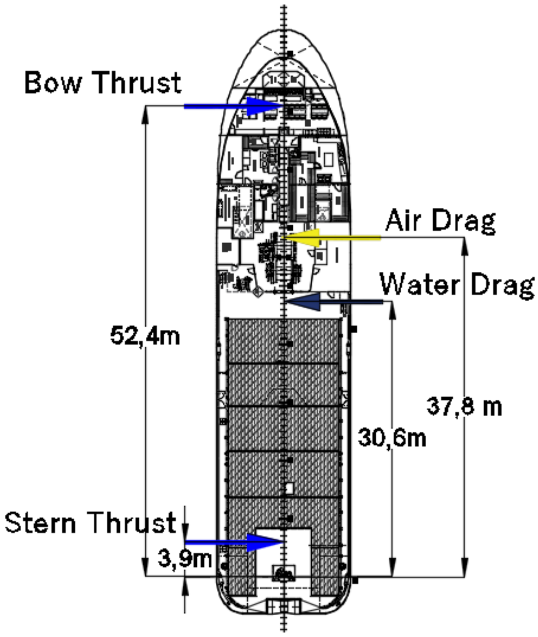
$$F_{yW} = C_y \frac{1}{2} \rho_{air} V_{air}{}^2 S_{trasW}$$

$$F_{yUW} = C_{uw} \frac{1}{2} \rho_w V_w{}^2 S_{trasUW}$$

- *Underwater:A C_{uw} of 0,42 is used as is only considered as a ellipse Shape- No wave-making as low Fn.*
- *Air:A Cy of 0,59 is supposed as Isherwood paper for Offshore Tug.*

	Long. Area [m^2]	*Force[mT]*	*Longitudinal centroid [m]*	*Vertical Moment[kN-m]*
Windage	367 m^2	4,29	37,89	1626,2
Underwater	288 m^2	6,56	30,69	2013,7
Total		**10,85**		**3639,9**

	Force[mT]	*Longitudinal position [m]*	*Vertical Moment[kN-m]*
Bow Thruster	7,5	52,46	3934,5
Stern Thruster	4,5	3,9	175,5
Total	**12**		**4110**



As a conclusion the two-bow thruster, are sufficient to keep position of the vessel. In case that the stern bow thruster fails, the moment to avoid yaw will be provided by the two propellers.

Manning estimate

The crew levels that are to carry out anchor handling assignments on board vessels should be determined and certain circumstances shall be considered. The neglecting of the minimum rest hours the crew on board should have, will easily make the crew members fatigue, especially when the anchor handling operation may go on for several days.

- ✓ REGULATIONS

1. *International Maritime Organization – Resolution A 890 (21) and Amendments - resolution A 955 (23)*
2. *ARGENTINE NATIONAL GUARDCOAST – Resolution N°3-09 – Chapter 5 – Annex 2*
3. *Maritime Labor Convention 2006 – Title 2 – Regulation 2.7- Manning levels*
4. *Maritime Labor Convention 2006 – Title 2 – Regulation 2.3- Hours of work and hours of rest*
5. *Argentine Ministry of labor, employment and social security - Agreement No. 1102/10*
6. *International Maritime Organization - The Special Purpose Ships (SPS) Code -*

- ✓ MINIMUM SAFE MANNING LEVEL

The Argentine Naval Prefecture, established the minimum safe manning level for Argentinean flag platform supply vessels.

SAFE MANNING (National Maritime Navigation)						
POSITION	PASSENGERS	TANK SHIP		BULK CARRIERS		TUG
		N.A.T >1600	N.A.T < 1600	N.A.T > 1600	N.A.T < 1600	Platforms Supply vessel
CAPTAIN	1	1	1	1	1	1
1° Deck officer	1	1	1	1	1	1
2° Deck officer	1	1	1(+)	1	1(+)	1(+)
3° Deck officer	1	1(+)	-------	1(+)	-------	-------
Seafarers	10	6(*)	4(*)	6	4	3
Chief engineer	1	1	1	1	1	1
1° Mach. officer	1	1	1	1	1	1
2° Mach. officer	1	1(-)	-------	1(-)	1(+)	-------
3° Mach. officer	1	1(-) (+)	-------	1(-) (+)	-------	-------
Oilers	3	2	1	2	1	1
Radio officer	(**)	(**)	(**)	(**)	(**)	(**)
Staff		-------	-------	-------	-------	-------
Observations:	(+) In trips less than one hundred and forty-four hours may dispense, and must comply with Art. 35 of Law No. 17,371 (-) with automated plant (UMS) may refrain. (*) A crewmember must fulfill the functions of firefighter (fire prevention and firefighting) (**) See table II art 307 of RESMMA					

The minimum level of safety crew for the project is 10 crew members

- CREWING LEVELS

According with de owner's requirements, the crew level shall be established with the operational requirement and an estimate of the level of crews on similar vessels

- OPERATION CRITERIA

1. *Crew size must meet flag state's safety manning regulations. Ship Owner shall also ensure manning levels comply with the requirements of the sovereign state of the continental shelf (coastal state) for rest and working hours throughout the assignment.*
2. *Vessels must be manned sufficiently to meet manning and rest requirements to ensure 24-hour operation, where necessary*
3. *Engine room to be manned always when vessel is operating inside 500m safety zone*
4. *Crew size should always enable two people to be on the bridge during loading or offloading operations within safety zone. One must be an experienced ship handler and the other a bridge watch duty-certified crew member. This must not lead to working hour regulations being exceeded.*
5. *A Cadet with a watchkeeping certificate may replace the number 2 person on bridge watch duty.*
6. *There should be at least 2 qualified seamen on deck during loading or offloading operations within safety zone.*

ANCHOR HANDLING TUG SUPPLY VESSEL					
POSITION	WORK SHIFT			CANT.	OPERATIONAL REQUERIMENT
	8 - HOURS	8 - HOURS	8 - HOURS		
MASTER	X			1	A compotent master who is familiar with the anchor handling operation can control the process of anchor handling operation and foresse the risk existed in the operation. Appropriate distance between AHTS and the rig and the tension of work wire should be controlled in a short time and adjusted to the offshore situation
DECK OFFICERS		X	X	2	Two Deck officers, one of whom is the Master or Chief Officer, shall be on the bridge throughout anchor handling operations or any other operation within safety zone. There must be at least two qualified
CHIEF ENGINEER	X			1	A chief engineer is responsible for all operations and maintenance that has to do with any and all engineering equipment throughout the entire ship
1° MACHINARY OFFICER		X		1	The officer responsible for supervising the daily maintenance and operation of the engine room. He or she reports directly to the chief engineer.
RADIO OPERATOR	X			1	-
DECK OPERATORS OR SEAFARERS	X	X		6	Personnel assigned independent work on deck during anchor handling operations shall be familiar with guidelines and procedures for this, and anchor handling
OILERS	X	X		2	-
MEDIC	STAND BY			1	-
STAFF	STAND BY			2	Additional Personnel
		TOTAL		**17**	*OPERATIONAL CREW*

Observations

As the vessel is being designed to fulfill with several kinds of operational conditions, the minimum safe manning, should be determinate in the contract, for each voyage taken into consideration the task to be carry out. Such as, D.P. mode, request some persons to be dedicate sole per the activities related to D.P.The vessel shall provide accommodation for the crew, additional technicians or persons rescued, a total of 40 persons.

Cost analysis

For the cost analysis estimation, this design team has consulted the paper "Product-Oriented Design and Construction Cost Model" from the Journal of Ship Production.

In the paper, a calculation method is stated for obtaining a cost estimation, based on regression equations that relates the weight of the groups that form the lightweightship of the ship with the labor man hours and material [USD].

This design team tried to contact with several shipyard in the United States, where there is planned to be constructed, but no answer from them was received.

Group	*LABOR MAN HOURS*	*MATERIAL DOLLARS*
HULL	$CFx177x\ Weight^{0,862}$	$800x\ Weight$
MACHINERY	$CFx365x\ Weight^{0,704}$	$15000 + 20000x\ Weight$
COMUNICATIONS	$682x\ Weight^{1,025}$	$25000x\ Weight$
ELECTRICAL	$1605x\ Weight^{0,795}$	$40000x\ Weight$
AUXILIARY	$CFx34,8x\ Weight^{1,24}$	$10000 + 10000x\ Weight$
OUTFITTING & FURNITURE	$310x\ Weight^{0,949}$	$5000 + 10000x\ Weight$

From the paper, a complexity factor CF of 1(one) was determinate for Naval Tug Oceangoing, as this vessel is of more complexity for build, as almost have double hull and a big accommodation structure, this design team decided to raise the complexity factor to 1,5.

Shipyard Input Data	
Labor rate [U$D/hr]	20
Complexity Factor	1,5
Overhead Rate	100%
Yard's Profit	10%
Allowance	10%

Lightship	*Weight*	*Manhours*	*Manhours [hr]*	*Materials [U$D]*	*Manhours [U$D]*	*Total Cost [U$D]*
Hull Structure	1086	177	109850	868.456 USD	2.197.008 USD	**3.065.464 USD**
Propulsion System	102	365	14225	2.059.000 USD	284.490 USD	**2.343.490 USD**
Electrical System	39	682	1121	967.500 USD	22.418 USD	**989.918 USD**
Comumunications	5	1605	8655	200.000 USD	173.092 USD	**373.092 USD**
Auxiliary Systems	144	34,8	24689	1.445.910 USD	493.785 USD	**1.939.695 USD**
Outfitting and furnishing	355	310	122473	3.558.620 USD	2.449.456 USD	**6.008.076 USD**
Mission Equipment	101	400	32065	2.125.000 USD	641.301 USD	**2.766.301 USD**

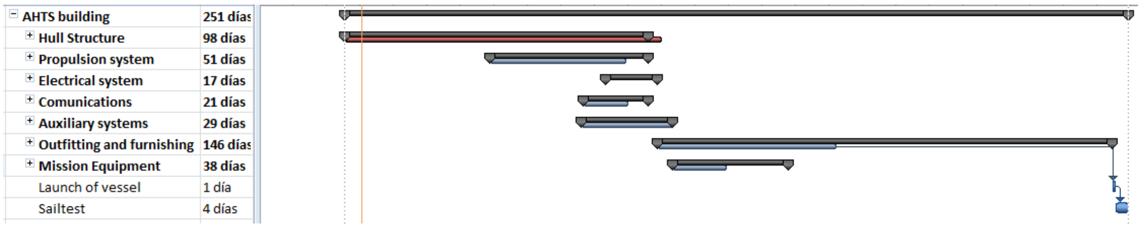
Total Labour Cost	6.261.551 USD
Overhead Cost	6.261.551 USD
Total Materials Cost	11.224.486 USD
Total (w/o Allowance)	23.747.588 USD
Yard's Profit	2.374.759 USD
Allowance	2.374.759 USD
GRAND TOTAL	**28.497.106 USD**

Construction Time

The estimation for the time construction of the vessel assumes of 787 shipyard operators that will be divided into the following schedule. A normal workable calendar of Monday to Saturday up to midday is assumed, and shift of 8 hours supposed. Consecuently and with the calendar days that each task will require, a Proyect is created, and with a rational divition of task and parallelism of them, a draft estimation of 251 days for the building is obtained.

A total calendar day of 400 days is obtained from the calculations with the use of the technical paper. With a rational parallelism between tasks the construction time was reduced to 251 calendar days. A better reduction might be done once the facilities of the shipyard are obtained.

	Shipyard staff	*Manhours*	*Calendar days*
Hull Structure	200	109850	98
Propulsion System	50	14225	51
Electrical System	12	1121	17
Comumunications	75	8655	21
Auxiliary Systems	150	24689	29
Outfitting and furnishing	150	122473	146
Mission Equipment	150	32065	38



Estimation of project schedule

Risk assessment

The following risk assessment it to analyses the different stages of the project and to recognize, which will need to be re-done in the following stage of the design spiral, which should be improved in the analysis and in which the design team has efficient prove. To do this the design team designed a risk matrix that will give as output the risk obtained. The risk of all stages is below the high risk.

CONSEQUENCE OF AN ERROR IN OBTAINED DESIGN SECTION		LACK OF CONFIDENCE IN TECHNICAL DEVELOPMENT REACHED				
		<Very low (1)	<Low (2)	Medium (3)	> Medium High (4)	High(5)
Insignificant 1	An error in this stage does not implies a revision of another project section	1	2	3	4	5
Low 2	An error in this stage might imply a revision of another stage of the project	2	4	6	8	10
Medium 3	Might affect cause to re-do current section and another calculus section	3	6	9	12	15
High 4	Might affect principal dimensions	4	8	12	16	20
Very High 5	The project must be re-done	5	10	15	20	25

1 - 6	-It can be deemed acceptable, to be optimized in the future.
8- 12	- A revision or improvement might be done
<15	- The risk of this stage is to high to move on with the design obtained

STEP DESCRIPTION	CONSEQ	L.C	RISK SCORE	CONTROL MEASURES
	CONSEQUENCE X L.C.=RISK			
INITIAL SIZING	5	1	5	NON- DIMENTIONS OBTAINED ARE DEEMED ACCEPTABLE
HULL MODELING	4	2	8	SOME EXTRA FAIRING MUST BE DONE TO THE HULL
AREA/VOLUME SUMMARY	3	1	6	NO RISK – VERIFIED BY MAXSURF CAPACITY
STRUCTURAL DESIGN	3	3	9	MUST RESEARCH OF SPECIAL CONSIDERATION CAUSE DIMENSIONS RELATION OF L/B
PROPULSION PLANT TRADE OFF	2	2	4	NO RISK – TYPE OF POWER PLANT SELECTED IS OK
EQUIPMENT SELECTION	3	3	9	A MORE DETAILED CALCULUS OF OUTFITTING EQUIPMENT MUST BE DONE. CAUSE A BIG UNCERTENTY IN WEIGHT ESTIMATION
ELECTRICAL LOAD	3	2	6	NO RISK- POWER VERIFIED WITH STATISTICAL DATA
WEIGHT ESTIMATION	3	3	9	EXPECTED RISK IN EARLY DESIGN STAGE. AN OBVIUS RECALCULATION MUST BE DONE- SEVERAL STAGES ARE TO RE ITERATE
INTACT/DAMAGE STABILITY ANALYSIS	4	3	12	ONCE THE WEIGHT ESTIMATION IS RE-DONE. STABILITY MUST BE RE-CHECKED
SPEED AND POWER & ENDURANCE	3	2	6	NO RISK- RESULTS ARE TO BE TRUSTED- A MODEL TEST IS TO BE PLANNED TO VALIDATE CFD RESULTS (CFD USERS HAVE VALIDATED THE SOFTWARE AT LLOYD´S REGISTER CFD WORKSHOP)
SEAKEEPING ANALYSIS	3	3	9	NO RAO INFORMATION FROM MODEL TEST IS OBTAINED- AS PER LACK OF OUTFITTING CENTER OF GRAVITY POSITION CONFIDENCE- MIGHT BE RECALCULATED
MANNING ESTIMATE	3	2	6	NO RISK- THE NUMBER OF PERSON ON BOARD IS OK – AND WITH RATIONAL
COST ESTIMATION	2	4	8	UNFORTUNETELY THE SHIPYARD´S ASKED FOR QUOTE FOR THE PROYECT DID NOT REPLY. VALUES USED ARE OBTAINED FROM SNAME PAPER- EXPERIENCE OF PROFESSIONALS INDICATE FIGURE IS OK

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Appendix 1- Electrical load Calculation sheet

Electrical Load Analysis

Ship: AHTS 100t BP

Date:01/05/2017

Nº	List of Loads / Groups	Capacity: Pn (kW)	Capacity: Qty. Installed	Capacity: Qty. In service	Capacity: Sum. Pn (kW)	Capacity: Efficiency	Capacity: Connected Load (kW)	Operational Profile At Day: DF	In Trasnsit Summer	DF	In Transit Winter	DF	Fire Fighting & DP II	DF	Handling Duties & DP II	DF	Charge & Discharge DP II	DF	Towing Duties	Emegency Condition: DF	Fire	Operational Profile At Night: DF	In Trasnsit Summer	DF	In Transit Winter	DF	Fire Fighting & DP II	DF	Handling Duties & DP II	DF	Charge & Discharge DP II	DF	Towing Duties	Emergency Condition: DF	Fire
	CONTINUOUS LOAD																																				
1	Engine Room ventilation	5,5	2,0	2,0	11,0	0,9	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	0,5	6,5	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	0,5	6,5
2	Fresh Water Maker	3,0	1,0	1,0	3,0	0,9	3,5	1,0	3,5	1,0	3,5	1,0	3,5	1,0	3,5	1,0	3,5	1,0	3,5	0,0	0,0	1,0	3,5	1,0	3,5	1,0	3,5	1,0	3,5	1,0	3,5	1,0	3,5	0,0	0,0
3	Steering Gear Pump	7,5	2,0	2,0	15,0	0,9	17,6	1,0	17,6	1,0	17,6	0,7	12,4	1,0	17,6	0,7	12,4	1,0	17,6	1,0	17,6	1,0	17,6	1,0	17,6	0,7	12,4	1,0	17,6	0,7	12,4	1,0	17,6	1,0	17,6
4	Air Conditioning Plant	25,0	1,0	1,0	25,0	0,9	29,4	0,8	23,5	1,0	29,4	0,7	20,6	1,0	29,4	0,7	20,6	1,0	29,4	0,0	0,0	0,8	23,5	1,0	29,4	0,7	20,6	1,0	29,4	0,7	20,6	1,0	29,4	0,0	0,0
5	Galley Exhaust Ventilation Fan	0,4	1,0	1,0	0,4	0,9	0,4	1,0	0,4	1,0	0,4	1,0	0,4	1,0	0,4	1,0	0,4	1,0	0,4	0,0	0,0	1,0	0,4	1,0	0,4	1,0	0,4	1,0	0,4	1,0	0,4	1,0	0,4	0,0	0,0
6	Wheel House air conditioning	2,1	2,0	2,0	4,2	0,9	4,9	1,0	4,9	1,0	4,9	1,0	4,9	0,5	2,5	0,5	2,5	0,5	2,5	0,0	0,0	1,0	4,9	1,0	4,9	1,0	4,9	1,0	4,9	0,5	2,5	0,5	2,5	0,0	0,0
7	Engine room lightining	-	-	-	3,7	0,9	4,1	0,5	2,1	0,5	2,1	1,0	4,1	1,0	4,1	1,0	4,1	1,0	4,1	1,0	4,1	1,0	4,1	1,0	4,1	1,0	4,1	1,0	4,1	1,0	4,1	1,0	4,1	1,0	4,1
8	Main deck lightning	-	-	-	3,0	0,9	3,3	0,2	0,7	0,3	1,0	0,3	1,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	1,7	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3
9	Forecastle lightning	-	-	-	3,0	0,9	3,3	0,0	0,0	0,2	0,7	0,2	0,7	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,7	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3
10	Wheel house lightning	-	-	-	9,5	0,9	10,6	0,6	6,3	0,6	6,3	0,2	2,1	0,2	2,1	0,2	2,1	0,2	2,1	0,8	8,4	1,0	10,6	1,0	10,6	1,0	10,6	1,0	10,6	1,0	10,6	1,0	10,6	1,0	10,6
11	Control and instrument	-	-	-	3,0	0,9	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3
12	Radio	-	-	-	3,0	0,9	3,3	0,5	1,7	0,5	1,7	1,0	3,3	0,8	2,7	1,0	3,3	0,8	2,7	0,5	1,7	0,5	1,7	0,5	1,7	1,0	3,3	0,8	2,7	1,0	3,3	1,0	3,3	1,0	3,3
13	Navigation lights	-	-	-	2,0	0,9	2,2	0,0	0,0	0,0	0,0	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2
	INTERMITTENT LOAD																																				
14	Oily water separator	3,0	1,0	1,0	3,0	0,9	3,5	0,5	1,8	0,5	1,8	0,2	0,7	0,2	0,7	0,5	1,8	0,2	0,7	0,0	0,0	0,5	1,8	0,5	1,8	0,2	0,7	0,2	0,7	0,5	1,8	0,2	0,7	0,0	0,0
15	General service pump	11,0	1,0	1,0	11,0	0,9	12,9	1,0	12,9	1,0	12,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	12,9	1,0	12,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
16	Bilges Pump	11,0	1,0	1,0	11,0	0,9	12,9	1,0	12,9	1,0	12,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	12,9	1,0	12,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
17	Fire pump	18,5	1,0	1,0	18,5	0,8	23,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	23,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	23,7
18	Sewage threatment plant	1,9	1,0	1,0	1,9	0,9	2,2	1,0	2,2	1,0	2,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	2,2	1,0	2,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
19	Fresh water pressure set pump	1,1	2,0	1,0	2,3	0,9	2,7	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3
20	Sea water pressure set pump	1,1	2,0	1,0	2,3	0,9	2,7	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3	0,5	1,3
21	Fuel oil transfer pump	11,0	1,0	1,0	11,0	0,9	12,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	12,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	12,9	0,0	0,0	0,0	0,0
22	Fuel oil cargo transfer pump	15,0	1,0	1,0	15,0	0,9	17,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	17,6	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	17,6	0,0	0,0	0,0	0,0
23	Dirty oil pump	2,2	1,0	1,0	2,2	0,9	2,6	1,0	2,6	1,0	2,6	1,0	2,6	1,0	2,6	1,0	2,6	1,0	2,6	0,0	0,0	1,0	2,6	1,0	2,6	1,0	2,6	1,0	2,6	1,0	2,6	1,0	2,6	0,0	0,0
24	Fresh water transfer pump	11,0	1,0	1,0	11,0	0,9	12,9	1,0	12,9	1,0	12,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	12,9	1,0	12,9	1,0	12,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	12,9
25	Galley & laundry equipment	15,7	-	-	15,7	0,9	18,5	0,2	3,7	0,2	3,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	9,2	0,5	9,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
26	Dry bulk Air Compressor	75,0	1,0	1,0	75,0	0,9	88,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	44,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	44,1	0,0	0,0	0,0	0,0
	MACHINARY LOAD																																				
26	Anchor winch / Towing winch	215,0	1,0	1,0	215,0	0,9	244,3	0,0	0,0	0,0	0,0	0,0	0,0	1,0	244,3	0,0	0,0	1,0	244,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	244,3	0,0	0,0	1,0	244,3	0,0	0,0
27	Tugger winch	36,0	1,0	1,0	36,0	0,9	40,9	0,0	0,0	0,0	0,0	0,0	0,0	1,0	40,9	1,0	40,9	1,0	40,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	40,9	1,0	40,9	1,0	40,9	0,0	0,0
28	Deck crane 5 Tn SWL	75,0	1,0	1,0	75,0	0,9	85,2	0,0	0,0	0,0	0,0	1,0	85,2	0,0	0,0	1,0	85,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	85,2	0,0	0,0	1,0	85,2	0,0	0,0	1,0	0,0
29	Shark jaw / Towing pin	15,0	1,0	1,0	15,0	0,9	17,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	17,0	0,0	0,0	1,0	17,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	17,0	0,0	0,0	1,0	17,0	0,0	0,0
30	Capstain	18,0	2,0	1,0	18,0	0,9	20,5	0,0	0,0	0,0	0,0	1,0	20,5	1,0	20,5	1,0	20,5	1,0	20,5	0,0	0,0	0,0	0,0	0,0	0,0	0,6	12,3	1,0	20,5	1,0	20,5	1,0	20,5	0,0	0,0
31	Bow thruster	500,0	2,0	1,0	500,0	0,9	568,2	0,0	0,0	0,0	0,0	0,4	227,3	0,8	454,5	0,8	454,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,4	227,3	0,8	454,5	0,8	454,5	0,0	0,0	0,0	0,0
32	Stern Thruster	300,0	1,0	1,0	300,0	0,9	340,9	0,0	0,0	0,0	0,0	0,2	68,2	0,4	136,4	0,4	136,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	68,2	0,4	136,4	0,4	136,4	0,0	0,0	0,0	0,0
	EMERGENCY LOAD																																				
33	Engine room ventilation fan	5,5	2,0	2,0	11,0	0,9	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9	1,0	12,9
34	Emergency genset supply fan	2,0	1,0	1,0	2,0	0,9	2,4	1,0	2,4	1,0	2,4	1,0	2,4	1,0	2,4	1,0	2,4	1,0	2,4	1,0	2,4	1,0	2,4	1,0	2,4	1,0	2,4	1,0	2,4	1,0	2,4	1,0	2,4	1,0	2,4
35	Emergency lightning	-	-	-	2,4	0,9	2,7	1,0	2,7	1,0	2,7	1,0	2,7	1,0	2,7	1,0	2,7	1,0	2,7	1,0	2,7	1,0	2,7	1,0	2,7	1,0	2,7	1,0	2,7	1,0	2,7	1,0	2,7	1,0	2,7
36	Radio system	-	-	-	3,0	0,9	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3
37	Navigation aids equipment	-	-	-	3,0	0,9	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	1,0	3,3	0,5	1,7	1,0	3,3
38	Navigation lights	-	-	-	2,0	0,9	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2	1,0	2,2
39	Emergency battery charger	-	-	-	3,0	0,9	3,4	1,0	3,4	1,0	3,4	1,0	3,4	1,0	3,4	1,0	3,4	1,0	3,4	1,0	3,4	1,0	3,4	1,0	3,4	1,0	3,4	1,0	3,4	1,0	3,4	0,0	0,0	1,0	3,4
40	Supply power for control equipm	-	-	-	5,0	0,9	5,7	1,0	5,7	1,0	5,7	1,0	5,7	1,0	5,7	1,0	5,7	1,0	5,7	1,0	5,7	1,0	5,7	1,0	5,7	1,0	5,7	1,0	5,7	1,0	5,7	0,0	0,0	1,0	5,7
41	General service pump	11,0	1,0	1,0	11,0	0,9	12,9	0,5	6,5	0,5	3,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,5	6,5	0,5	6,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
42	Fire pump	18,5	2,0	2,0	37,0	0,8	47,4	0,5	23,7	0,5	11,9	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	47,4	0,5	23,7	0,5	23,7	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	1,0	47,4

	Day: In Transit Summer	Day: In Transit Winter	Day: Fire Fighting & DP II	Day: Handling Duties & DP II	Day: Charge & Discharge DP II	Day: Towing Duties	Day: Emergency (Fire)	Night: In Transit Summer	Night: In Transit Winter	Night: Fire Fighting & DP II	Night: Handling Duties & DP II	Night: Charge & Discharge DP II	Night: Towing Duties	Night: Emergency (Fire)
Continuous Load	77,1	84,0	71,6	80,9	67,4	80,9	46,2	91,6	97,5	85,0	98,5	82,5	96,7	54,3
Intermittent Load	51,8	51,8	6,0	6,0	81,7	6,0	39,3	57,3	57,3	6,0	6,0	81,7	6,0	39,3
Machinary Load	0,0	0,0	401,1	913,6	737,5	322,7	0,0	0,0	0,0	393,0	913,6	737,5	322,7	0,0
Emergency Load	66,2	51,1	36,0	36,0	36,0	36,0	83,5	66,2	66,2	36,0	36,0	36,0	25,2	83,5

	In Transit Summer	In Transit Winter	Fire Fighting & DP II	Handling Duties & DP II	Charge & Discharge DP II	Towing Duties	Emergency	In Transit Summer	In Transit Winter	Fire Fighting & DP II	Handling Duties & DP II	Charge & Discharge DP II	Towing Duties	Emergency
Total (kW)	195,1	186,9	514,7	1036,5	922,7	445,6	169,0	215,1	221,0	520,0	1054,1	937,8	450,5	177,1
%Load Used	0,3	0,3	0,9	0,9	0,8	0,4	0,3	0,4	0,4	0,9	0,9	0,8	0,4	0,3
Gensent Used	**1 x 600 kW**	**1 x 600 kW**	**1 x 600 kW**	**2 x 600kW**	**2 x 600 kW**	**2 x 600 kW**	**1 x 600 kW**	**1 x 600 kW**	**1 x 600 kW**	**1 x 600 kW**	**2 x 600 kW**	**2 x 600 kW**	**2 x 600 kW**	**1 x600 kW**

GENSET CONFIGURATION	**2 Shaft Generators 600 kW** **2 Auxiliary Generator 600 kW** **1 Emergency Generator 250 kW**

Appendix 2- Structural Analysis Calculation sheet

CHAPTER 2 Hull Structures and Arrangements
SECTION 1 Longitudinal Strength

1 Application

As the vessel in consideration comply with:			
Proportions:	L/B<5	3,7	Special consideration shall be taken
	B/D>3.0	2,3	Ok
Length:	L>305m	57,9	Ok
Block Coefficient:	C_b<0.6	0,74	Ok
Large openings		No	Ok
Vessel with large flare		No	Ok
Vessel carrying heated cargoes		No	Ok
Unusual type of design		No	Ok

Although special considerations is said to be taken, we have seen that all our statistics fleet did not verify the requirement and also taken into consideration that if the relation decrees also the strength

3 Longitudinal Hull Girder Strength

3.1 Minimum Section Modulus for Vessels Under 61 m (200 ft) in Length

SM= $C_1*C_2*L^2*B*(C_B+0.7)$ m-cm^3

Parameters & Constants			
C_1=	0.044L+3.75	6,2	-
C_2=	-	0,01	-
L=	-	56,2	m
B=	-	15,1	m
C_b=	-	0,74	-

SM_1= 4284,96 cm^3

3.5 Wave Loads

3.5.1 Wave Bending Moment Amidships

M_{ws}= $-k_1*C_1*L^2*B*(C_B+0.7)\ x10^{-3}$ kN/m Sagging Moment
M_{wh}= $k_2*C_1*L^2*B*C_B\ x10^{-3}$ kN/m Hogging Moment

Parameters & Constants			
C_1=	0.044L+3.75	6,2	-
k_1=	-	110	-
k_2=	-	190,00	-
L=	-	56,2	m
B=	-	15,1	m
C_b=	-	0,74	-

M_{ws}= -47134,57 kNm
M_{wh}= 41837,88 kNm

3.7 Bending Strength

3.7.1 Hull Girder Section Modulus

The required hull girder section modulus for 0.4L amidships is to be the greater of the followings values:

SM_2= M_t/f_p cm2-m

Parameters & Constants			
M_t=	M_{ws}+ M_{wh}	88972,4	kNm
f_p=	-	17,5	kN/cm^2

SM= 5084,14 cm^2-m

SMmin= 5084,14 cm2-m

3.7.2 Hull Girder Moment of Inertia

I= L*SM/33.3 cm^4

Parameters & Constants			
SM=	Max (SM_1 & SM_2)	5084,1	cm^3
L=	-	56,2	m

I= 8572,72 cm^4

SECTION 2 Shell Plating

1 Application

$t_{shmin=}$ $(s*k(q*h)^{0.5}/254)+2.5$ mm

Parameters & Constants			
s=	-	650,0	-
k=	(3.075*(α)^0.5-2.077)/(α+0.272)	0,9874851	-
Panel Width=	-	3480,00	mm
Panel Depth=	-	1950,0	mm
α=	Long panel/Short panel	1,8	mm
q=	235/Y	1,00	m
Y=	-	235,0	kN/mm^2
h=	Max (D, 0.1L, 1.18d)	6,58	m

$t_{shmin=}$ 8,98 mm

3 Shell Plating Amidships

3.9 Side Shell Plating

t_{shell1} = (s/645) ((L-15.2)*(ds/Ds))$^{0.5}$ + 2.5 mm

t_{shell2} = 0.035 (L + 29) + 0.009s mm

Parameters & Constants			
s=	-	650	mm
L=	-	56,20	m
ds=	Scantling draft	5,108	m
Ds=	Scantling depth	6,58	m
ds/Ds=	ratio	0,78	-

t_{shell1} = 8,19 mm

t_{shell2} = 8,83 mm

t_{shell} = 8,83 mm

3.13 Sheer Strake

b= 5L+800 mm

Parameters & Constants			
L=	(L<200m)	56,20	m

b= 1081,00 mm

3.15 Bottom Shell Plating Amidships

3.15.1 Bottom Shell Plating

t= (s/519)*(L-19.8)*(ds/Ds)$^{0.5}$ + 2.5 mm

Parameters & Constants			
s=	-	650	mm
L=	(L<183m)	56,20	m
ds=	Scantling draft	5,108	m
Ds=	Scantling depth	6,58	m
ds/Ds=	ratio	0,78	-

t= 9,16 mm

t_{2a}= 0.009*sb+2.4 mm

Parameters & Constants			
sb=	longitudinal spacing @ decks	585	mm

t_{2a}= 7,67 mm

3.15.2 Minimum Bottom Shell Plating

t= s*(L+45.73)/(25*L+6082) mm

Parameters & Constants			
s=	not less than: 2.08*L+438	650	mm
L=	(L<183m)	56,20	m

t= 8,85 mm

tmax= 9,16 mm

t= *10,00* **mm** *Adopted*

14 Bilge Plating

t_{shmin}= (s*k*(q*h)$^{0.5}$/254) +2.5 mm

Parameters & Constants			
s=	-	650,0	-
k=	(3.075*(α)^0.5-2.077)/(α+0.272)	0,9875	-
Panel Width=	-	3480,00	mm
Panel Depth=	-	1950,0	mm
α=	Long panel/Short panel	1,8	mm
q=	235/Y	1,00	m
Y=	-	235,0	kN/mm^2
h=	Max (D, 0.1L, 1.18d)	6,58	m

t_{shmin}= 8,98 mm

t= *10,00* **mm** *Adopted*

2 Hull Structures and Arrangements

SECTION 3 Decks

t_1= s*h^{0,5}/254 + 1.5 mm

Parameters & Constants			
s=	longitudinal spacing @ decks	585	mm
h=	-	7,13	m

t_1= 7,65 mm

4 Bottom Structures

1 Double Bottoms

The depth of the double bottom : hdb> **B/20** 0,76 **m**

Parameters & Constants			
B=	-	15,14	m

2 Hull Structures and Arrangements
SECTION 3 Decks

t_1= $s*h^{0,5}/254 + 1.5$ mm

Parameters & Constants			
s=	longitudinal spacing @ decks	585	mm
h=	-	7,13	m

t_1= 7,65 mm

t_{2b}= sb*(L+48.76)/(26*L+8681)

Parameters & Constants			
sb=	longitudinal spacing @ decks	585	mm
L=	-	56,20	m

t_{2b}= 6,05 mm

tmin= 7,67 **mm** Required
t= *10,00* **mm** *Adopted*

ABS Rules for Building and Classing Steel Vessels under 90m in Length

Pt 3, Ch 2, Sec. 4-Bottom structures-
1.5 Side Girder-

t= 0.036*L+c mm

Parameters & Constants			
c=	-	4,7	-
L=	-	56,20	m

t= 6,72 **mm**

tmin= 7,53 **mm** Required
t= *10,00* **mm** *Adopted*

3.1.1 Center Girder & Side Girder Depth:

h_g= 760 **mm**

3.1 Center Girder

t= 0.056*L + 5.5 mm

Parameters & Constants			
L=	-	56,2	m

t= 8,65 **mm** Required
t= *10,00* **mm** *Adopted*

RINA OSV Rules SCANTLING CHECKS FOR SHIPS LESS THAN 65 M IN LENGTH

Side Girder-
Pt B, Ch 5, App 1 - Table 4 : Scantlings of double bottom structures

t= $0.054* L* k^{0.5} +4.5$ mm

Parameters & Constants			
k=	-	1	-
L=	-	56,20	m

t= 7,53 **mm**

Section 5 Frames
3 Side Frames
3.1 Transverse Frames

SM= $s*l^2*(h+b*h_1/30)*(7+45/l^3)$ cm^3

Parameters & Constants			
s=	-	1,875	m
h=	-	4,201	m
b=	-	1,77	m
h_1=	$h_{fb}+h_{c1}+h_{c2}+h_{cn}+h_E+0.5*(h_{p1}+h_{p2}+h_{pn})$	3,66	m
h_{FB}=		0	
h_{C1}=		0	
h_{C2}=		0	
h_E=		3,66	
h_{p1}=		0	
h_{p2}=		0	
l=	-	4,76	m

SM= 1390,20 **cm^3** Required
SM= **cm^3** *Adopted*

5 Solid Floors

t= 0.036*L+4.7+c mm

Parameters & Constants			
c=	-	0	mm
L=	-	56,20	m

t=	6,72	**mm**	Required
t=	*10,00*	**mm**	*Adopted*

9 Inner-bottom Plating

9.1 Inner-bottom Plating Thickness

t= 0.037L + 0.009*s–c+ b mm

Parameters & Constants			
c=	-	0,5	mm
s=	-	650	mm
b=	-	2	mm
L=	-	56,20	m

t=	9,43	**mm**	Required
t=	*12,00*	**mm**	*Adopted*

7 Structural Arrangements and Details

7.2 Overlap of Brackets

7.2.2 *Detail A*

x= 1,4y+30 mm

Parameters & Constants			
t=	thinner plate	10	mm
y=	-	220	mm

x=	338,00	**mm**	Required
x=	*340,00*	**mm**	*Adopted*
width=	45,00	**mm**	Required
width=	*48,00*	**mm**	*Adopted*

Section 7 Beams and Longitudinals

3 Beams and Longitudinals

3.1 Strength Requirements

SM= $7.8 \cdot c \cdot h \cdot s \cdot l^2$ cm^3

Parameters & Constants			
c=	-	0,585137507	m
s=	-	2,45	m
h=	-	2,424	m
l=	-	1,95	m
k=	$SM_R \cdot Y/I_A$	0,00	-
Y=			m
I_A=		8572,72	cm^4

SM=	103,07	**cm^3**	Required	
SM=	*129,00*	**cm^3**	*Adopted*	L 125 x 75 x 10

5 Side Stringers

5.1 Side Stringers

SM= 4.74*c*h*s*l^2 cm^3

Parameters & Constants			
c=	-	1,5	m
s=	-	4	m
h=	-	2	m
l=	-	1,95	m

SM=	216,29	**cm^3**	Required	
SM=	*223,00*	**cm^3**	*Adopted*	L 180 x 7 x 10

Section 8 Beams and Longitudinals

5 Deck Girders and Transverses

5.3 Deck Girders

SM= $4.74 \cdot c \cdot b \cdot h \cdot l^2$ cm^3

Parameters & Constants			
c=	-	1	-
b=	-	5,8	m
h=	-	7,13	m
l=	-	1,95	m

SM=	745,64	**cm^3**	Required	
SM=	*750,00*	**cm^3**	*Adopted*	L 280 x 14 - 150 x 10

Section 9 Watertight Bulkheads and Doors

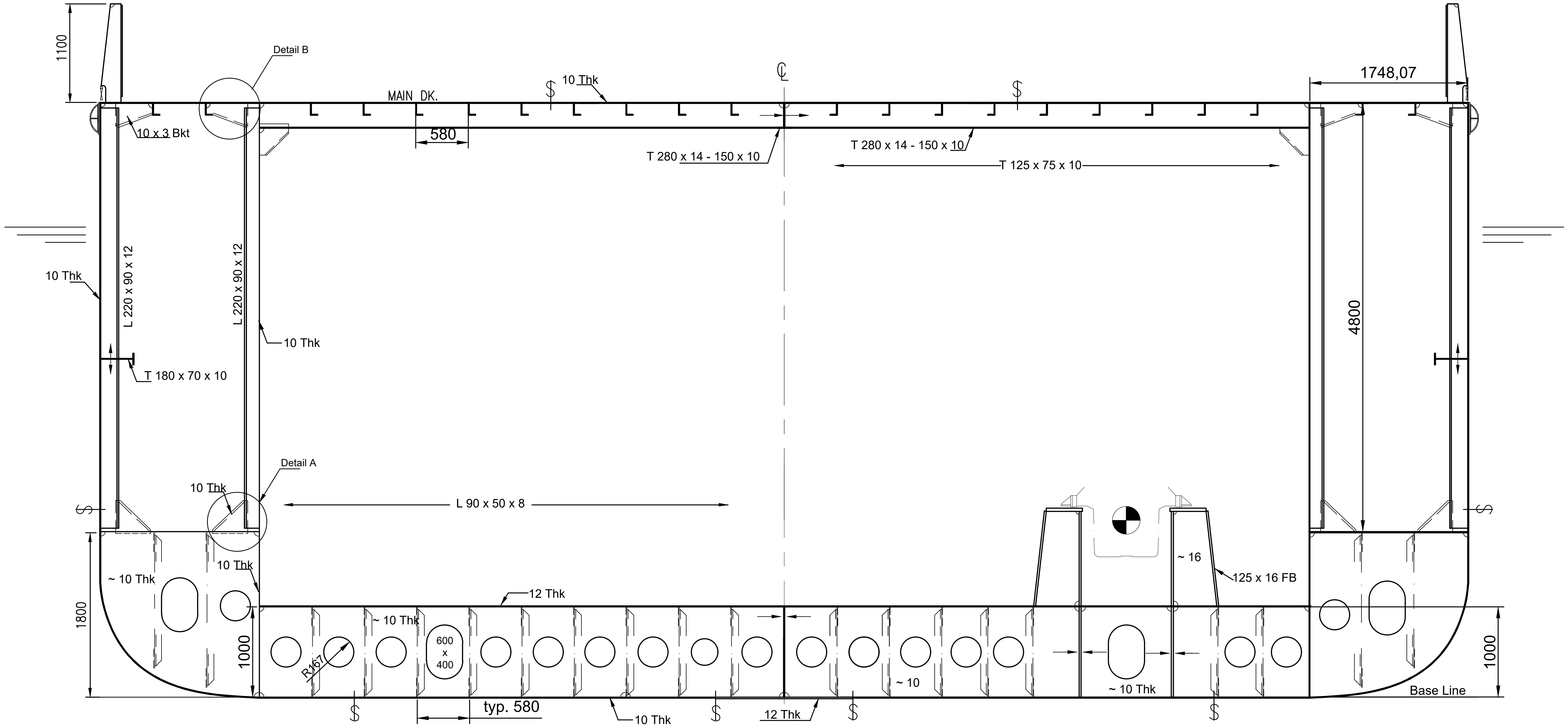
5 Construction of Watertight Bulkheads

5.1 Plating

t= $(s \cdot k(q \cdot h)^{0.5}/c) + 1.5$ mm

Parameters & Constants			
s=	-	650,0	-
k=	(3.075*(α)^0.5-2.077)/(α+0.272)	0,820101859	-
Panel Width=	-	4800,00	mm
Panel Depth=	-	650,0	mm
α=	Long panel/Short panel	7,4	mm
q=	235/Y	1,00	m
Y=	-	235,0	kN/mm^2
c=	254->Collision bulkhead; 290 other	290,0	-
h=		4,8	m

t=	5,53	mm	
t=	*10,00*	**mm**	*Adopted*



MIDSHIP SECTION-
FRAME 43

WEB FRAME SECTION IN ENGINE ROOM
FRAME 37

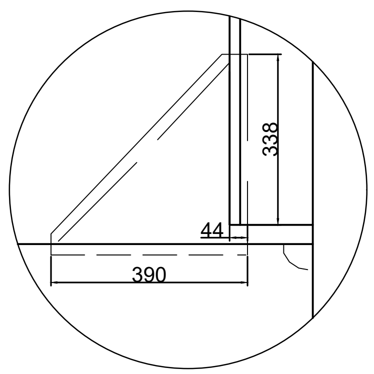
GENERAL NOTES:

ALL DIMENSIONS ARE INDICATED IN MILIMETERS UNLESS STATED OTHER WISE

PRINCIPAL PARTICULARS

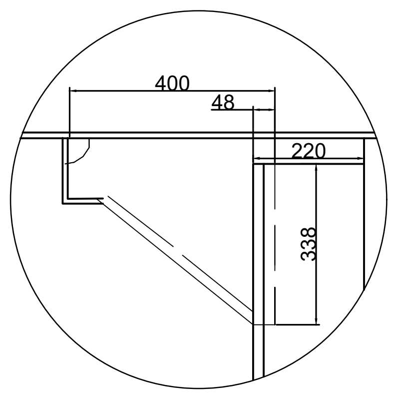
LENGTH, OVERALL.. 65.000 m
LENGTH, WATERLINE.................................. 60.320 m
BEAM, MOULDED.. 15.14 m
DEPTH, MOULDED:.. 6.58 m
DESIGN DRAFT... 5.21 m
TRANSVERSAL FRAMING..................................650mm
DECK LONGITUDINAL FRAMING.........................580mm

Detail A



SCALE:
1 : 15

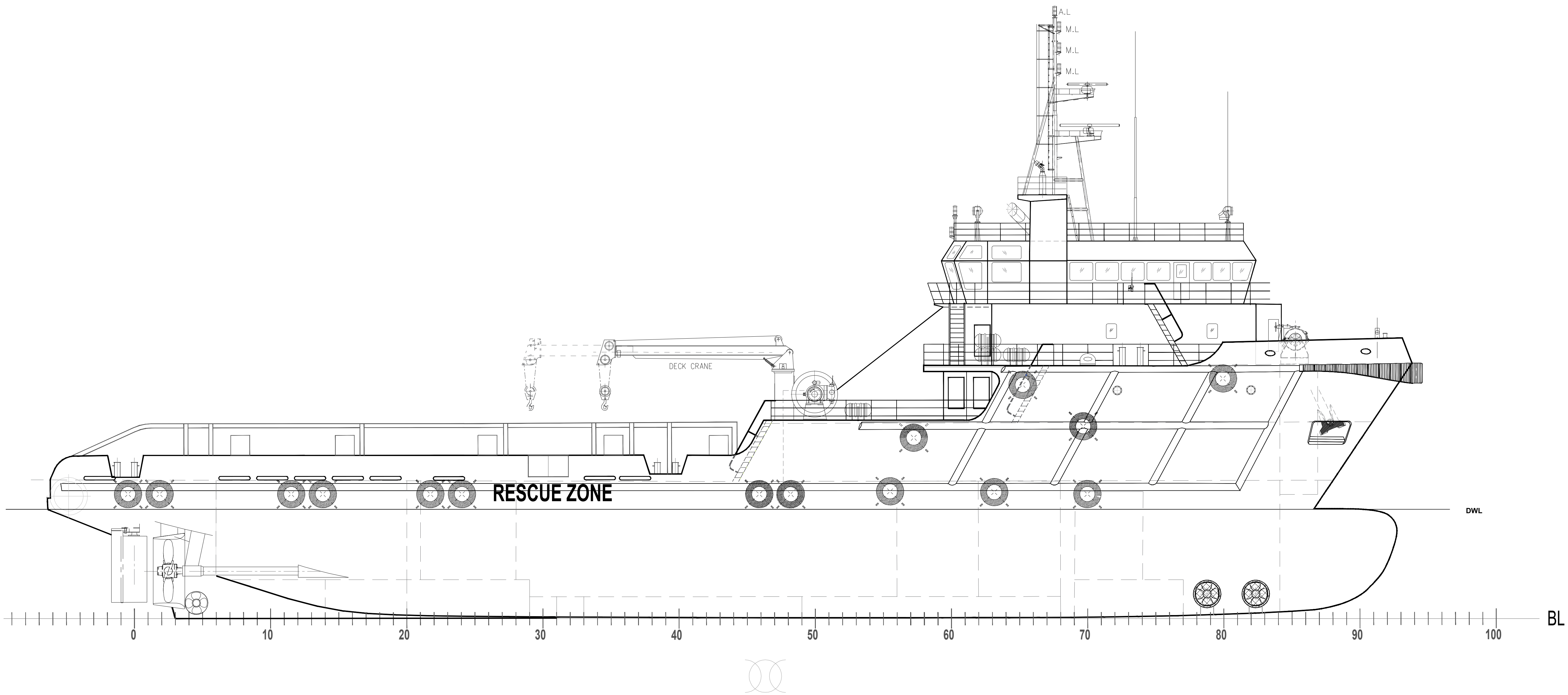
Detail B



SCALE:
1 : 15

UTN.BA
UNIVERSIDAD TECNOLÓGICA NACIONAL
FACULTAD REGIONAL BUENOS AIRES

SHEET 1 / 2	NAME	VESSEL TYPE: AHTS - 100 TON	DATE ISSUED: APR - /17	APPROVAL DATE:
DRAWN BY:	NM		DWG: AHTS - 001	SIGNATURE:
CHECKED BY:	MJ	PLANE: MIDSHIP SECTION	REVISION N° 001	
APPROVED BY:			SCALE: 1 : 50	SIZE: A3



PRINCIPAL PARTICULARS

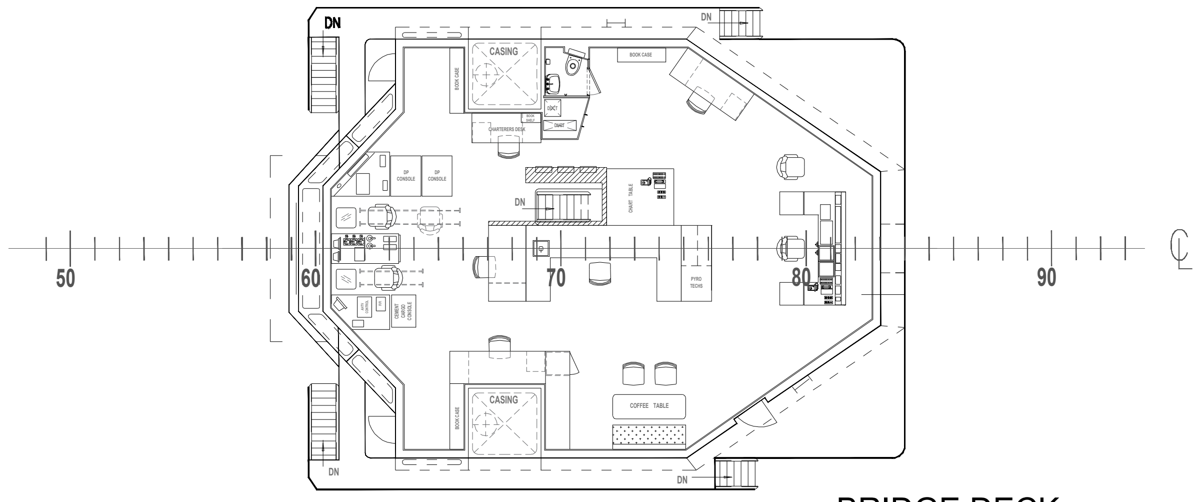
LENGTH, OVERALL.. 65.000 m
LENGTH, WATERLINE.................................. 60.320 m
BEAM, MOULDED.. 15.14 m
DEPTH, MOULDED:... 6.58 m
DESIGN DRAFT.. 5.21 m
FRAME SPACING... 2.813 m
BUTTOCK SPACING...1.500 m
WATERLINE SPACING......................................1.000 m
SECTION SPACING (from FR 0 to FR 21)..........2.183 m

GENERAL NOTES:

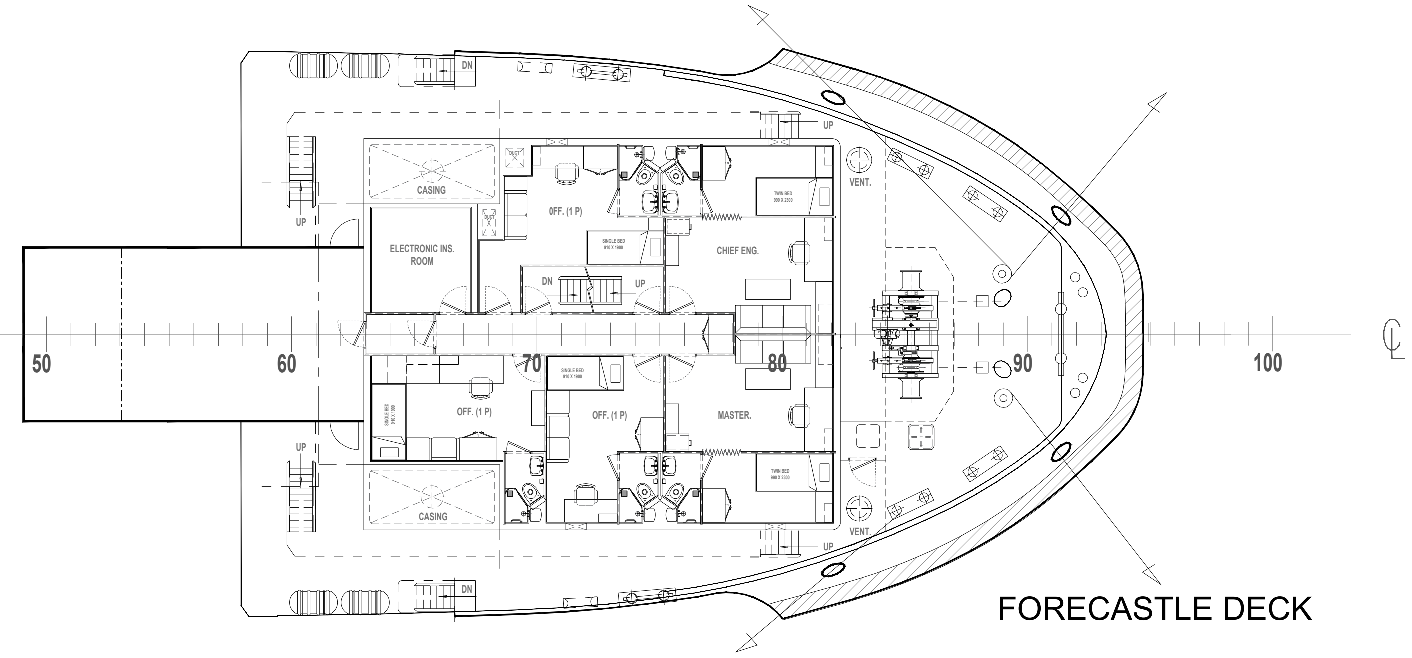
ALL DIMENSIONS ARE INDICATED IN MILIMETERS UNLESS STATED OTHER WISE

UTN.BA
UNIVERSIDAD TECNOLÓGICA NACIONAL
FACULTAD REGIONAL BUENOS AIRES

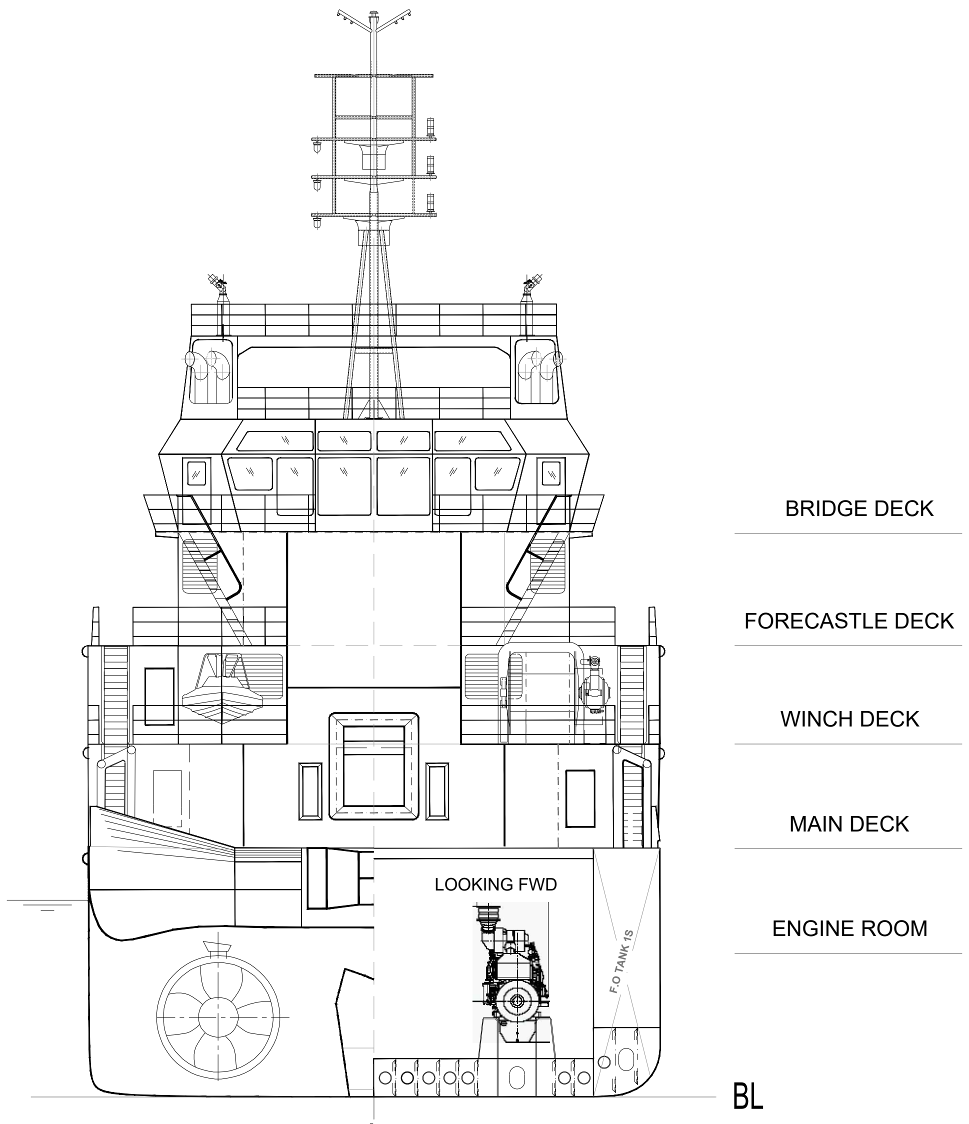
SHEET 1 / 3	NAME	VESSEL TYPE: AHTS - 100 TON	DATE ISSUED: APR - /17	APPROVAL DATE:
DRAWN BY:	FC		DWG: AHTS - 001	SIGNATURE:
CHECKED BY:	MJ	DRAWING: GENERAL ARRANGEMENT	REVISION N° 001	
APPROVED BY:			SCALE: 1 : 200	SIZE: A3



BRIDGE DECK

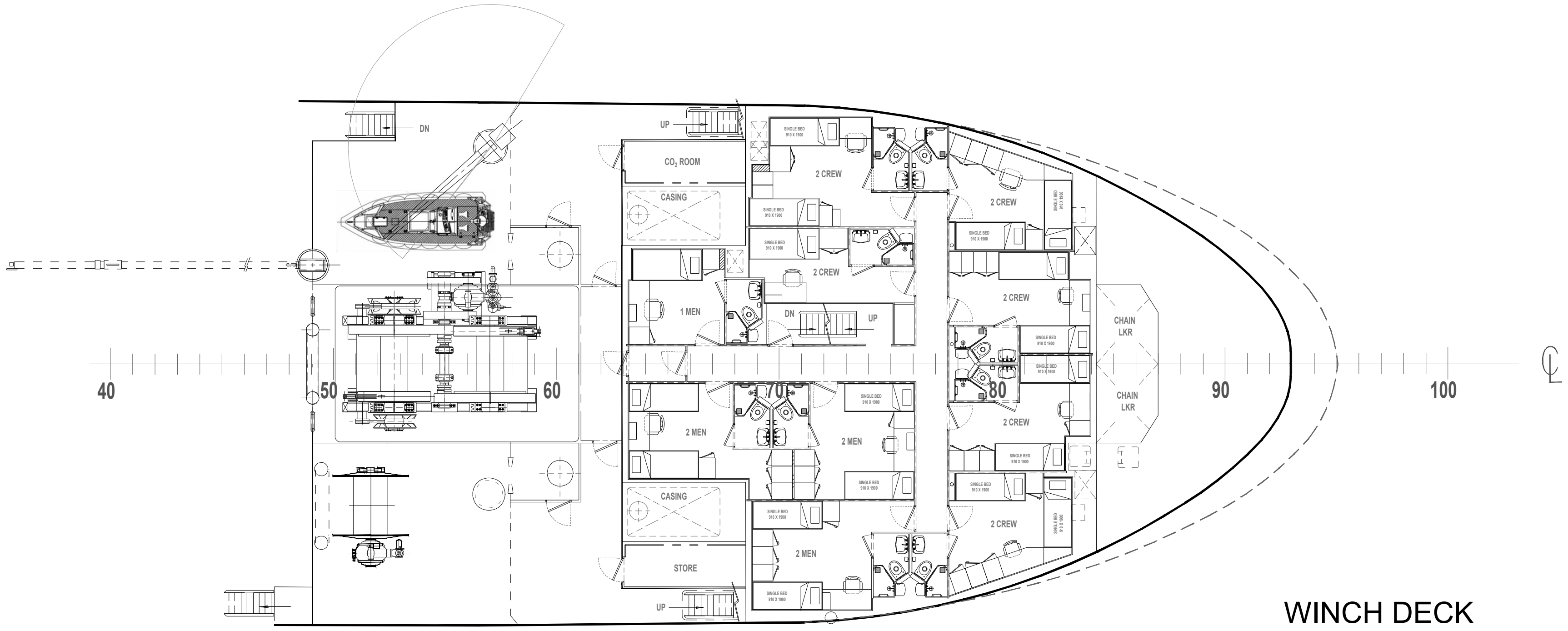


FORECASTLE DECK



SECTIONAL VIEW

FRAME 32 - LOOKING FWD



WINCH DECK

GENERAL NOTES:

ALL DIMENSIONS ARE INDICATED IN MILIMETERS UNLESS STATED OTHER WISE

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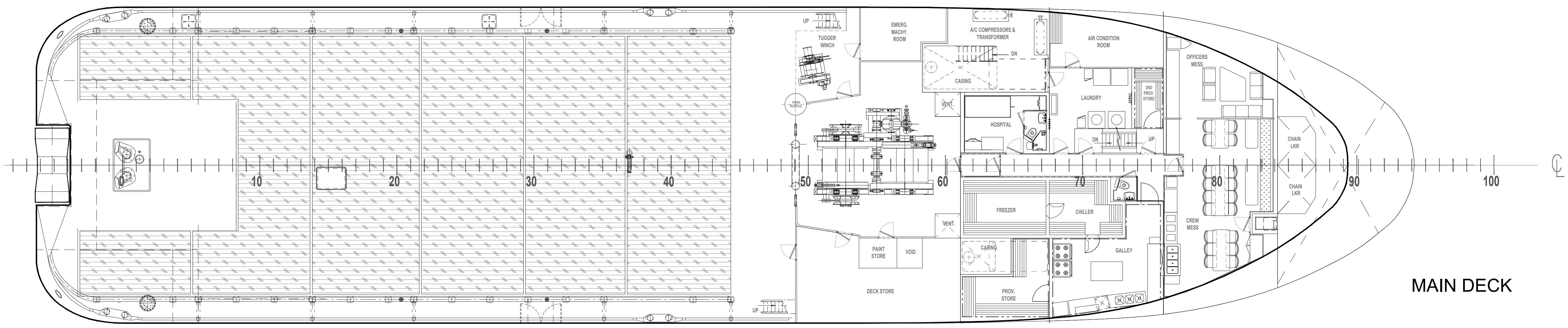
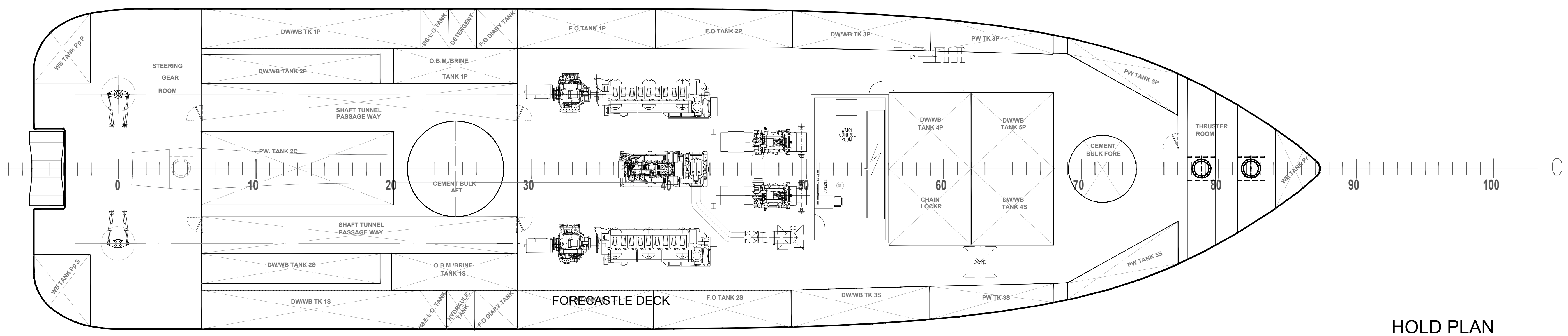
SHEET 2 / 3	NAME	VESSEL TYPE: AHTS - 100 TON	DATE ISSUED: APR - /17	APPROVAL DATE:
DRAWN BY:	FC		DWG: AHTS - 001	SIGNATURE:
CHECKED BY:	MJ	DRAWING: GENERAL ARRANGEMENT	REVISION N° 001	
APPROVED BY:			SCALE: 1 : 200	SIZE: A3



MAIN DECK



HOLD PLAN

PRINCIPAL PARTICULARS

LENGTH, OVERALL.. 65.000 m
LENGTH, WATERLINE................................... 60.320 m
BEAM, MOULDED... 15.14 m
DEPTH, MOULDED:.. 6.58 m
DESIGN DRAFT... 5.21 m
FRAME SPACING... 2.813 m
BUTTOCK SPACING..1.500 m
WATERLINE SPACING.......................................1.000 m
SECTION SPACING (from FR 0 to FR 21)..........2.183 m

GENERAL NOTES:

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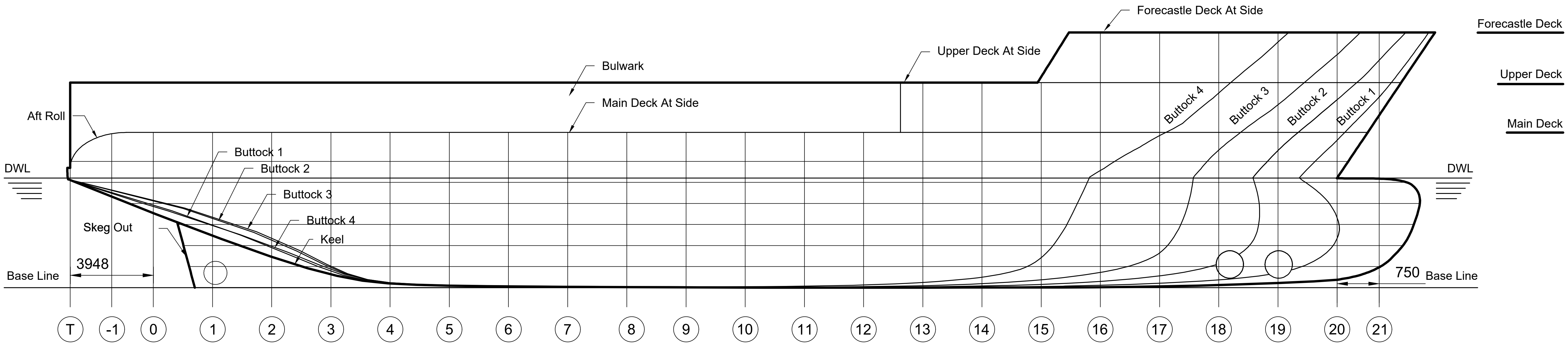
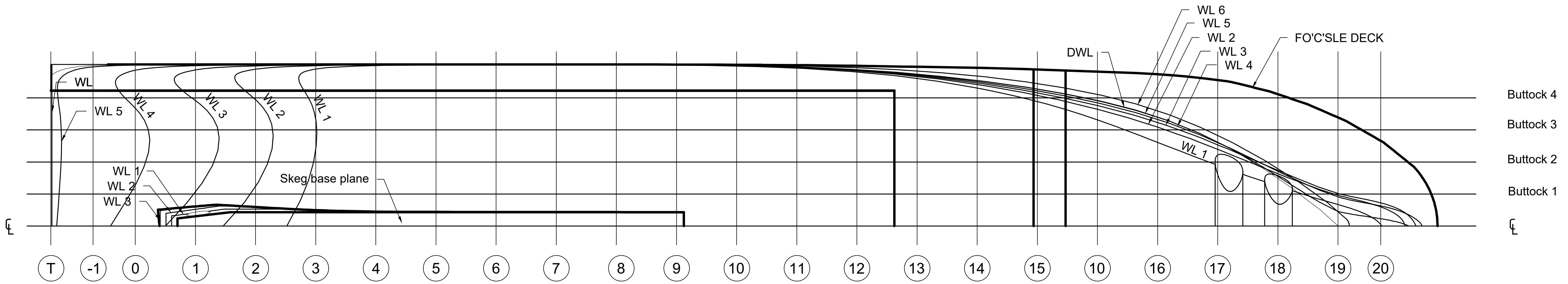
APPROVED BY:			SCALE: 1 : 200	SIZE: A3

LONGITUDINAL PROFILE VIEW





PLAN VIEW

PRINCIPAL PARTICULARS

LENGTH, OVERALL.. 65.000 m
LENGTH, WATERLINE................................... 60.320 m
BEAM, MOULDED... 15.14 m
DEPTH, MOULDED:.. 6.58 m
DESIGN DRAFT... 5.21 m
FRAME SPACING... 2.813 m
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SECTION SPACING (from FR 0 to FR 21)..........2.813 m

GENERAL NOTES:

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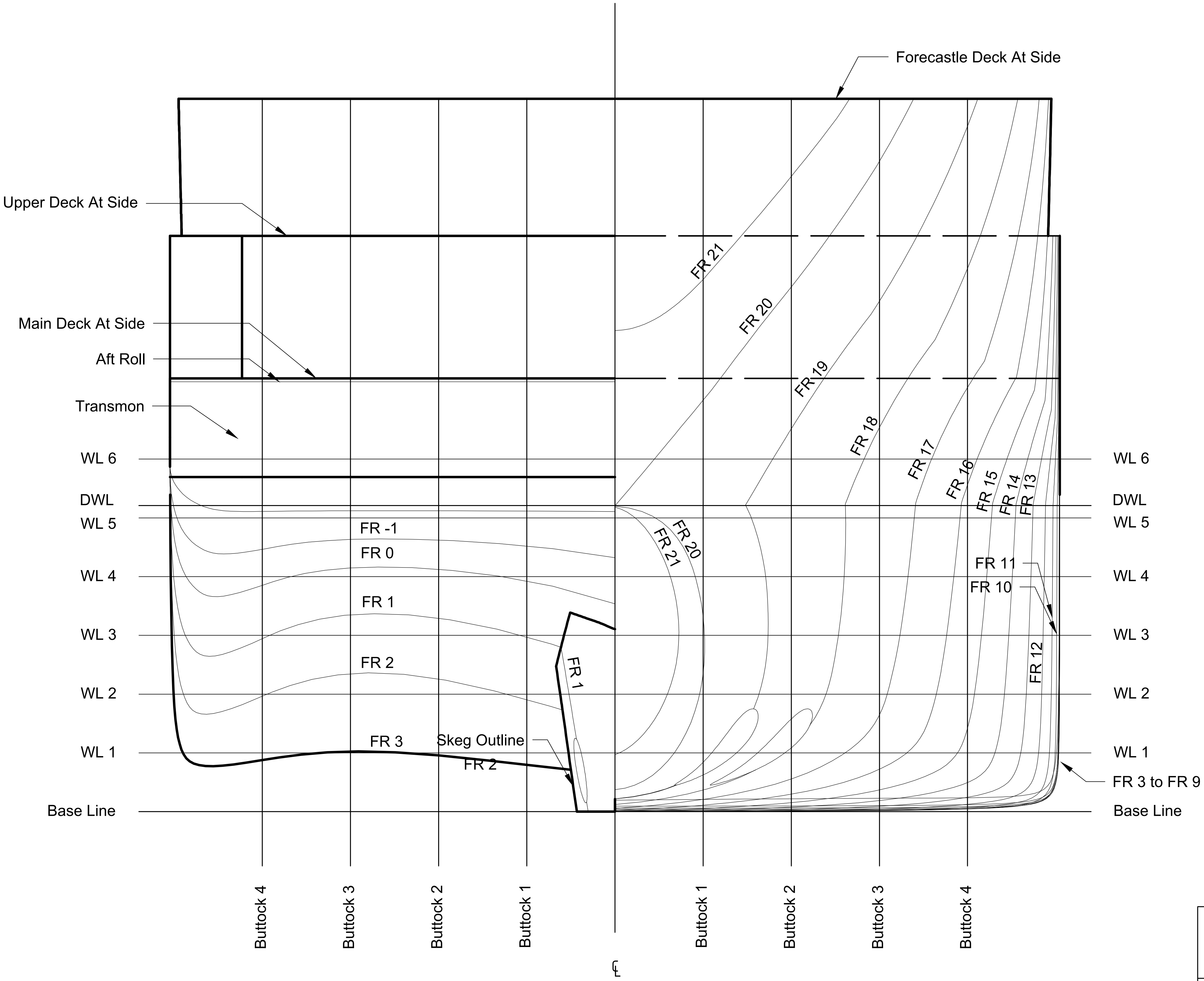
SHEET 1 / 2	NAME	VESSEL TYPE: AHTS - 100 TON	DATE ISSUED: APR - 13 /17
DRAWN BY:	GD		DWG: AHTS - 001
CHECKED BY:	NM	PLANE: LINES PLAN	REVISION N° 001
APPROVED BY:	MJ		SCALE: 1 : 200 SIZE: A3



BODY PLAN

PRINCIPAL PARTICULARS

LENGTH, OVERALL.. 65.000 m
LENGTH, WATERLINE.................................. 60.320 m
BEAM, MOULDED.. 15.14 m
DEPTH, MOULDED:... 6.58 m
DESIGN DRAFT... 5.21 m
FRAME SPACING... 2.813 m
BUTTOCK SPACING...1.500 m
WATERLINE SPACING.......................................1.000 m
SECTION SPACING (from FR 0 to FR 21)..........2.183 m

GENERAL NOTES:

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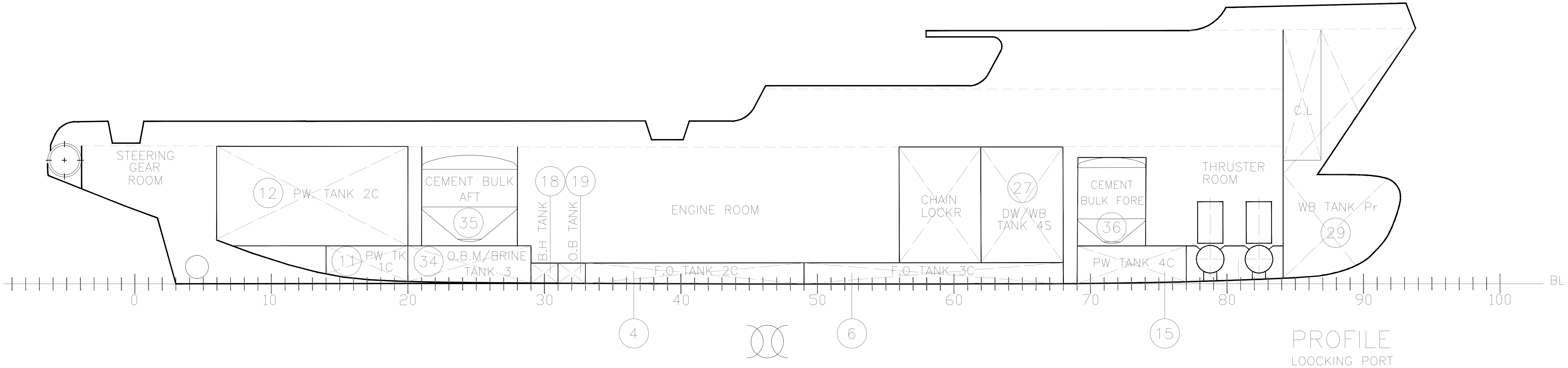
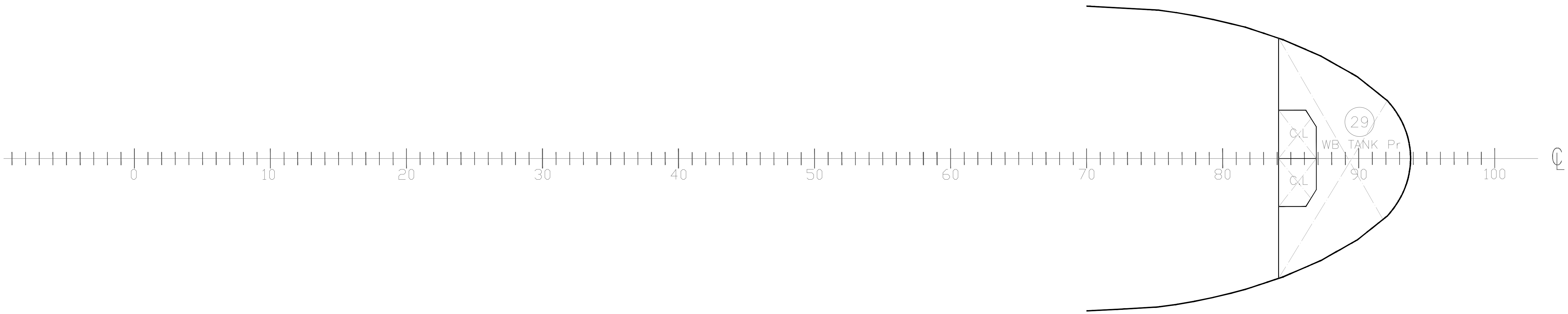
CHECKED BY:	NM	PLANE: LINES PLAN	REVISION N° 001
APPROVED BY:	MJ		SCALE: 1 : 200 — SIZE: A3



PROFILE

LOOCKING PORT



BELOW FORECASTEL-DECK

12000 ABOVE BL

GENERAL NOTES:

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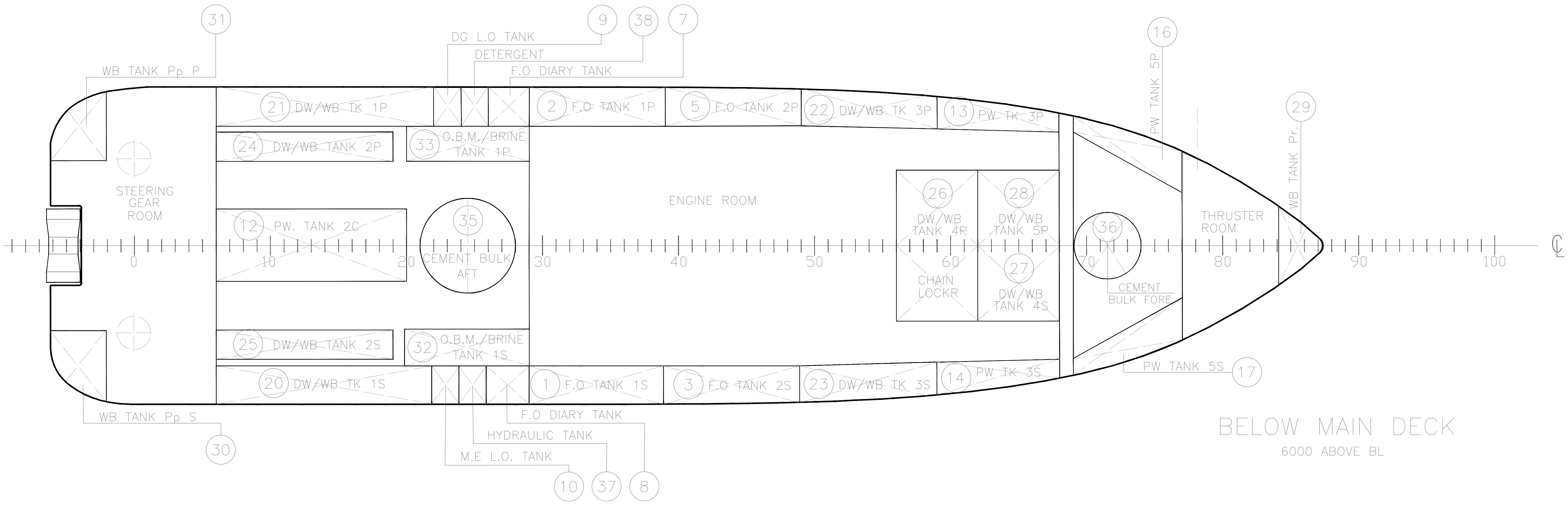
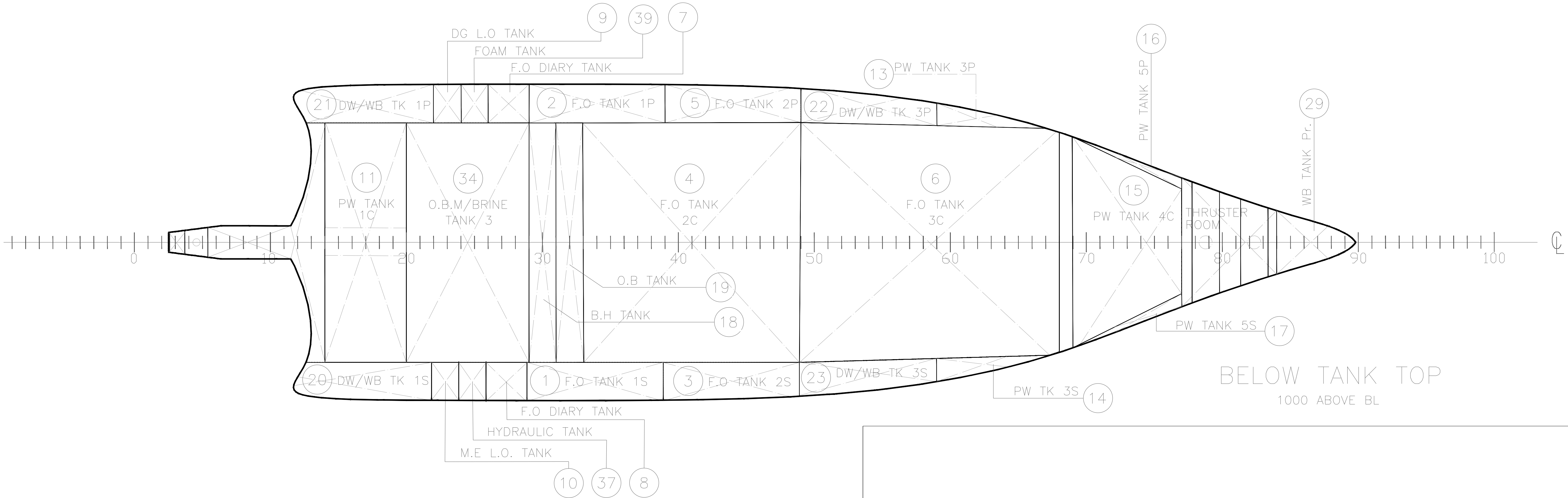
DRAWN BY:	FC		DWG: AHTS - 001	SIGNATURE:
CHECKED BY:	MJ	DRAWING: **TANK PLAN**	REVISION N° 001	
APPROVED BY:			SCALE: 1 : 200	SIZE: A3





GENERAL NOTES:

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DRAWN BY:	FC		DWG: AHTS - 001	SIGNATURE:
CHECKED BY:	MJ	DRAWING: TANK PLAN	REVISION N° 001	
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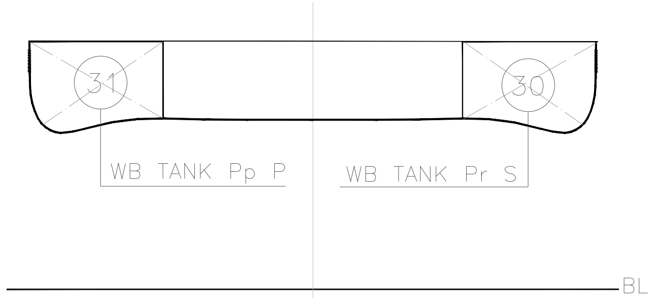
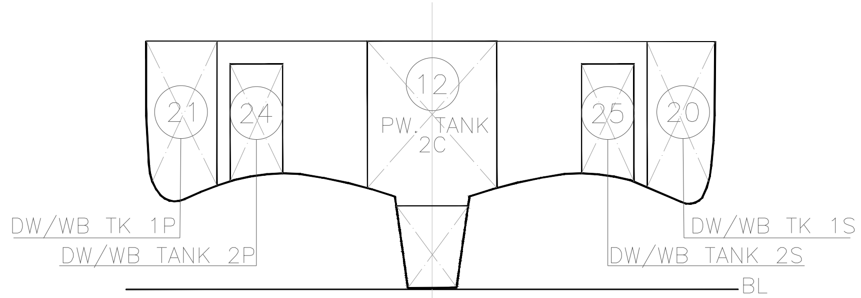
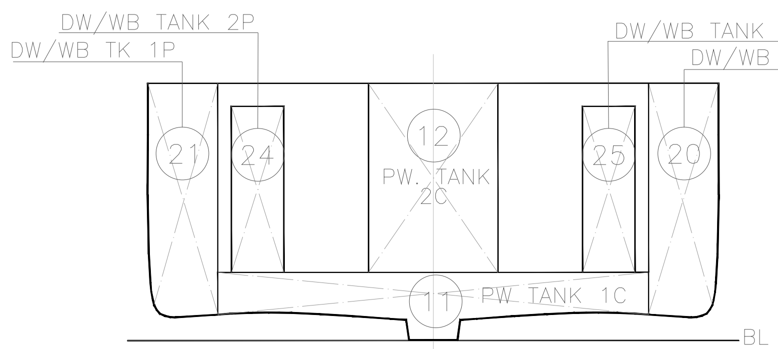


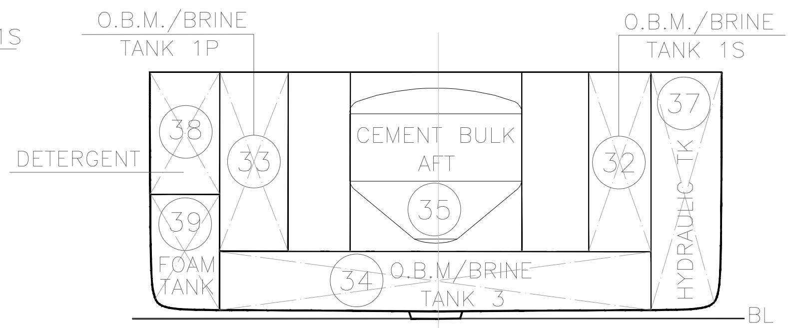
FR. −2



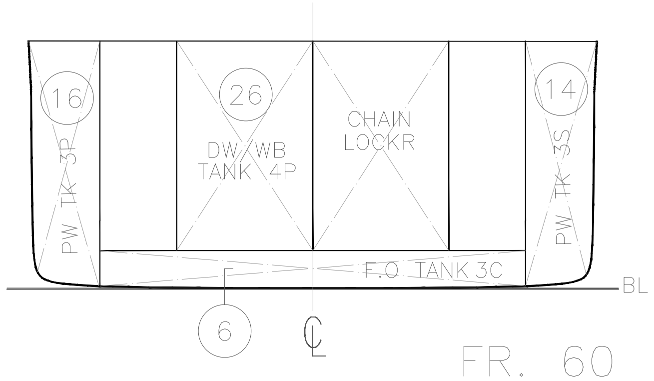
FR. 13



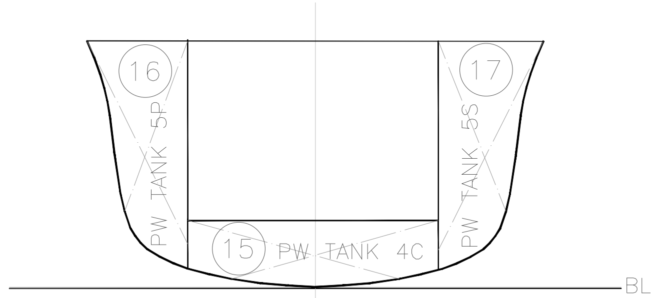
FR. 17



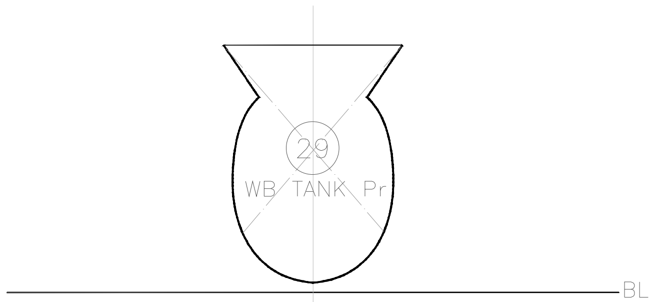
FR. 25



FR. 60



FR. 75



FR. 84

TANK NO.	TANK ID.	FRAME MIN. #	FRAME MAX. #	CONTENTS	DENSITY (T/M³)	VOLUME (M³)	WEIGHT (T)	CENTER OF GRAVITY (M) LCG (AP)	VCG (BL)	TCG (CL)
	FUEL OIL TANKS									
1	FO TANK 1S	29	39	FO	0.840	73,678	62,405	22.099	6.650	3.356
2	FO TANK 1P	29	39	FO	0.840	108,331	91,756	26.663	0	0.508
3	FO TANK 2S	39	49	FO	0.840	73,678	62,405	22.099	−6.650	3.356
4	FO TANK 2C	33	49	FO	0.840	108.331	91.756	28.552	−6.620	3.378
5	FO TANK 2P	39	49	FO	0.840	71,028	60,161	28.552	6.620	3.378
6	FO TANK 3C	44	68	FO	0.840	114,635	97,096	37.675	0	0.537
7	FO DIARY TANK	26	29	FO	0.840	22,051	18,677	17.875	−6,651	3.367
8	FO DIARY TANK	26	29	FO	0.840	22,051	18,677	17.875	6.651	3.367
	SUBTOTAL F.O					777,164	652,818	27.509	0	2.227
	LUBE OIL TANKS									
9	D.G L.O TANK	22	24	LO	0,910	13.866	12.618	14.950	−6.650	3,382
10	M.E L.O TANK	22	24	LO	0,910	13.866	12.618	14.950	6.650	3.382
	SUBTOTAL L.O					27,732	25,236	14.950	0	3.382
	POTABLE WATER									
11	PW TANK 1C	14	20	PW	1,000	67.057	67.057	11.142	0	1.020
12	PW TANK 2C	6	20	PW	1,000	136.899	136.899	8.527	0	4.453
13	PW TANK 3P	49	68	PW	1,000	32.451	32.451	40.843	−6.033	3.992
14	PW TANK 3S	49	68	PW	1,000	32.451	32.451	40.843	6.033	3.992
15	PW TANK 4C	69	77	PW	1,000	55.462	55.462	47,144	0	1,044
16	PW TANK 5P	69	77	PW	1,000	25.743	25.743	47,976	−4,266	3,880
17	PW TANK 5S	69	77	PW	1,000	25.743	25.743	47,976	4,266	3,088
	SUBTOTAL P.W					375.804	375.804	25.678	0	3,106
	OILY WATER AND BILGE									
18	B.H TANK	29	31	BIL	0,913	13.313	12.115	20,801	0	0,516
19	O.B TANK	31	33	BIL	0,913	13.212	12.023	19,501	0	0,520
	SUBTOTAL BILGE					26.525	24.138	20,153	0	0,518
	DRILL WATER/BALLAST WATER									
20	DW/WB TANK 1S	6	22	DW	1.000	102.172	102.172	9,487	6.646	3.727
21	DW/WB TANK 1P	6	22	DW	1.000	102.172	102.172	9.487	−6.646	3.727
22	DW/WB TANK 3P	49	59	DW	1.000	60.567	60.567	34.957	−6.427	3.532
23	DW/WB TANK 3S	49	59	DW	1.000	60.567	60.567	34.957	6.427	3.532
24	DW/WB TANK 2P	6	19	DW	1.000	45.634	45.634	8.305	−4.702	3.995
25	DW/WB TANK 2S	6	19	DW	1.000	45.634	45.634	8.305	4.702	3.995
26	DW/WB TANK 4P	56	F.E	DW	1.000	61.285	61.285	38.350	−1.800	3.250
27	DW/WB TANK 5S	62	68	DW	1.000	61.285	61.285	42.250	1.800	3.250
28	DW/WB TANK 5P	62	68	DW	1.000	61.285	61.285	42.250	−1.800	3.250
29	WB TANK Pr	84	F.E	WB	1,025	194.097		56.546	0	8.114
30	WB TANK Pp S	−6	−2	WB	1,025	15.967		−2.492	0	0,516
31	WB TANK Pp P	−6	−2	WB	1,025	15.967		−2.492	−5.780	5.657
	SUBTOTAL DRILL WATER					826.630	832.240	31.624	−0.136	4.800
	OIL BASED MUD/BRINE									
32	O.B.M./BRINE TANK 1S	20	29	MUD	2.400	41.755		15.925	4.876	3.900
33	O.B.M./BRINE TANK 1P	20	29	MUD	2.400	41.755		15.925	−4.876	3.900
34	O.B.M./BRINE TANK 3	20	29	MUD	2.400	106.741		15.946	0	0.938
	SUBTOTAL O.B.M					190.251		15.937	0	2.238
	CEMENTO BULK									
35	C.B Aft	21	28	CEM	2.400	64.026	89.636	15.925	0	3.900
36	C.B Fore	69	74	CEM	2.400	66.203	92.684	36.475	0	3.900
	SUBTOTAL CEMENTO					130.228	182.320	31.455	0	2.238
	OTHER TANKS									
37	HYDRAULIC TANK	24	26	OTHERS	0.960	14.662	14.075	16.250	6.651	3.374
38	DETERGENT	24	26	OTHERS	0.900	7.154	6.439	16.251	−6.642	1.731
39	FOAM	24	26	OTHERS	0.960	7.507	7.207	16.250	−6.660	4.940
	SUBTOTAL EXTRA CONSUMABLES					29.324	27.722	16.250	0.103	3.400

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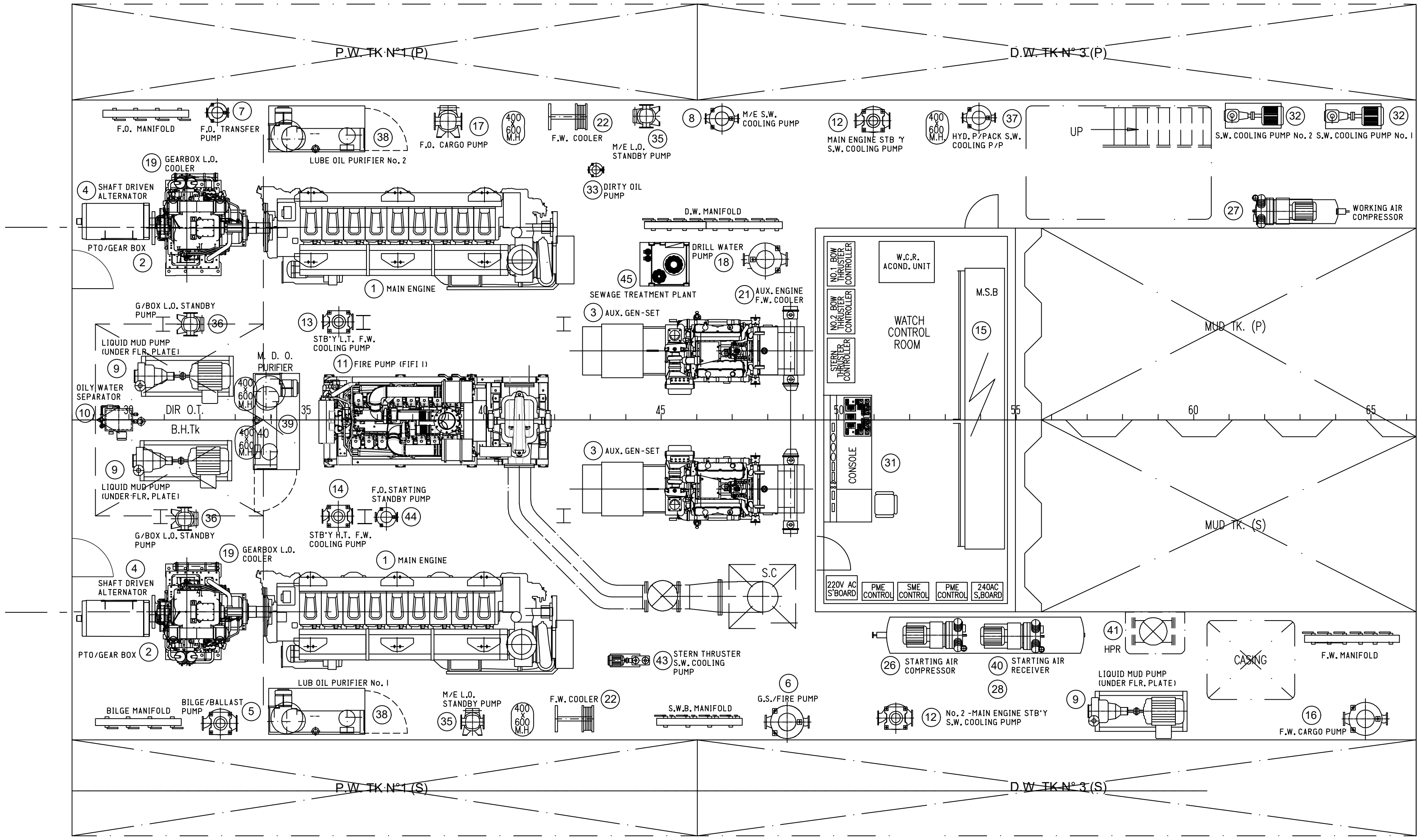
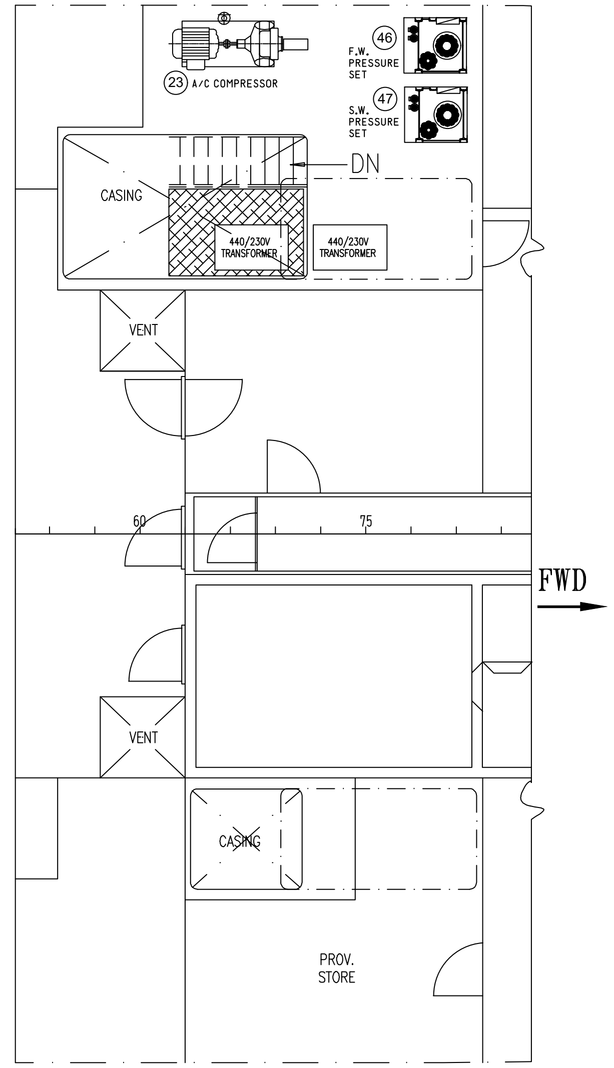
CHECKED BY:	MJ	DRAWING: TANK PLAN	REVISION N° 001	
APPROVED BY:			SCALE: 1 : 200	SIZE: A3



BELOW MAIN DECK PLAN



MAIN DECK PLAN

NO.	DESCRIPTION	QTY.	CAPACITY	REMARKS
1	MAIN ENGINE	2	3000 kW AT 600 RPM	MAK 6M 32C
2	GEAR-BOX	2	GEAR RATIO: 4.90 :1	SCV 68-P46 / PTO 1800Kw@1800RPM
3	AUXILIARY GENSET	2	600 kW @ 400V/3PH/50HZ	ECM-750/CCFJ600J
4	SHAFT DRIVEN ALTERNATOR	2	600 kW @ 400V/3PH/50HZ	MARATHON MX-H-630-4
5	BILGE/BALLAST PUMP	1	75 M3/HR @ 40 M.HD.	AZCUE CM-EP 80/20R
6	G.S./FIRE PUMP	1	75 M3/HR @ 40 M.HD.	AZCUE CM-EP 80/20R
7	F. O. TRANSFER PUMP	1	75 M3/HR @ 40 M.HD.	AZCUE CM-EP 80/20R
8	MAIN ENGINE S. W. COOLING PUMP	2	120 M3/HR @ 25 M.HD.	AZCUE VM-100/26
9	LIQUID MUD PUMP	3	100 M3/HR @ 75 M.HD.	MISSION MAGNUM 4x3x13
10	OILY WATER SEPARATOR	1	10 M3/HR @ 40 M.HD.	AZCUE LN 32/160
11	FIRE PUMP (FIFI 1)	1	1268 kW @ 2400 M3/HR	HYDRODIESEL FIREPAK 2400
12	MAIN ENGINE STB'Y S.W. COOLING PUMP	1	150 M3/HR @ 30 M.HD.	AZCUE VM-100/33
13	STB'Y H.T. F.W. COOLING PUMP	1	33 M3/HR.@ 33 M.HD.	AZCUE MN-40/125
14	STB'Y L.T. F.W. COOLING PUMP	1	33 M3/HR.@ 33 M.HD.	AZCUE MN-40/125
15	MAIN SWITCHBOARD	1	–	ELECTRO MARINE SERV.

NO.	DESCRIPTION	QTY.	CAPACITY	REMARKS
16	F. W. CARGO PUMP	1	75 M3/HR @ 40 M.HD.	AZCUE CM-EP 80/20R
17	F. O. CARGO PUMP	1	150 M3/HR.@ 75 M.HD.	AZCUE BT-LV110T-F
18	DRILL WATER PUMP	1	100 M3/HR.@ 75 M.HD.	AZCUE CM-EP 80/20R
19	GEARBOX L. O. COOLER	2	45 KW	MOUNTED
20	REFEGER'N PLANT CONDENSER	2	1.75 KW COOLING CAPACITY	BITZER TYPE IV/ TORRENT MT3 (BOW THRUSTER)
21	AUX. ENGINE F.W. COOLER	2		MAKER'S SUPPLY
22	MAIN ENGINE F.W. COOLER	2	21.84 M2	ALFA LAVAL / M10-BFM
23	A/C COMPRESSOR	2	25 KW COOLING CAPACITY	CARRIER (MAIN DECK)
24	A/C CONDENSER	1		MT-50 (MAIN DECK)
25	E/RM SUPPLY FAN	2	34000 M3/HR	HISON
26	STARTING AIR COMPRESSOR	2	38 M3/HR; 30 BAR W.P.	SPERRE HL2/90
27	WORKING AIR COMPRESSOR	1	51 M3/HR; 7 BAR W.P.	INGERSOLL RAND 2545A
28	STARTING AIR RECEIVER	2	1000 LITRES	M/E MAKER'S SUPPLY
29	M/E EXHAUST SILENCER	2	600A SPARK ARRESTOR	M/E MAKER'S SUPPLY
30	A/E EXHAUST SILENCER	2	200A SPARK ARRESTOR	A/E MAKER'S SUPPLY

NO.	DESCRIPTION	QTY.	CAPACITY	REMARKS
31	ENGINE CONTROL CONSOLE	1		
32	A/C S. W. COOLING PUMP	2	60 M3/HR @ 25 M.HD.	AZCUE CA80/7A
33	DIRTY OIL TRANSFER PUMP	1	65 M3/HR @ 25 M.HD.	AZCUE CA80/7A
34	DECK MACHINERY HYD POWER PACK	1	2 x PVP100362362RHLA	IN TOWING WHICH HOUSE PORTSIDE
35	M/E L.O. STANDBY PUMP	2	50 M3/HR @ 80 M.HD.	AZCUE BT-LV 90T
36	G/BOX L. O. STANDBY PUMP	2	2.4M3/HR @150BAR;5.7M3/HR@5BAR	PARKER P31B197BIQ017-25**07/1
37	HYD. P/PACK S.W. COOLING P/P	1	25 M3/HR @ 30 M.HD.	AZCUE VM-EP 50/16R
38	L. O. PURIFIER	2	RATED CAP.: 400L/HR.	OSC 5-02-066/4
39	M. D. O. PURIFIER	1	RATED CAP.: 1300 L/HR.	OSC 5-02-066/4
40	WORKING AIR RECEIVER	1	250 LITRES; 7 BAR W.P.	
41	HPR	1	HIPAP 500	KONGSBERG DP2
42	OILY BILGE PUMP	1	0.4Kw/15 PPM BILGE ALARM	TAIKO KIKAI USC-10 X LD-1NSA
43	STERN THRUSTER S.W. COOLING PUMP	1	2.0 M3/HR @ 25 M.HD.	AZCUE, SP-BO 19/20
44	F. O. STARTING STANDBY PUMP	1	65 M3/HR @ 25 M.HD.	AZCUE CA80/7A
45	SEWAGE TREATMENT PLANT	1	PERSONS ON BOARD 22	HAMANN HL - CONT 0125
46	F.W.PRESSURE SET	1	2 X 1,13 KW	AZCUE
47	S.W. PRESSURE SET	1	2 X 1,13 KW	AZCUE

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DRAWN BY:	IL		DWG: AHTS - 001
CHECKED BY:	NM	DRAWING: ENGINE ROOM ARRANGEMENT	REVISION N°: 001
APPROVED BY:	MJ		SCALE: 1 : 100 / SIZE: A3