ARGENTINIAN NATIONAL TECHNOLOGICAL UNIVERSITY
BUENOS AIRES FACULTY

DR. JAMES A. LISNYK STUDENT SHIP DESIGN COMPETITION 2025

PROJECT OF A 75-TON BP GREEN POWERED AHTS

MAKING WAVES IN THE MARITIME INDUSTRY

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.

STUDENT NAME	SIGNATURE
BALTAZAR PABLO HUMARAN KILLAMET *(Team Leader)*	
PEDRO GUASTALEGNAME	
TOMAS AGUSTIN MUENA	
AGUSTIN GARCIA	
MARCIO SALNISKY	
MANUEL PAPALEO	

MAXIMILIANO FABIAN MAVICA

FACULTY ADVISOR

SNAME MEMBER ID

20103114

OWNER'S REQUIREMENTS FOR A 75-TON BP GREEN POWERED AHTS

Introduction

This document establishes the owner's technical and operational requirements for the construction and outfitting of a 75-ton Bollard Pull Anchor Handling Tug Supply (AHTS) Vessel. The vessel is intended for operations in the Argentinean Sea, supporting the upcoming deployment of deepwater platforms in the region, with the flexibility to operate in Brazilian waters as an alternative service route.

The vessel must be designed to efficiently transport cargo, heavy machinery, pipelines, anchors, chains, passengers, and provisions for offshore platform crews. Additionally, it must be equipped to carry out anchor handling, towing, fire-fighting operations, and oil spill response activities.

In alignment with modern environmental and regulatory standards, the vessel shall incorporate low-emission and energy-efficient technologies, ensuring compliance with international sustainability initiatives and minimizing its ecological footprint.

Navigation Routes

The vessel must be capable of operating across various offshore locations, specifically:

- **Primary route:** Between offshore platforms in the Northern Argentinean Basin (Cuenca Argentina Norte) and the port of Mar del Plata (Buenos Aires, Argentina).

- **Secondary route:** The vessel must also be able to reach the ports of Rio de Janeiro (Brazil) to provide services to deepwater platforms in Brazilian waters.

Speed & Endurance

The vessel shall be capable of achieving an **economic service speed of 12.5 knots**, ensuring an operational range of at least 4,000 nautical miles, considering an optimal sea margin.

During **sea trials** at 100% Maximum Continuous Rating (MCR), the vessel should demonstrate an additional speed margin of at least 1 knot above the economic service speed.

Bollard Pull

The vessel shall be designed to achieve a bollard pull of at least 75 metric tons when developing 100% of the installed power.

Deck Load Capacity

To ensure the efficient transportation of heavy machinery, pipelines, anchors, and chains, the vessel's deck shall be designed for a minimum load capacity of 7.5 Metric tons per square meter.

Design considerations

Limiting Particulars

The vessel's size shall be constrained by operational and port infrastructure limitations:

- <u>Length:</u> no more than 75 meters.

Due to terminal size restrictions

- <u>Draft:</u> no more than 7 meters.

The vessel's design draft must remain within this limit to ensure accessibility to the ports.

Seakeeping

Given the challenging weather conditions along the vessel's operational routes, the vessel must be designed to provide safe and comfortable operational conditions for the crew. The seakeeping performance shall be evaluated based on established industry criteria, ensuring operational efficiency and crew well-being. The vessel must demonstrate adequate seakeeping capabilities across its designated routes, considering the environmental conditions characteristic of each region.

Special design features

Environmental sustainability

The vessel's design must prioritize environmental sustainability, incorporating features that actively reduce emissions.

Compliance with MARPOL Annex VI is mandatory, ensuring adherence to NOx, SOx, and greenhouse gas (GHG) emission limits.

The vessel shall be Tier III compliant, in anticipation of stricter future environmental regulations governing low-emission propulsion systems.

Integration of energy-efficient propulsion systems and alternative fuel capabilities should be considered to further reduce environmental impact.

Anchor handling & towing equipment

The vessel must be equipped with a main winch with a minimum capacity of 150 Metric tons.

Dynamic positioning system

A DP-2 dynamic positioning system with redundancy shall be installed, ensuring high-precision station-keeping capabilities.

Regulations

The vessel shall adhere to the latest editions of the following international and national regulations:

- International Load Lines Convention (ILLC), 1966.
- Argentina National Coast Guard Regulations (REGINAVE), 2024.
- Marine Pollution Prevention (MARPOL), 1973/1978.
- Safety of Life at Sea (SOLAS), 1974.
- International Regulations for Preventing Collisions at Sea (COLREG), 1972.
- International Labour Organization (ILO).
- All applicable regulations established by the International Maritime Organization (IMO).

Classification

The vessel shall be designed in compliance with the latest standards of the American Bureau of Shipping (ABS), with the following class notation:

- +A1, Offshore Support Vessel (AH, Supply, Tow).

Alternatively, an equivalent classification from any International Association of Classification Societies (IACS) member may be accepted.

Registry

The vessel shall be registered under the Argentinean flag, ensuring full compliance with national maritime regulations.

Crew complements

The vessel shall be manned in compliance with Argentinean registry regulations, ensuring safe and efficient operation while meeting all applicable minimum crewing requirements.

TABLE OF CONTENT

List of Figures

List of Tables

ACKNOELEDGMENTS

Eng. Jose Oscar Alvarez – Director of Naval Engineering department – UTN FRBA

Eng. Nancy Figueroa – Technical Secretary of Naval Engineering department – UTN FRBA

Eng. Agustin Serra – Professor at “Ship Design” - UTN FRBA

Eng. Rodolfo Francisco Rioja – 2nd Professor at “Structural Calculation for Ships” - UTN FRBA

Eng. Nicolas Agustin Imprenta – 2nd Professor at “Naval Drawing” - UTN FRBA

Eng. Esteban D’addino – 2nd Professor at ““Ship Design” - UTN FRBA

Eng. Ignacio Lozano - 3rd Professor at ““Ship Design” - UTN FRBA

LIST OF ABBREVIATIONS

Δ	Displacement	I_T	Momentum of Inertia
A	Area	KB	Height of center of buoyancy
A_0	Disc area	kg	Kilograms
ABS	American Bureau of Shipping	KG	Vertical center of gravity
A_E	Expanded area	Kq	Torque coefficient
AWA	Apparent wind angle	Kt	Thrust coefficient
EN	Equipment Number	kts	Knots
A_W	Waterplane area	l	Liters
A_X	Midship area	LCG	Longitudinal centre of gravity
B	Beam moulded	Lll	Freeboard Length
BHP	Brake horse power	LCB	Longitudinal Center of Bouyancy
BL	Base line	LOA	Length overall
BP	Bollard Pull	Lpp	Length between perpendiculars
CO2	Carbon dioxide	LSW	Light Ship Weight
C_B	Block coefficient	L_{WL}	Length on the design waterline
Cd	Merit coefficient	MARPOL	International Convention for the Prevention of Pollution from Ships
CL	Center line	MCR	Maximum Continous Rating
C_P	Longitudinal prismatic coefficient	MDO	Marine diesel oil
C_W	Waterplane coefficient	MLC	Maritime Labour Convention
D	Depth	MS	Midship Section
DAR	Developed Area Ratio	MT	Metric Tonne
DHP	Delivered horse power	nm	Nautical miles
Dp	Propeller diameter	N	Engine Speed at MCR
DWT	Deadweight tonnage	P/D	Pitch diameter ratio
EAR	Expanded area ratio	PBU	Pressure Build-Up Unit
ECA	Emission Controlled Area	Q	Torque
EHP	Effective Horse Power.	Rn	Reynolds number
FB	Freeboard	rpm	Rotation rate in minutes^{-1}
Fn	Froude Number	SOLAS	International Convention for the Safety of Life at Sea

FR	Frame Reference	SFC	Specific Fuel Consumption
g	Acceleration due to gravity (9,81 m/s^2)	T	Draft
GA	General Arrangement	TCS	Tank Connection Space
GM	Metacentric height	TCG	Transverse center of gravity
H	Draft	TWA	True wind angle
h_{db}	Height of double bottom	Vs	Service Speed
HVAC	Heating, ventilation and air conditioning	VCG	Vertical center of gravity
IMO	International Maritime Organization	z	Blades number
ISO	International Standards Organization	S	Wetted surface

0 EXECUTIVE SUMMARY

This project was conceived to meet the owner's requirements for an Anchor Handling Tug Supply (AHTS) vessel, specifically designed to operate in future deep-water platforms in the Argentine Sea. To provide added versatility, the vessel was also designed to operate along the southern Brazilian coast.

The design team consists of one senior student and five advanced students from the Naval Engineering Department at the National Technological University, Buenos Aires Regional Faculty. The team worked under the guidance of a faculty advisor acting as a mentor.

The design prioritizes minimizing environmental impact, ensuring full compliance with the latest IMO regulations and industry sustainability objectives. A key aspect of this commitment is the integration of methanol as an alternative fuel, aimed at reducing greenhouse gas (GHG) emissions while maintaining high operational efficiency. Since methanol typically requires greater storage volume than traditional diesel or HFO, this factor was carefully considered in the vessel's layout and tank arrangement.

The final design features a length overall of 66.34 meters, a length between perpendiculars of 57.8 meters, a beam of 16.1 meters, a depth of 6.9 meters, and a desing draft of 5.74 meters. The vessel has a displacement of 4197 Metric tons, with a service speed of 12.5 knots.

Although the vessel is primarily designed to operate on methanol, it is also capable of running on diesel fuel, allowing operational flexibility depending on cost or availability. In both fuel modes, it complies with IMO Tier III emission standards thanks to the installation of Selective Catalytic Reduction (SCR) systems on the exhaust lines.

The vessel employs electric propulsion and is equipped with two azipods. Propulsion is provided by three methanol-fueled engines, each rated at 1800 kW. Additionally, the vessel features two bow thrusters rated at 600 kW, as well as a winch with a pulling capacity of 250 Metric tons.

The vessel has the capacity to transport:

- 229 m³ of cement
- 245 m³ of drilling mud
- 847 m³ of drilling water/ballast
- 403 m³ of fresh water

It is also equipped to recover up to 245 m³ of spilled oil.

The vessel is outfitted with a Dynamic Positioning System (DP) Class 2, a bollard pull of 75 Metric tons, and a deck load capacity of 7.5 Metric tons/m².

In addition to its methanol fuel tanks, the vessel includes MDO tanks for use as pilot fuel and for the emergency generator.

To address one of the major design challenges associated with methanol (the need for cofferdams), an innovative technology for tank construction was implemented that eliminates the requirement for cofferdams altogether. This allows for more efficient use of internal volume and maximizes tank capacity dedicated to fuel storage.

The vessel was designed in compliance with American Bureau of Shipping (ABS) classification standards and the specific requirements of the Argentine Coast Guard (Prefectura Naval Argentina).

1 SUMMARY OF PRINCIPAL PARTICULARS

Dimension	Abbreviation	Value	Unit
Length, overall	LOA	66.34	m
Length, between perpendiculars	Lpp	57.8	m
Beam, moulded	B	16.1	m
Depth, moulded	D	6.9	m
Draft	H	5.74	m
Freeboard	FB	1.16	m
Full load displacement	Δ	4197	MT
Fuel Methanol	-	563	MT
Fuel Diesel Oil	-	37	MT
Light Ship Weight	LSW	1414	MT
LCG (from midship, positive forward)	LCG	27.9	m
VCG (from BL)	VCG	5.32	m
Service Speed	V_s	12.5	knots
Endurance (At service speed)	-	4620	nm
Crew	-	32	People
Total Power Installed	-	5800	kW
Configuration Adopted	3x1800kW		
Classification	ABS		
Notation	✠A1,Ⓔ ,Offshore Support Vessel (AH, Supply, Tow, FFV 1,OSP-S1), Methanol Fuel Ready, HYBRID [SCN],BWT, ✠DPS-2, EGC-SCR		

2 PROJECT OVERVIEW

2.1 Context

The AHTS vessel currently under development by our team is conceived as part of Argentina's growing offshore energy sector. Exploratory and future production activities are concentrated in offshore areas more than 300 kilometers off the coast of Mar del Plata. These projects are part of a national strategy to enhance domestic hydrocarbon production and reduce dependency on imports

The vessel will be specifically designed to provide integral support to both current and future offshore platforms along the Argentine coast. Exploration zones include the Northern Argentina Basin, particularly the blocks CAN 100, CAN 108, and CAN 114. Among them, Block CAN 100 stands out due to the Argerich Project, Argentina's first ultra-deepwater exploratory well, which aims to explore 15,000 km² at over 300 km off the coast of Buenos Aires, with a seabed depth of 1,527 meters. Blocks CAN 100 and 108 are located approximately 307 km offshore from the city of Mar del Plata, while CAN 114 lies at about 443 km.

Projects in depths greater than 1,000 meters require the use of floating platforms anchored to the seabed. The main factor determining the type of platform used is the seabed depth: fixed platforms, which do not require mooring systems with anchors and chains, are suitable for shallow waters. However, for deeper zones, semi-submersible platforms or similar structures that rely on advanced mooring systems are required.

This is precisely where anchor handling tug supply vessels become essential, as they are responsible for the deployment, tensioning, and maintenance of the mooring systems these platforms depend on.

While the Northern Basin is not yet in production, future developments are expected to use semi-submersible platforms, which makes the vessel under design particularly well-suited to operate in this context.

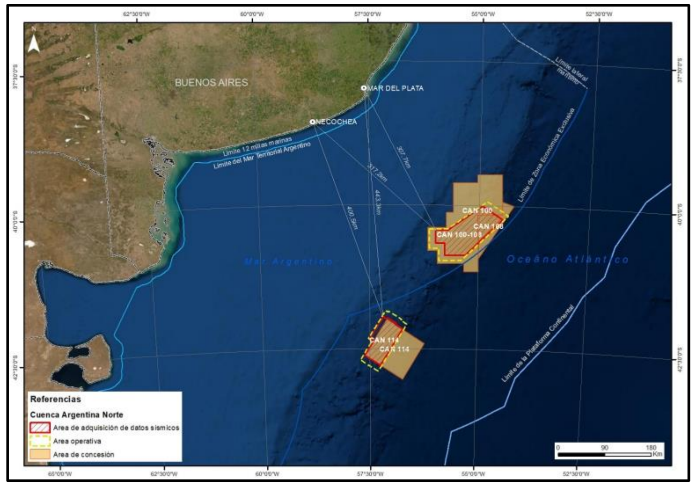


Figure 2.1-1. Northern Argentina Basin

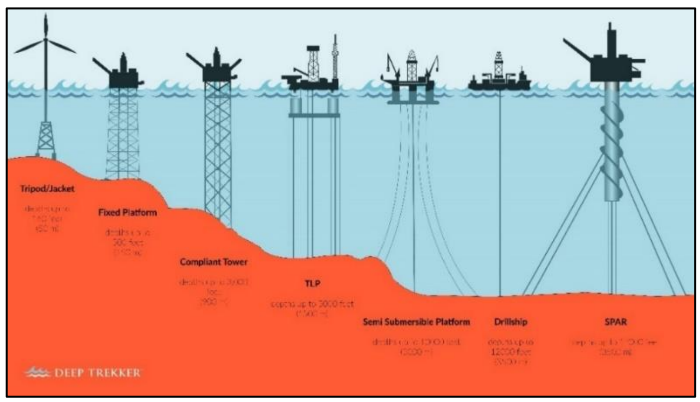


Figure 2.1-2. Offshore Platforms

To provide added versatility, the vessel has also been designed to operate along the southern coast of Brazil, where similar offshore activities are being carried out in deep and ultra-deep waters, particularly in the pre-salt region. This expanded operational scope not only enhances the commercial potential of the vessel but also ensures interoperability with regional offshore supply chains and infrastructure.

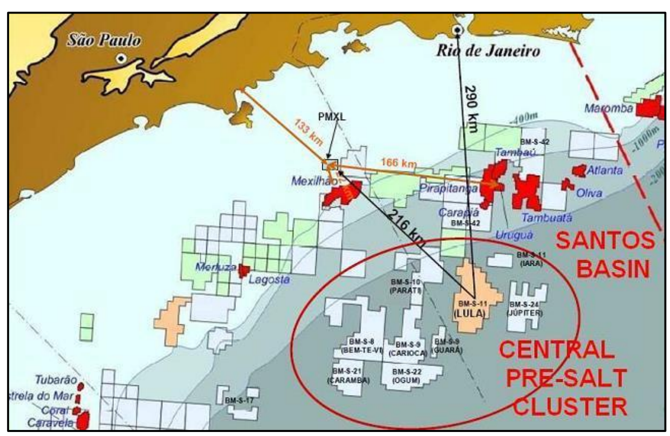


Figure 2.1-3. Pre-salt region

2.2 Vessel Mission and Capabilities of AHTS Vessels

Anchor Handling Tug Supply (AHTS) vessels play a critical and multipurpose role in offshore oil and gas operations. Their primary mission involves anchor handling for jack-up rigs, semi-submersible platforms, accommodation barges, and Floating Production Storage and Offloading (FPSO) units. AHTS vessels also support platform and barge repositioning, towage operations and external fire-fighting using high-mounted water monitors.

Figure 2.2-1- External fire-fighting operation.

These vessels are also equipped for oil spill response, carrying equipment such as inflatable booms, skimmers, storage tanks, and portable submersible hydraulic pumps. Alternatively, they may use dispersant liquids sprayed via rotating booms, powered by a seawater pump and dosing unit.
One key design difference between AHTS and standard Offshore Supply Vessels (OSVs) is the open stern of the AHTS, which facilitates towing cable and work gear transfer. Due to their specialized operations, AHTS vessels require significantly higher horsepower to achieve the necessary Bollard Pull (BP) for anchor handling and towing.

Figure 2.2-2- Offshore platform towing operation.

AHTS vessels typically feature small cranes for tasks like rescue boat handling, provisioning, and equipment transfer. Dynamic Positioning Systems (DPS) are standard, allowing them to maintain position using thrusters and propulsion control systems, which are essential during supply transfer operations offshore.

Figure 2.2-3- Offshore platform supply operation

Offshore Cargo Handling

Cargo carried by AHTS vessels is tailored to offshore drilling and production operations. Supplies are divided into two main types:

A) Bulk Cargo:

Includes both liquid and dry bulk materials transported in integrated tanks or hoppers. Liquid cargo comprises fuel, potable water, drilling water, brine, and oil-based mud. Dry cargo includes cement, barite, and bentonite. Specialized tanks with agitators or circulation systems are used for transporting oil-based mud to keep solids in suspension.

B) Deck Cargo:

- Tubulars: Drilling pipes and test tubes essential for well operations.
- Containerized Cargo: ISO or mini-containers used for food, chemicals, drill bits, etc.
- Other Deck Cargo: Includes large spares or replacement parts often required urgently.

Transporting deck cargo requires careful consideration of weather conditions and safety. Lashing systems, quick-release chains, and dedicated rails ensure secure stowage and ease of discharge.

Each voyage may impose limits on cargo based on deadweight, hull capacity, deck space, or vessel stability.

Anchor Handling Operations
Many offshore platforms use fixed anchors and chains to maintain position. AHTS vessels are uniquely equipped for this, with anchor handling/towing winches that include multiple gears for high torque at low speed or high speed at reduced torque. These winches may be powered hydraulically, electricallyl.
In summary, the AHTS vessel's mission is to provide robust logistical support, safe towing, anchor handling, fire-fighting, pollution response, and precise positioning to offshore oil and gas platforms, all while handling specialized cargo efficiently and reliably.


Figure 2.2-4- Anchor handling operation

3 POWERING AND PROPULSION CONCEPTS

3.1 Sustainable Fuels for AHTS

The objective of this section is to review and analyze potential alternative fuels for Anchor Handling Tug Supply (AHTS) vessels. Our analysis focuses on emission reduction, as well as the technical, economic, and practical factors, including fuel availability in the near-term future.

3.2 Introduction

The maritime industry is under increasing pressure to transition to sustainable fuels to reduce greenhouse gas (GHG) emissions and comply with stricter environmental regulations. The selection of alternative fuels must consider multiple factors, including emissions reduction potential, technical feasibility, economic viability, fuel availability, and operational practicality.

This report analyzes several alternative fuels:

- Liquefied Natural Gas (LNG)
- Methanol
- Ammonia
- Synthetic Natural Gas (SNG)
- Hydrogen
- Battery-Electric Systems

Assessing their advantages and disadvantages for implementation in AHTS vessels. After comprehensive evaluation, methanol is identified as the most feasible option for achieving decarbonization in this sector.

3.3 Alternative Fuels Analysis

3.3.1 Liquefied Natural Gas (LNG)

LNG has been widely adopted as a transitional fuel due to its ability to reduce CO_2 emissions by up to 20% compared to traditional marine fuels. Key considerations include:

- Lower Carbon Intensity: LNG produces significantly lower CO_2 and NO_x emissions than heavy fuel oil (HFO) and marine gas oil (MGO).
- Storage & Handling Challenges: Requires cryogenic storage at -162°C, which increases both capital and operational costs.
- Methane Slip Issue: Methane emissions from LNG combustion remain a major concern due to their high global warming potential.
- Infrastructure Availability: While LNG bunkering infrastructure is expanding, it remains limited in certain regions.

3.3.2 *Methanol*

Methanol has emerged as a strong candidate for decarbonizing AHTS vessels due to the following advantages:

- Storage at Ambient Conditions: Unlike LNG, methanol remains liquid at ambient temperature and pressure, reducing infrastructure complexity. However, methanol storage and fuel tanks take about 2.4 times more space than those for MGO-powered ships. This disadvantage is partially mitigated by the fact that methanol can be stored in conventional fuel tanks and even ballast tanks onboard, unlike LNG and H_2, which require cryogenic storage.
- Existing Supply Chain: Methanol is already widely transported as cargo, with established safety protocols in ports worldwide. There is extensive operational experience among officers, class surveyors, maritime authorities, and dry-docking yards. Additionally, the handling experience from methanol tankers and offshore vessels provides a solid foundation for its use as a fuel. Offshore vessels are thus better positioned to adopt methanol than container or dry cargo vessels.
- Engine Compatibility: Can be used in modified diesel engines with a small percentage of pilot fuel (MGO or biodiesel).
- Environmental Benefits: The potential for bio-methanol and e-methanol production enhances long-term sustainability. Methanol dissolves rapidly if spilled in seawater and is biodegradable. The lethal concentration for marine life is lower than that of fossil fuels.
- Higher Initial Costs: Methanol engines are currently more expensive, but costs are expected to decrease with increased adoption.
- Safety Considerations: Requires corrosion-resistant tanks and safety measures for handling toxic exposure risks. Methanol is corrosive, so tanks must be constructed from stainless steel or protected with corrosion inhibitors and special coatings if made from carbon steel. Lessons from methanol carriers and offshore vessels provide guidance on materials and maintenance standards.
- Fire & Explosion Risks: Methanol burns in concentrations from 6-36%, producing a blue, smokeless flame that is difficult to see in daylight. Liquid methanol and vapors must be kept away from ignition sources, and fuel tanks should be inerted to reduce explosion risks. Methanol vapors, being heavier than air, accumulate at deck level and in poorly ventilated areas such as engine room corners.

One of methanol's key advantages as an alternative fuel is that it offers a favorable energy density while remaining liquid at ambient conditions. Although producing green methanol is complex, its handling costs are low, simplifying storage and bunkering infrastructure at ports. Additionally, methanol is already a common cargo in many seaports worldwide, with established safety procedures for handling it as both cargo and fuel.

Methanol, along with LNG, has an advantage over other alternative fuels, as it is already included in the IGF Code, whereas ammonia and hydrogen require case-by-case approval under the alternative design principle.

A methanol-powered vessel can seamlessly transition between biomethanol and synthetic methanol, as well as biodiesel and E-MGO, depending on availability and preference.

3.3.3 *Ammonia*

Ammonia is a carbon-free fuel, meaning no CO_2 is emitted during combustion. However, its adoption faces several challenges.

One key advantage is that, like methanol, ammonia is already produced on an industrial scale and globally traded, primarily as a feedstock for fertilizers. This long-standing industrial use has led to well-established safety and handling protocols.

- No Carbon Emissions: A major advantage over fossil-based fuels.
- Combustion Characteristics: Ammonia has a relatively slow combustion rate, making it better suited for two-stroke diesel engines rather than four-stroke engines, which require specialized designs.
- Toxicity & Safety Risks: Ammonia is highly toxic and requires strict safety protocols. However, it is less flammable and explosive than hydrogen in all concentrations. Additionally, its strong odor at low ppm levels provides an early warning of leaks before reaching hazardous concentrations.
- Storage Advantages: Ammonia liquefies at only -33°C and has an energy density 2.9 times that of liquid diesel, allowing for more compact storage compared to other alternative fuels.
- Production Challenges: Most ammonia is currently produced using fossil fuels, and while green ammonia is under development, it remains in its early stages.

- Environmental Concerns: A significant challenge is the potential formation of nitrous oxide (N_2O) during combustion, a greenhouse gas with a global warming potential 270 times greater than CO_2.

3.3.4 *Synthetic Natural Gas (SNG)*

Synthetic Natural Gas (SNG) is a carbon-neutral alternative fuel produced using green hydrogen and captured CO_2.

Key aspects include:

- Chemical Composition: SNG is chemically identical to methane (CH_4), the primary component of LNG. However, since it is synthesized using green hydrogen, it is considered carbon-neutral.
- Mature Technology: The technological processes for SNG production are already well-established.
- Engine Compatibility: Its chemical composition makes it an ideal fuel for combustion in both two- and four-stroke dual-fuel engines.
- Seamless Transition: Since SNG is chemically identical to LNG, it can be progressively blended and utilized within existing LNG infrastructure.
- Cryogenic Storage Required: Like LNG, SNG must be stored at -162°C, which increases operational complexity.
- High Production Costs: The energy-intensive production process makes SNG less economically viable in the near term.

3.3.5 *Hydrogen*

Hydrogen is a promising zero-emission fuel, but its implementation in large-scale maritime applications faces significant obstacles. It is a highly combustible fuel with the notable advantage of producing only water vapor (H_2O) upon combustion, resulting in zero CO_2 or other greenhouse gas (GHG) emissions. However, hydrogen also presents several challenges that make its use as a fuel complex. The primary issues are its low volumetric energy density and extremely high flammability.

- No CO_2 Emissions: The only byproduct of combustion is water vapor.
- Storage & Infrastructure Limitations: Hydrogen requires cryogenic storage at -253°C or high-pressure tanks, which increases space and cost requirements. Despite this, it still occupies several times the volume of LNG. Additionally, the equipment required to store and handle liquid hydrogen is large and technologically complex. In practical applications, hydrogen fueling systems require six to seven times more installation space compared to conventional liquid fuel systems.
- Safety Concerns: High flammability and leakage risks demand specialized handling.
- Use in Fuel Cells: Hydrogen is more viable in fuel cells than in direct combustion engines for maritime use.
- Alternative Storage Method - LOHC (Liquid Organic Hydrogen Carrier): The third option for storing hydrogen is absorbing it in an organic liquid, such as dibenzyltoluene, known as LOHC. The liquid can be stored in conventional tanks and has handling characteristics similar to heating oils. This makes handling easier and safer, while also reducing the required storage volume. However, an additional storage tank is needed for the dehydrogenated liquid. The hydrogen is extracted from the liquid before being fed to a fuel cell or engine, minimizing the volumes of pure hydrogen onboard and thus reducing the risks associated with hydrogen.

Methanol, together with LNG, has the advantage over other fuels in that they are included in the IGF Code, while ammonia and hydrogen require case-by-case approval according to the alternative design principle.

3.3.6 *Battery-Electric Systems*

Battery technology is evolving, but its application in AHTS vessels remains limited. Current battery chemistries cannot power the entire vessel. However, batteries can play a valuable role in improving the specific fuel consumption of combustion engines by providing peak power and recovering kinetic energy from winches and cranes.

- High Efficiency: Electric motors and batteries are significantly more efficient than internal combustion engines.
- Energy Density Challenges: Batteries currently lack the energy density required for long-range maritime operations.
- Hybrid Potential: Batteries can complement other fuels by storing energy for peak power needs and load balancing.

Batteries can contribute to peak shaving and provide a power margin, allowing gensets to operate at a better engine load factor. These benefits apply to vessels with gensets, regardless of the fuel used.

3.4 Fuel Availability & Infrastructure Considerations

Fuel availability is a critical factor influencing the adoption of alternative fuels:

- LNG: Increasingly available, though some major ports still lack LNG infrastructure.
- Methanol: Already transported in bulk and handled in many ports, offering a more practical near-term solution.
- Ammonia & Hydrogen: Limited current infrastructure, with substantial investment required for future scaling.
- SNG: Could leverage existing LNG networks, but production at scale remains uncertain.

3.5 Fuel Selection Methanol as the Optimal Fuel for AHTS Vessels

After evaluating all alternative fuels, methanol emerges as the most viable option for AHTS vessels due to several key advantages:

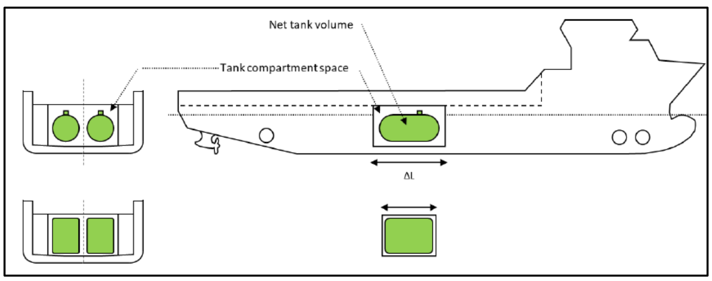


Figure 3.5-1. Methanol vs LNG storage comparison

1. Storage and Handling

Methanol does not require cryogenic or high-pressure storage, unlike LNG, ammonia, and hydrogen. It can be safely stored below the main deck in structural tanks, utilizing the vessel's hull-integrated space with appropriate coatings, sensors, pumps, and pipe connections. This optimizes space utilization without compromising cargo or operational capacity. In contrast, fuels like LNG, LPG, hydrogen, and ammonia require specialized pressure vessels that consume significant internal volume and increase costs.

Methanol has a higher energy density than other potential fuels, including LNG, ammonia, and hydrogen, especially when considering the size of storage tanks, secondary barriers, and cofferdams. This gives methanol a storage advantage, as less volume is required to store the same energy content, which is particularly beneficial for optimizing vessel space.

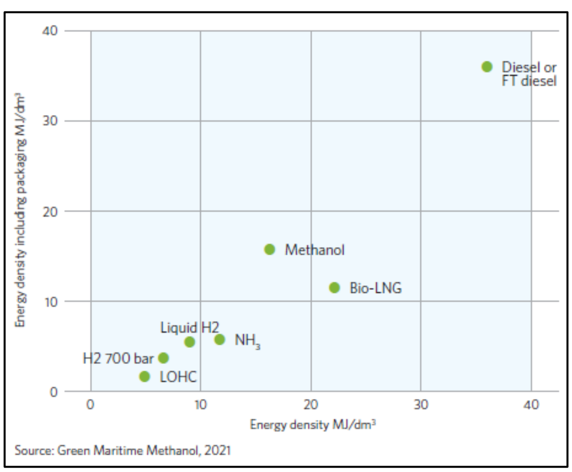


Figure 3.5-2-Energy Density of Different Fuel Types.

2. Availability and Infrastructure

Methanol benefits from an existing global supply chain, making it readily available in many ports. The infrastructure for its storage, handling, and distribution is already established, reducing logistical challenges compared to fuels that require extensive new infrastructure development.

3. Engine Compatibility

There are commercially available engines specifically designed for direct use with methanol, utilizing a pilot fuel system. These engines are reliable and ready for use with methanol as a primary fuel, facilitating a smooth integration into new vessel designs.

4. **Environmental Sustainability**

Methanol offers several environmental benefits over conventional marine fuels:

- Lower Emissions: Reduces SOX by 99%, PM by 95%, and NOX by up to 80% compared to HFO and MGO. While CO2 emissions from methanol vary depending on the production method, bio-methanol and e-methanol significantly reduce carbon emissions compared to conventional fuels, with no methane slip concerns.

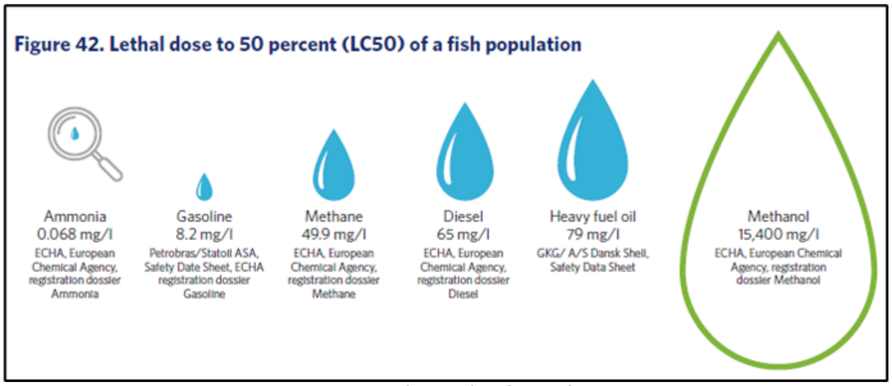


Figure 3.5-3. Lethal Dose for 50% (LC50) of a Fish Population

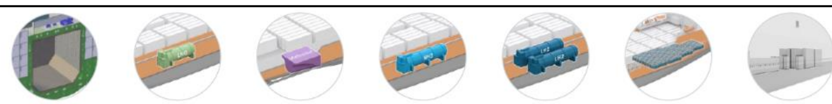
- Spill Impact: Being fully miscible in water, methanol dilutes rapidly in case of a spill and biodegrades within one to seven days, significantly reducing environmental risks. Microbes readily break it down into CO2 and water at concentrations below 3000 mg/l. However, methanol is toxic to aquatic organisms at concentrations above 1000 mg/l. To provide context, the LC50 (Lethal Concentration 50) for methanol in fish is 15,400 mg/l, compared to just 79 mg/l for HFO, meaning that an HFO spill is 200 times more toxic than a methanol spill of the same volume.

5. Fuel Redundancy and Risk Mitigation

While methanol is an excellent primary fuel, backup fuel options remain necessary for operational redundancy. Diesel is the most viable choice due to its global availability, ensuring stability in fuel costs and mitigating risks related to supply fluctuations. The engines used in methanol-powered vessels are also capable of running on diesel, providing additional flexibility. Moreover, these engines can function with other alternative fuels, further enhancing their versatility in case of supply shortages or sudden price changes, making them adaptable to changing market conditions.

6. Fuel Production and Future Scalability

The availability and cost of alternative fuels are difficult to predict with certainty. However, methanol has a strong case for long-term scalability due to its existing production infrastructure and the potential for cost reductions as bio-methanol and e-methanol production expand.



Fuel type	Low Sulphur Fuel Oil @ 20°C	Liquified Natural Gas @ -162°C	Methanol @ 20°C	Ammonia @ -33°C	Liquid Hydrogen @ -253°C	Compressed Hydrogen @ 350bar	Marine Battery Rack
Fuel price factor (per GJ)[1)]	1x	1.1x – 4.6x[2)]	2.6x – 5.5x[3)]	2.4x – 4.3x[4)]	3.6x – 4.6x[4)]	2.1x – 3.1x[4)]	2.0x – 5.3x[8)]
Fuel price factor in 2035, incl. carbon tax[1) 5)]	1x	0.8x – 1.4[2)]	0.8x – 1.6x[3)]	0.7x – 1.2x[4)]	1.2x – 1.5x[4)]	0.6x – 1.0x[4)]	0.8x – 2.0x[8)]
Gross tank size factor[6)]	1x	1.7x – 2.4x[7)]	1.7x	3.9x	7.3x	19.5x	~40x (~20x potential)

1) Fuel production cost estimate for 2025 and 2035; source: Maersk Mc-Kinney Møller Center for Zero Carbon Shipping – NavigaTE 2023; 2) Price range spans between fossil & electro- methane; 3) Price range spans between bio- & electro- methanol; 4) Price range spans between blue- & electro- ammonia/hydrogen; 5) Assuming 100% consumption subject to EU Fit-for-55, EU allowances at EUR 159/ton (source: Transport & Environment NGO); 6) Gross tank estimations based on Wärtsilä data; 7) 1.7x membrane tanks, 2.4x type C tanks; 8) Shore energy price EUR 0.1-0.27/kWh

Figure 3.5-4-Marine Fuel Comparison.

As illustrated in the Wärtsilä graph, methanol prices are projected to drop considerably over the next decade, eventually aligning with LNG prices. This trend further strengthens methanol's long-term viability and cost-effectiveness as a marine fuel option.

Conclusion

Methanol stands out as the most practical alternative fuel for AHTS vessels due to its superior storage efficiency, established supply chain, and significant environmental benefits. Unlike other alternative fuels that require costly and space-consuming pressure vessels, methanol can be seamlessly integrated into a new vessel design, minimizing the need for extensive modifications compared to other fuels. While challenges such as initial investment and fuel availability remain, methanol's green production potential and regulatory support make it a leading candidate for sustainable offshore operations.

4 REGULATIONS

This section outlines the most relevant regulations and standards that must be applied at this initial stage of the project, without constituting a complete list of all provisions in IMO circular MSC.1/Circ.1621 (2020) (Interim Guidelines for the Safety of Ships Using Methyl/Ethyl Alcohol as Fuel).

These regulations address key aspects related to the safety, operation, storage, and handling of alternative fuels such as methanol, as well as requirements for fuel supply systems, engines, and fire protection.

Compliance with these standards from the outset is essential to ensure the safety of personnel, environmental protection, and the integrity of the vessel. It also facilitates approval by classification societies and competent authorities, laying the groundwork for safe and efficient project development in subsequent phases.

4.1 Ship Design and Arrangement

The goal of this section is to ensure the safe location, proper space arrangements, and mechanical protection of power generation equipment, fuel storage systems, fuel supply equipment, and refueling systems.

This section provided the design team with a fundamental guideline that, among other things, facilitated the general arrangement and optimal placement of the equipment on board the ship.

> *5.2.2 Fuel containment systems, fuel piping and other fuel release sources should be located and arranged such that released fuel, either as vapour or liquid, is led to safe locations*
>
> *5.2.3 The access or other openings to spaces containing potential sources of fuel release should be arranged such that flammable. asphyxiating or toxic vapours or liquids cannot escape to spaces that are not designed for the presence of such substances.*
>
> *5.3.1 Tanks containing fuel should not be located within accommodation spaces or machinery spaces of category A.*

- Interpretation of Paragraph 5.3.1 of MSC.1/Circ.1621 (IACS UI GF20, October 2024) by ABS:
  Integral methyl/ethyl alcohol tanks may be placed between the aftmost and foremost boundaries of them machinery spaces of Category A, provided that a cofferdam of at least 600mm width with A60 insulation is fitted between the tank and the machinery space. Integral Tanks arranged accordingly are not regarded asbeing with Machinery Space of Category A.

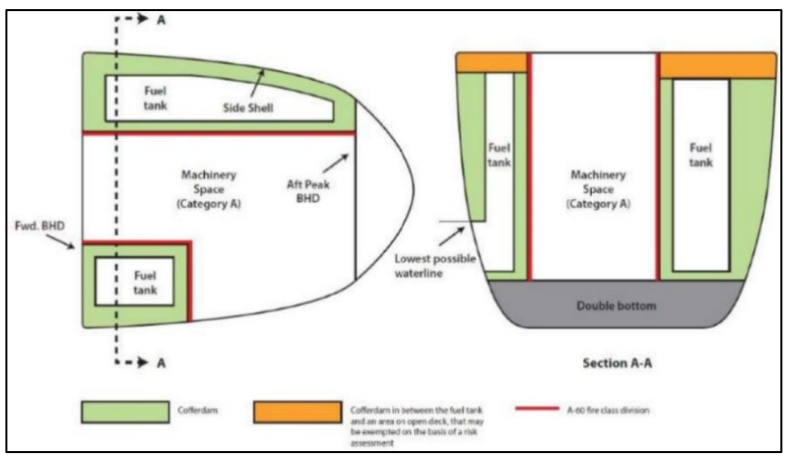


Figure 4.1-1-Fuel tank arrangement

> *5.3.2 Integral fuel tanks should be surrounded by protective cofferdams. except on those surfaces bound by shell plating below the lowest possible waterline. other fuel tanks containing methyl/ethyl alcohol. or fuel preparation space.*

- Interpretation of Paragraph 5.3.2 of MSC.1/Circ.1621 (IACS UI GF20, October 2024) by ABS: It is possible to exempt the arrangement of cofferdams between the fuel tank and an area on open deck. Exemption would be permitted, provided the arrangement has been considered by the risk assessment as per paragraph

Section 4.2 taking into account the use of the area, fire, toxicity, and possible additional construction and survey requirements.

SPS Selection: These requirements, in addition to increasing the volume of fuel needed, also result in a significant volume being dedicated solely to fuel transportation, reducing the available cargo or operational space. Given the complexity and spatial implications of complying with these regulations, alternative solutions were investigated. One such solution was found in the Methanol Storage Solution offered by SRC Group.

SPS-Based Methanol Storage Solution - SRC Group: SRC has developed an innovative methanol storage system utilizing the Sandwich Plate System (SPS), replacing the need for large protective cofferdams. The system features:

1. A 25 mm thick SPS panel, eliminating the need for traditional cofferdams
2. A60 fire rating
3. Triple-barrier safety design
4. No inspection or maintenance requirements for cofferdams
5. Maximized usable volume for methanol storage

Proven Performance: Over 20 years of marine industry use, SPS has undergone extensive testing, including:

1. 120+ fire tests
2. Chemical resistance (including methanol and ethanol)
3. 3Fatigue resistance
4. Impact protection

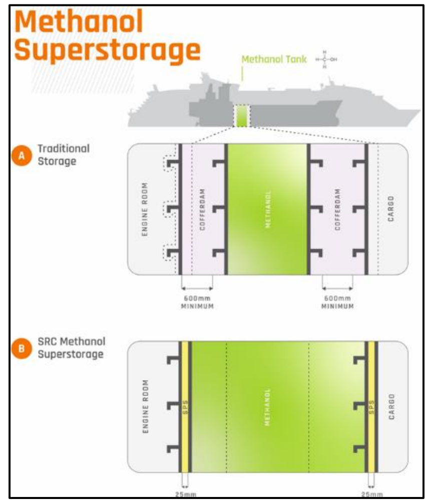


Figure 4.1-2- Comparison of Traditional vs. SRC Methanol Storage.

This Methanol Superstorage system has received Approval in Principle (AiP) from both Lloyd's Register and RINA for use as a methanol/ethanol fuel tank without cofferdams.

While AiP confirms feasibility and compliance at the conceptual level, final approval is vessel- and flag-state-specific and will require further detailed review

Follow-Up with SRC Group - Technical Clarifications: Following initial evaluation, SRC was contacted to address some key concerns raised by our design team

1. Construction Method and Impact on Costs/Timeline: For newbuilds, SPS steelwork (perimeter bars and top plates) is typically handled by the shipyard along with other steel works and does not significantly impact the construction schedule. The general principle for SPS installation involves welding perimeter bars onto the existing bulkhead, then welding the top plate onto the perimeter bars to seal the cavity before injecting the elastomer.

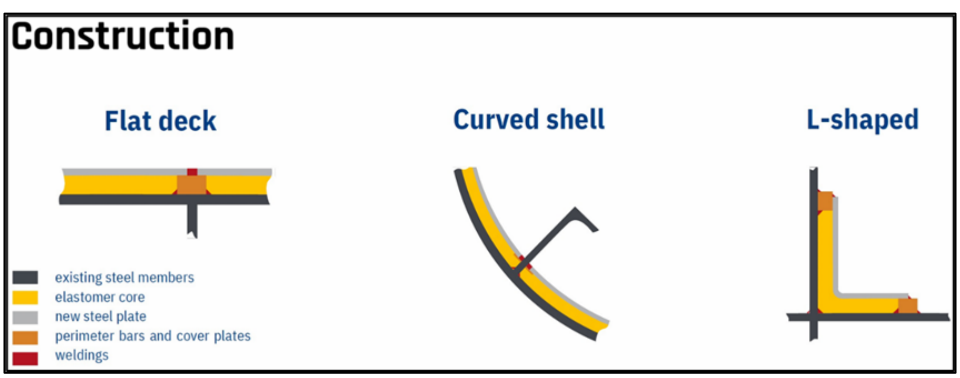


Figure 4.1-3-Methanol Tank Structural Integration Methods

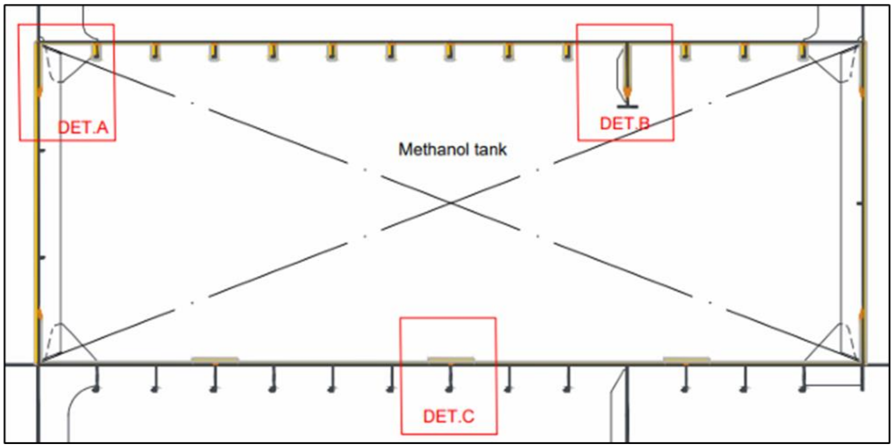


Figure 4.1-4-Methanol Tank Arrangement with Structural Details (DET.A, DET.B, DET.C).

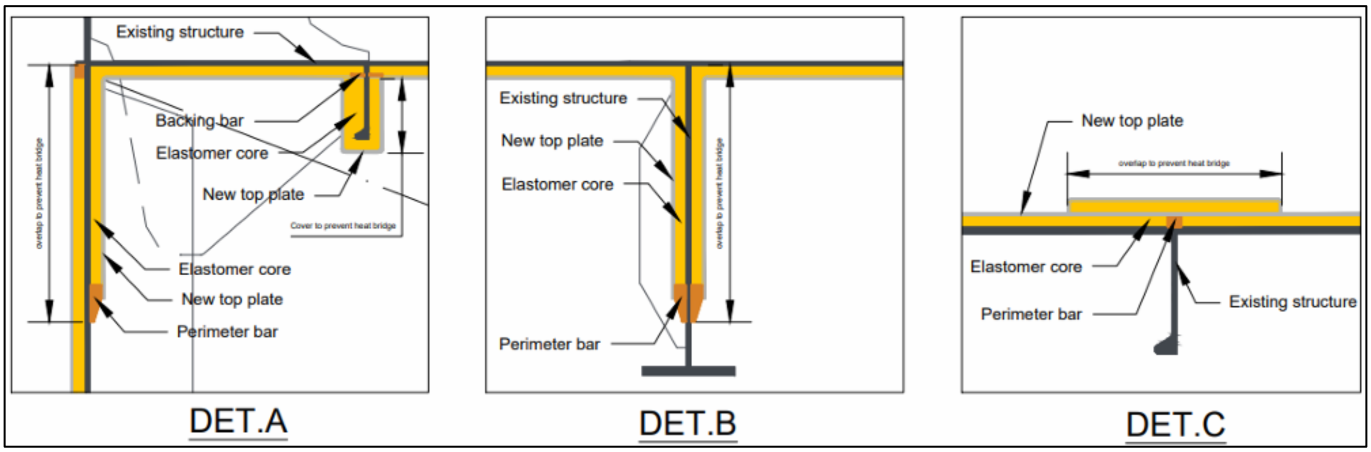


Figure 4.1-5-Structural Details of Methanol Tank Integration (DET.A, DET.B, DET.C).

2. Limitations of the System - Working Deck Considerations (AHTS Vessel): There are no specific limitations to using SPS on working decks. SPS has been widely deployed in decks exposed to heavy cargo loads, anchor handling operations, and other high-impact areas.

The system performs exceptionally well under cyclic loading and impacts, offering excellent fatigue resistance and puncture strength. The elastomer core is highly durable and remains stable over time. It has been successfully used in offshore support vessels, FPSOs, and other high-load applications without issue.

5.3.3 The fuel containment system should be abaft of the collision bulkhead and forward of the aft peak bulkhead.

5.6.2 All fuel piping within machinery space boundaries should be enclosed in gas and liquid tight enclosures

5.7.2 Fuel piping should not be led directly through accommodation spaces. service spaces. electrical equipment rooms or control stations as defined in the SOLAS Convention.

5.7.4 Fuel piping that passes through enclosed spaces in the ship should be enclosed in a pipe or duct that is gas and liquid tight towards the surrounding spaces with the fuel contained in the inner pipe. Such double walled piping is not required in cofferdams surrounding fuel tanks. fuel preparation spaces or spaces containing independent fuel tanks as the boundaries for these spaces will serve as a second barrier.

5.8 Fuel preparation spaces should be located outside machinery spaces of category A.

5.9.1 Bilge systems installed in areas where methyl/ethyl alcohol can be present should be segregated from the bilge system of spaces where methyl alcohol or ethyl alcohol cannot be present.

5.9.2 One or more holding tanks for collecting drainage and any possible leakage of methyl/ethyl alcohol from fuel pumps. valves or from double walled inner pipes located in enclosed spaces should be provided. Means should be provided for safely transferring contaminated liquids to onshore reception facilities

5.10.1 Drip trays should be fitted where leakage and spill may occur. in particular. in way of single wall pipe connections.

5.11.6 For safe access. horizontal hatches or openings to or within fuel tanks or surrounding cofferdams should have a minimum clear opening of 600 mm x 600 mm that also facilitates the hoisting of an injured person from the bottom of the tank/cofferdam. For access through vertical openings providing main passage through the length and breadth within fuel tanks and cofferdams. the minimum clear opening should not be less than 600 mm x 800 mm at a height of not more than 600 mm from bottom plating unless gratings or footholds are provided. Smaller openings may be accepted provided evacuation of an injured person from the bottom of the tank/cofferdam can be demonstrated.

4.2 Fuel containment system

The goal of this section is to provide for a fuel containment system where the risk to the ship, its crew and to the environment is minimized to a level that is at least equivalent to a conventional oil-fuelled ship.

6.2.2 The fuel tanks should be designed such that a leakage from the fuel tank or its connections does not endanger the ship, persons on board or the environment.

6.2.3 The fuel containment system and the fuel supply system should be designed such that safety actions after any leakage, irrespective of in liquid or vapour phase, do not lead to an unacceptable loss of power

6.3.2 A fixed piping system should be arranged to enable each fuel tank to be safely gas freed, and to be safely filled with fuel from a gas-free condition.

6.4.1 All fuel tanks should be inerted at all times during normal operation.

6.4.10.3 Gas freeing operations must be carried out in such a way that vapours are discharged through outlets located underwater.

6.5.1 Inert gas should be available permanently on board in order to achieve at least one trip from port to port considering maximum consumption of fuel expected and maximum length of trip expected, and to keep tanks inerted during 2 weeks in harbour with minimum port consumption.

6.5.4 The production plant, if fitted, should be capable of producing inert gas with oxygen content at no time greater than 5% by volume.

The inert gas system is provided by the Methanol PAC from Wärtsilä, as referenced in section 71Methanol PacMethanol Pac

4.3 Bunkering

The goal of this section is to provide for suitable systems on board the ship to ensure that bunkering can be conducted without causing danger to persons, the environment or the ship.

In addition, the bunkering station is provided by the Methanol PAC system from the manufacturer Wärtsilä, which ensures compliance with the technical requirements established by the applicable regulations. The design team ensures a reliable and safe installation, aligned with the standards required for the handling of fuels such as methanol. This allows the solution to be efficiently integrated while reducing risks.

8.3.1.1 The bunkering station should be located on open deck so that sufficient natural ventilation is provided.

8.3.1.2 Entrances, air inlets and openings to accommodation, service and machinery spaces and control stations should not face the bunkering station.

8.3.1.3 Bunkering lines should not be led directly through accommodation, control stations or service spaces. Bunkering lines passing through non-hazardous areas in enclosed spaces should be double walled or located in gastight ducts.

8.5.1 Means should be provided for draining any fuel from the bunkering lines upon completion of operation.

4.4 Power generation

The goal is provide safe and reliable delivery of mechanical, electrical or thermal energy.

Following a discussion with a representative from the manufacturer of the selected engines, the design team verified and ensured that these engines complied with all the required regulations and technical specifications. This confirmation allowed them to proceed confidently with the selection, guaranteeing safety, efficiency, and regulatory compliance in the ship's operation.

10.3.2 Engine components containing methyl/ethyl alcohol fuel should be effectively sealed to prevent leakage of fuel into the machinery space.

10.3.4 A means should be provided to monitor and detect poor combustion or misfiring.

4.5 Fire Safety

The goal of this section is to provide fire protection, detection and fighting for all systems related to storing, handling, transfer and use of methyl/ethyl alcohol as fuel.

11.4.1 For the purposes of fire protection. fuel preparation spaces should be regarded as machinery space of category A. Should the space have boundaries towards other machinery spaces of category A. accommodation. control station or cargo areas. these boundaries should not be less than A-60. Any boundary of accommodation up to navigation bridge windows. service spaces. control stations. machinery spaces and escape routes. facing fuel tanks on open deck should have A-60 fire integrity.

11.6.5 A fixed fire detection and fire alarm system complying with Fire Safety System Code should be provided for all compartments containing the methyl/ethyl alcohol fuel system.

11.7.1 Machinery space and fuel preparation space where methyl/ethyl alcohol-fuelled engines or fuel pumps are arranged should be protected by an approved fixed fire-extinguishing system in accordance with SOLAS regulation II-2/10 and the FSS Code. In addition. the fire-extinguishing medium used should be suitable for the extinguishing of methyl/ethyl alcohol fires

11.7.2 An approved alcohol-resistant foam system covering the tank top and bilge area under the floor plates should be arranged for machinery space category A and fuel preparation space containing methyl/ethyl alcohol.

4.6 Control Monitoring and Safety Systems

Table I below presents the different systems and their respective control and monitoring equipment, which must comply with the established requirements for equipment related to the methanol fuel system.

These control and monitoring devices are an integral part of the methanol PAC system supplied by the manufacturer Wärtsilä, thus ensuring safe and efficient operation.

Table I - Control Monitoring and Safety Systems.

Parameter	Alarm	Automatic shutdown of tank valve	Automatic shutdown of master fuel valve	Automatic shutdown of bunkering valve	Comments
High-level fuel tank	x			x	Each fuel tank should be fitted with a visual and audible high-level alarm.
High-high-level fuel tank	x			x	An additional sensor (high-high-level) should automatically actuate a shut-off valve to avoid excessive liquid pressure in the bunkering line and prevent the tank from becoming completely filled with liquid. The operation of the remote control valves and the indication of these alarms should be located at a safe remote location.
Loss of ventilation in the annular space in the bunkering line	x			x	If the ventilation in the ducting enclosure or annular spaces of the double walled bunkering lines stops. an audible and visual alarm should be activated at the bunkering control location.
Gas detection in the annular space in the bunkering line	x			x	If fuel leakage is detected in ducting enclosure or the annular spaces of the double walled bunkering lines. an audible and visual alarm and emergency shutdown of the bunkering valve should automatically be activated.
Loss of ventilation in ventilated areas	x				Any loss of the required ventilating capacity should give an audible and visual alarm on the navigation bridge. and in a continuously manned central control station or safety centre as well as locally.
Manual shutdown				x	The closure of the bunkering shut-off valve should be possible from the control location for bunkering and from another safe location.
Liquid methyl/ethyl alcohol detection in the annulalr space of the double walled bunkering line	x			x	If fuel leakage is detected in ducting enclosure or the annular spaces of the double walled bunkering lines. an audible and visual alarm and emergency shutdown of the bunkering valve should automatically be activated.
Vapour detection in ducts around fuel pipes	x				Permanently installed gas detectors should be fitted in all ventilated annular spaces of the double walled fuel pipes;
Vapour detection in cofferdams surrounding fuel tanks. One detector giving 20% of LEL	x				For ventilated ducts and annular spaces around fuel pipes in machinery spaces containing methanol/ethanol-fueled engines. the alarm limit should be set at 20% of the Lower Explosive Limit (LEL).

Parameter	Alarm	Automatic shutdown of tank valve	Automatic shutdown of master fuel valve	Automatic shutdown of bunkering valve	Comments
Vapour detection in airlocks	x				Permanently installed gas detectors should be fitted in airlocks
Vapour detection in cofferdams surrounding fuel tanks.Two detectors giving 40% of LEL	x	x		x	Permanently installed gas detectors should be fitted in cofferdams and fuel storage hold spaces surrounding fuel tanks. The safety system should be activated at 40% of LEL at two detectors.
Vapour detection in ducts around double walled pipes. 20% of LEL	x				The alarm limit should be set at 20% of the Lower Explosive Limit (LEL).
Vapour detection in ducts aroud double walled pipes. 40% of LEL	x	x	x		Two gas detectors to give min. 40% of LEL before shutdown
Liquid leak detection in annular space of double walled pipes	x	x	x		The annular space in a double walled piping system should be monitored for leakages and the monitoring system should be connected to an alarm system
Liquid leak detection in engine-room	x	x			Liquid leakage detection should be installed in the protective cofferdams surrounding the fuel tanks. in all ducts around fuel pipes. in fuel preparation spaces. and in other enclosed spaces containing single walled fuel piping or other fuel equipment.
Liquid leak detection in fuel preparation space	x	x			Liquid leakage detection should be installed in the protective cofferdams surrounding the fuel tanks. in all ducts around fuel pipes. in fuel preparation spaces. and in other enclosed spaces containing single walled fuel piping or other fuel equipment.
Liquid leakage detection in protective cofferdams surrounging fuel tanks	x				Liquid leakage detection should be installed in the protective cofferdams surrounding the fuel tanks. in all ducts around fuel pipes. in fuel preparation spaces. and in other enclosed spaces containing single walled fuel piping or other fuel equipment.

5 IMO TIER III COMPLIANCE

The IMO Tier III NOx emission standard entered into force in 2016. It applies to:

- New marine diesel engines with power output >130 kW
- Installed on ships with keel-laying dates on or after January 1st, 2016
- Operating within designated Emission Control Areas (ECAs), including the North American ECA, the US Caribbean Sea ECA, and the Baltic and North Sea ECAs

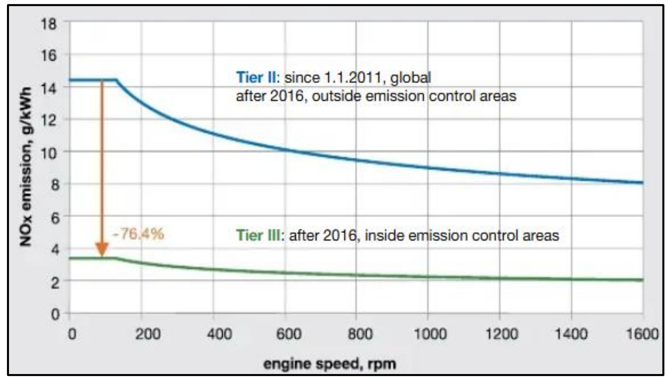


Figure 4.6-1 - Nox Emission vs Engine Speed.

While the current vessel design is not intended to operate within these zones, Tier III compliance was specified by the shipowner. This decision provides commercial advantages in terms of sustainability image, aligns with anticipated future regulatory expansions, and contributes to reduced environmental impact, although it comes with increased operational costs.

Wärtsilä Methanol engines complies with IMO Tier II limits in both Diesel and Methanol modes. Achieving IMO Tier III compliance, however, requires the installation of a Selective Catalytic Reduction (SCR) system.

Water blending in Methanol mode is planned for testing during the project execution phase. Preliminary estimations suggest that a 20%-mass water content could potentially reduce NOx emissions below the Tier III threshold. However, this approach may impact engine performance and must be validated through testing. As such, Tier III compliance cannot be guaranteed without SCR.

Selective Catalytic Reduction (SCR) - Wärtsilä NOx Reducer (NOR)

The Wärtsilä NOx Reducer is a proven emission after-treatment system based on SCR technology. Developed and validated specifically for Wärtsilä medium-speed engines, it ensures reliable, long-term compliance with IMO Tier III standards across the engine's lifecycle. It is available for both newbuilds and retrofits and supports a wide range of fuels, from high-sulphur HFO to methanol and future alternative fuels such as ammonia.

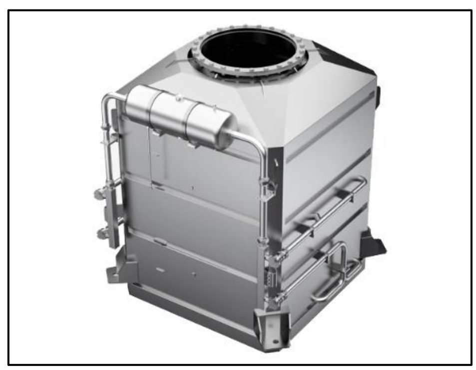


Figure 4.6-2-SCR.

SCR is currently one of the most effective NOx reduction technologies, achieving reductions of over 90%. In this process:

- A 40% urea solution is injected into the hot exhaust gases.
- The injected urea decomposes to form ammonia (NH_3), which reacts with NOx over a catalyst.
- The reaction converts harmful NOx into nitrogen (N_2) and water (H_2O).

The main components of the NOR system include:

- Reactor with catalyst elements and soot blower
- Urea pump unit
- Urea dosing and injection unit
- Mixing section integrated in the exhaust stream

6 CONCEPT SELECTION/INITIAL DEFINITION AND SIZING

The initial main dimensions and parameters were determined using a statistical analysis of existent vessels with similar characteristics, which were found after a thorough investigation. Their dimensions are presented in the table in APPENDIX I: EXAMPLE VESSELS & GT-NT COEFFICIENTS.

The statistical analysis consisted of performing linear regressions based on the data from the previously obtained table.

6.1 Power (P)

Given that these are high bollard pull vessels, it was observed that the total installed power is essentially a function of the bollard pull, with the propulsion power required for navigation being comparatively lower. Therefore, the following regression was carried out to estimate the total installed power based on the bollard pull.

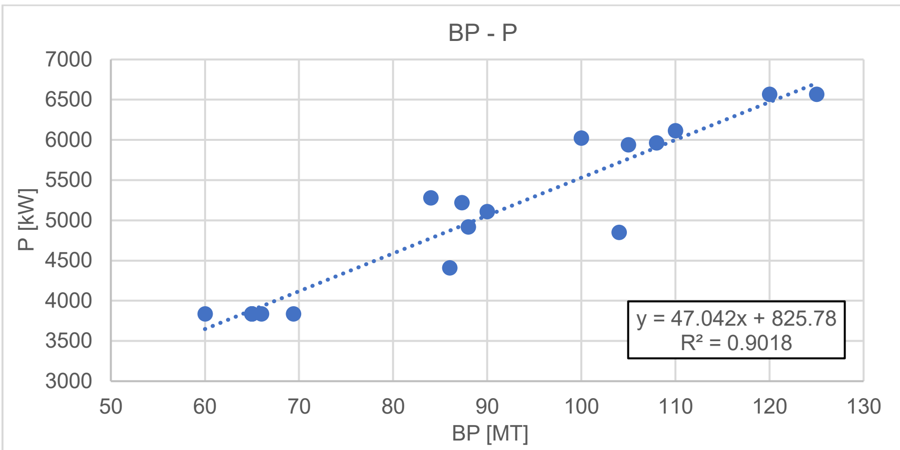


Figure 6.1-1 - Bollard Pull vs Power.

Obtaining:

$$P = 4354\ kW \tag{1}$$

In order to verify this value, we used Mohd. Ramzan Mainal's regression to determine the power:

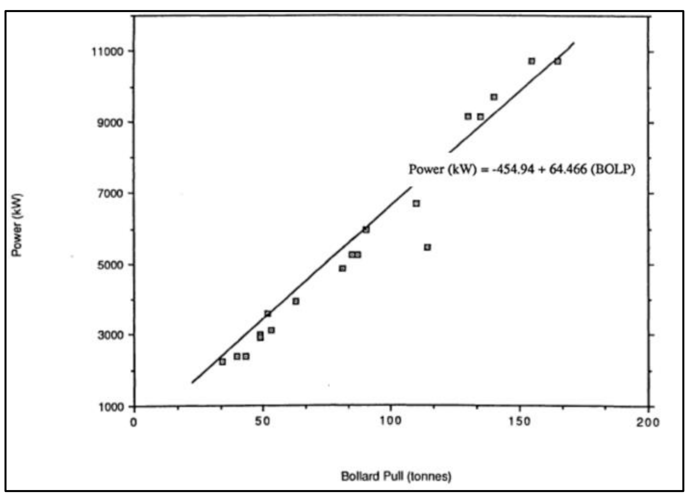


Figure 6.1-2 - Relation between Bollard Pull and Power.

$$\boldsymbol{P} = 64.466 \cdot BP - 454.94 = \mathbf{4380}\boldsymbol{kW} \tag{2}$$

The obtained values are similar; therefore, we will consider 4380 kW as the power value for the following analyses.

6.2 Deadweight Tonnage (DWT)

As mentioned in the previous section, the selected fuel is methanol, which has a lower calorific value compared to conventional MDO. Consequently, a larger fuel volume is required. In order to size the vessel based on the minimum fuel volume requirement, a regression analysis between fuel volume and DWT will be performed. As a first step, the required fuel volume will be calculated.

The minimum total capacity of Methanol and MDO (pilot fuel) on board is a function of the required range, service speed, propulsive power, and specific fuel consumption.

$$W_{fuel} = SFC \cdot BHP \cdot A/V_S \cdot SM \tag{3}$$

Where:

- SFC: Specific fuel consumption of main engine. At full MCR power, a similar BHP methanol engine has a fuel consumption of 365 g/kWh and a pilot fuel (MDO) consumption of 16.5 g/kWh.
- A: Range set from owner's requirements in nautical miles.
- Vs: Speed of vessel set from owner's requirements as 12.5 knots.
- SM: safety margin, adopted at 10%.
- BHP: refers to the power required for sailing at 12.5 knots. Since this value is unknown at the current stage of the project, the total installed power in kilowatts will be used instead. Although this approach is not entirely accurate, considering that in this type of vessel the total power is primarily defined by its bollard pull capacity and does not reflect the power consumed during navigation, it is considered a suitable and conservative approximation for this phase of the project.

Table II - Fuel Weight Estimation.

Fuel Weight			
Parameter	**Symbol**	**Value**	**Unit**
Specific fuel methanol consumption	SFC	365	g/kWh
Specific fuel diesel oil consumption	SFC	17	g/kWh
Maximum continuous rating	P	4380	kW
Range set	A	4000	NM
Service Speed	S	12.5	knts
Safety Margin	SM	1.1	-
Fuel weight methanol	$W_{fuel\text{-}methanol}$	**563**	**MT**
Fuel weight diesel oil	$W_{fuel\text{-}MDO}$	**25**	**MT**
Fuel volume – Methanol	$V_{fuel\text{-}methanol}$	**712**	**M^3**
Fuel volume – MDO	$V_{fuel\text{-}MDO}$	**30**	**M^3**

Based on the calculated fuel volume, a regression was then performed to estimate the required deadweight tonnage.

Figure 6.2-1. Fuel vs Deadweight Tonnage.

Obtaining:

$$\boldsymbol{DWT = 2178\ MT} \tag{4}$$

6.3 Length Overall (Loa)

The following regression was carried out to estimate the cubic numeral based on the deadweight tonnage:

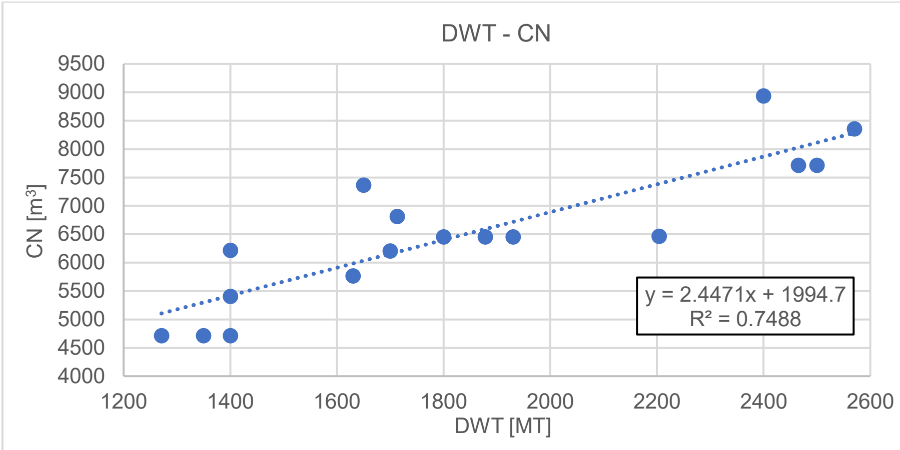


Figure 6.3-1. Deadweight Tonnage vs Cubic Numeral.

Obtaining:

$$\boldsymbol{CN = 7324.55\ m^3} \tag{5}$$

Next, we obtain the Loa using the CN determined earlier:

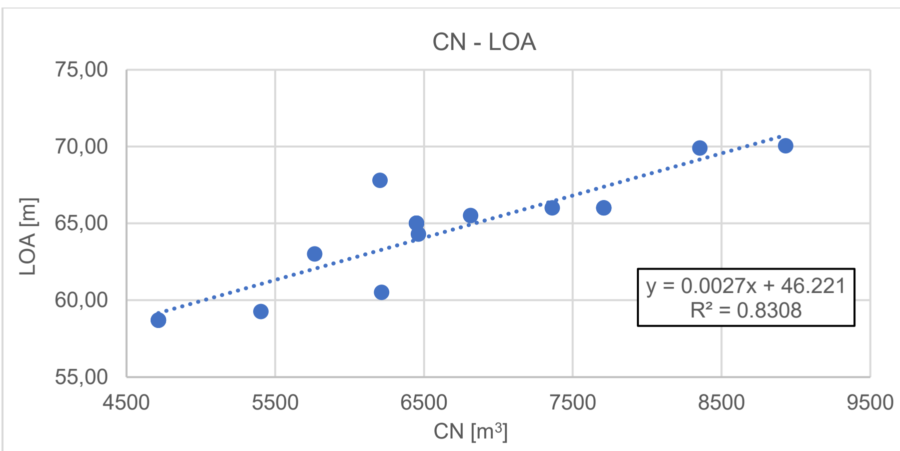


Figure 6.3-2. Cubic Numeral vs Length Overall.

Obtaining:

$$LOA = 66.34\ m \tag{6}$$

6.4 Length Between Perpendiculars (Lpp)

From the data in the table in APPENDIX I: EXAMPLE VESSELS & GT-NT COEFFICIENTS we obtain the average percentage of Lpp/Loa, therefore:

$$Lpp = 90.13\% \cdot Loa = 59.8m \tag{7}$$

6.5 Length on Waterline (Lwl)

From the table in APPENDIX I: EXAMPLE VESSELS & GT-NT COEFFICIENTS we obtain the average percentage of Lwl/Loa, therefore:

$$Lwl = 96.69\% \cdot Lwl = 64.14m \tag{8}$$

6.6 Beam (B)

The following regression was carried out to estimate the Beam numeral based on the cubic numeral:

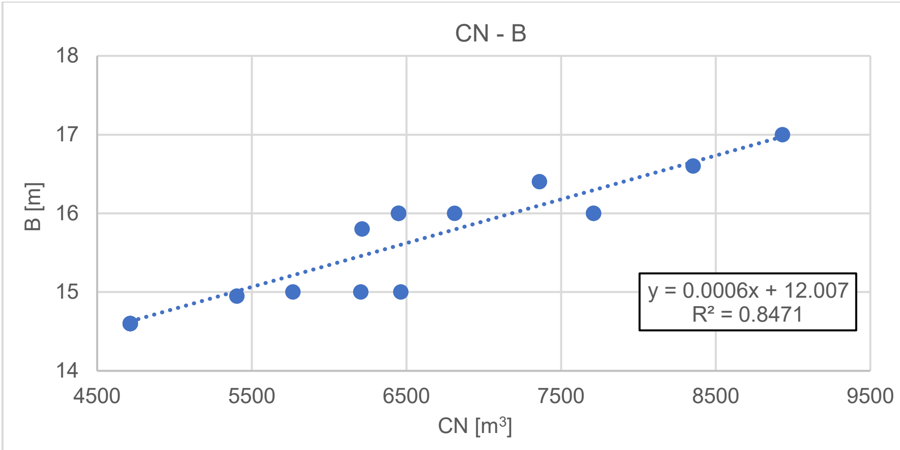


Figure 6.6-1. Cubic Numeral vs Beam.

Obtaining:

$$B = 16.10\ m \tag{9}$$

6.7 Depth (D)

The depth is determined using the cubical numeral:

$$CN = Loa \cdot B \cdot D = 6.90m \tag{10}$$

6.8 Draft (H)

The draft is calculated using the average H/D ratio obtained from the table of similar vessels:

$$H = H/D \ \cdot D = 5.74m \tag{11}$$

6.9 Final Dimensions

Table III - Final Main Dimensions.

Dimensions	Value	Unit
LOA	66.33	m
Lpp	59.80	m
Lwl	64.13	m
B	16.10	m
D	6.90	m
H	5.74	m
FB	1.16	m

It is important to note that these dimensions are based on statistical data from vessels equipped with conventional shaft lines and rudders. This clarification is made due to the limited availability of information on vessels using alternative propulsion systems. Consequently, the Lpp will be adjusted in later sections to reflect the implications of the selected propulsion configuration.

6.10 Additional Parameters

6.10.1 Deck Area

The following regression was carried out to estimate the deck area based on the product of the length between perpendiculars and beam:

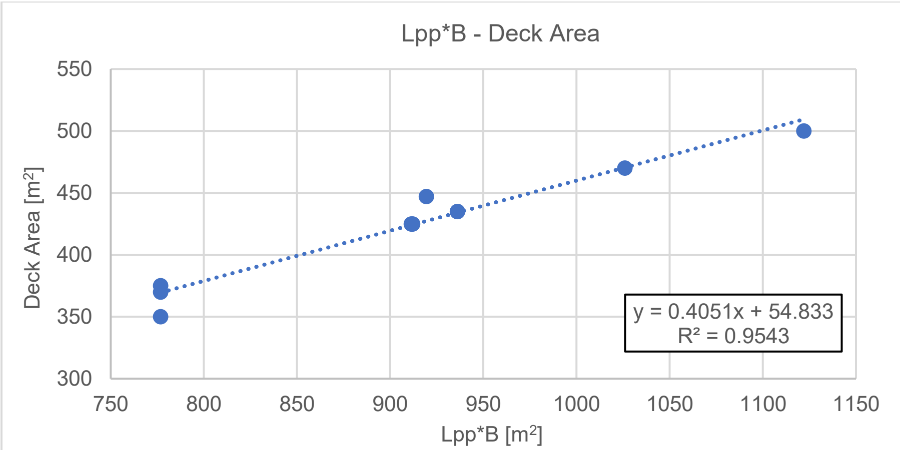


*Figure 6.10-1 - (Length Between Perpendiculars * Beam) vs Deck Area.*

Obtaining:

$$Deck\ Area = 444.86\ m^2 \tag{12}$$

6.10.2 Longitudinal Center of Buoyancy (LCB)

First, we calculated the Froude number (Fn):

$$Fn = Vs/\sqrt{g \cdot Lwl} = 0.257 \tag{13}$$

Then, using the following graph, we determined the possible % Lpp range where the LCB can be located, either forward or aft of amidships:

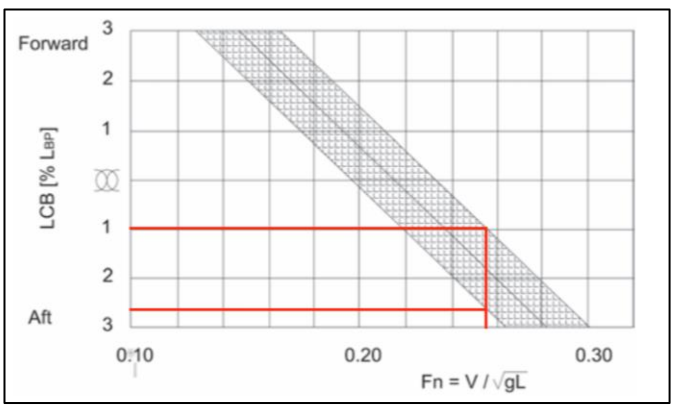


Figure 6.10-2 - Approximate Optimal Longitudinal Position of Center of Buoyancy vs Froude Number According to Guldhammer-Harvard (1974).

It was determined that the LCB is located between 1% and 2.6% of the Lpp aft of amidships.

Then, using a formula provided by author Manuel Ventura, we verified the position of the LCB relative to amidships:

$$LCB = (8.8 - 38.9 \cdot Fn)/100 = -1.18\% \tag{14}$$

6.10.3 Gross Tonnage (GT) and Net Tonnage (NT)

Gross and Net Tonnage can be approximated at this stage as follows. The coefficients K1 and K2 are estimated as the average values obtained from the sample vessels included in the statistical study. The resulting average values for K1 and K2 are presented in APPENDIX I: EXAMPLE VESSELS & GT-NT COEFFICIENTS, with the following results:

$$GT = K1 \cdot CN0.319 \cdot CN = \mathbf{2338.50}$$
$$NT = K2 \cdot GT0.301 \cdot GT = \mathbf{703.32} \tag{15}$$

7 HULL FORM DEVELOPMENT

The next step in the design stage is to estimate values of hull forms coefficients to have an efficient hull form.

7.1 Block Coefficient (Cb)

We determined the block coefficient using a graph (Figure 7.1-1) provided in the literature that relates the Froude number with the block coefficient of different AH/Tug/Supply.

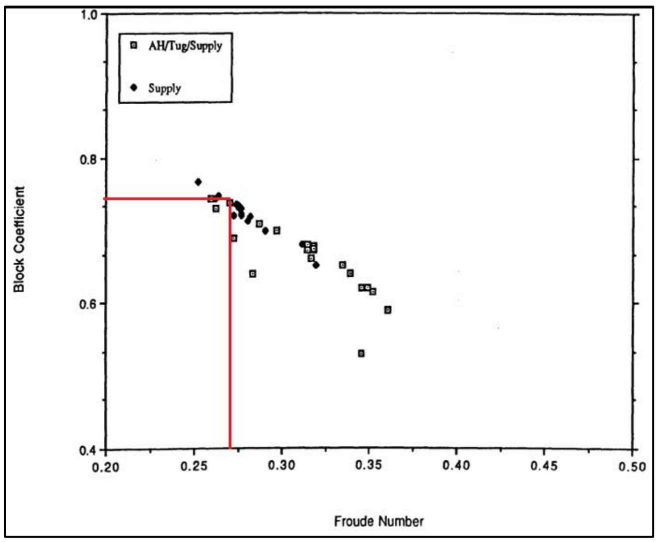


Figure 7.1-1 - Relation between Block Coefficient and Froude Number.

Obtaining:

$$\boldsymbol{Cb = 0.735} \tag{16}$$

7.2 Midship Area Coefficient (Cm)

Different authors propose formulas to calculate this coefficient:

Table IV - Midship Area Coefficient.

Midship Area Coefficient		
Method	**Formula**	**Value**
Van Lammeren	$0.9 + 0.1 \cdot Cb$	0.974
Kerlen	$1.006 - 0.0056 \cdot Cb^{-3.56}$	0.989
HSVA	$\frac{1}{1 + (1 - Cb)^{3.5}}$	0.991

We adopted the highest midship section coefficient based on the reference vessels.

$$Cm = 0.991 \tag{17}$$

7.3 Prismatic Longitudinal Coefficient (Cpl)

We obtained this coefficient based on the relationship between Cb and Cm:

$$Cpl = \frac{Cb}{Cm} = 0.742 \tag{18}$$

7.4 Waterplane Area Coefficient (Cwl)

We calculated this coefficient using a formula proposed by Manuel Arnaldos for tugs:

$$Cwl = Cb + 0.2 = 0.935 \tag{19}$$

7.5 Prismatic Vertical Coefficient (Cpv)

We obtained this coefficient based on the relationship between Cb and Cwl:

$$Cpv = \frac{Cb}{Cwl} = 0.786 \tag{20}$$

8 WEIGHT ESTIMATION (STAGE I)

In this section, an initial estimation of the ship's weight was made. In this early stage of the project, the estimates were based on the dimensions and main characteristics of the vessel, in order to obtain a preliminary classification of the weights. This classification was analyzed in more detail in the second phase of the weight estimation.

To carry out the estimation, the total displacement of the vessel was divided into the lightship weight (LSW) and the total deadweight (DWT).

$$\Delta = LSW + DWT \tag{21}$$

8.1 Lightship weight

The lightship weight corresponds to the total weight of the vessel without cargo, passengers, fuel, lubricants, potable water, or other operational fluids. Essentially, it depends on the weight of the steel, machinery, outfitting, and safety margin, as it is an initial estimate.

$$LSW = (W_{st} + W_m + W_o) \cdot (1 + M) \tag{22}$$

Where:

- Steel weight (Wst).
- Machinery Weight (Wm).
- Outfit Weight (Wo).
- Margin (M)

8.1.1 Steel weight

The steel weight includes the weight of the structural steel used in the hull and decks of the ship. It is a critical component, impacting the strength and overall durability of the vessel

$$W_{st} = W_{hull} + W_{decks} \tag{23}$$

8.1.1.1 Harvald & Jensen´s method

The method uses as a basis the approximate enclosed volume of steel structure VC, which includes the volume of the main hull, of the superstructures and Superstructures; furthermore, a coefficient for the steel structural density CS is employed.

To calculate the weight of the decks, this method was used, which proposes the following formula.

$$W_{steel} = (C_s \cdot LOA \cdot B \cdot D) + (C_s \cdot Superstructure\ volume)$$
$$C_s = C_{so} + 0.064 \cdot e^{(-0.05 \cdot \log(\Delta) + 1 - 0.1 \cdot (\log(\Delta) - 2)^{2.45})} \quad (24)$$

Ship type	C_{S0} (t/m³)
Support vessels	0.0974
Tugs	0.0892
Cargo ships (3 decks)	0.0820
Cargo ships (2 decks)	0.0760
Cargo ships (1 deck)	0.0700
Tankers	0.0752
Bulk carries	0.0700
Product carriers	0.0664
Train ferries	0.0650
VLCC	0.0645
Reefers	0.0609
Passenger ship	0.0580
Rescue vessels	0.0232

Figure 8.1-1 - Cso for Different type of Vessel.

The method is simple and satisfactory, as long as sufficient data from similar ships is available. The volume and deck area values have been taken from AHTS vessels with similar main dimensions. It was observed that for this type of vessel, these values tend to repeat.

The bibliography indicates that the accuracy of the method is sufficient for the initial design stage.

In our case, the value of Cso will be 0.0974.

Forecastle deck

- Area: 370.5 m^2
- Height: 2.7 m
- Volume 1000.35 m^3

Upper forecastle deck:

- Area: 171 m^2
- Height: 2.7 m
- Volume 461.7 m^3

Wheelhouse

- Area: 158.7 m^2
- Height: 2.7 m
- Volume: 426 m^3

Table V - Weights for Steel.

Item	Weight [MT]
Hull	880.3
Forecastle	120.2
Upper forecastle	55.5
Bridge	51.2
Total	**1107**

The vertical position of the decks, according to the author Apostolos Papanikolau, is estimated as a percentage of the height “h” of each deck, assuming the following:

- *0.82 * h for decks with internal walls*

The longitudinal position of the basic hull weight will typically be slightly aft of the LCB position. Watson gives the suggestion:

$$LCG_{Whull} = -0.15\% + LCB \quad (25)$$

Where LCB and LCG are expressed as a percentage of the ship's length relative to the midship section.

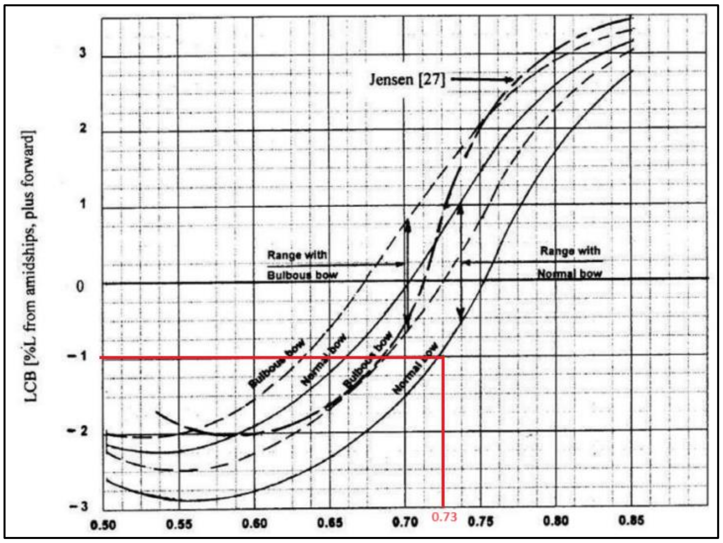


Figure 8.1-2 - LCB as a Function of Cb.

At this stage of the project, since we have not yet conducted the resistance to forward motion study, it has not been decided whether the hull will have a bulb or not. To make an estimate and based from the database available, we will use the curve for a vessel without a bulb.

Table VI - Position of the Center of Gravity.

	From the midship section.		From the stern perpendicular.
	%	m	m
LCB	-1	-0.5978	29.29
LCG	-1.15	-0.68747	29.20

The vertical position of the center of gravity will be calculated using the formula proposed by Alvariño.

$$VCG_{Whull} = 0.01 \cdot D\left(46.6 + 0.135 \cdot (0.81 - C_B) \cdot \left(\frac{L_{pp}}{B}\right)^2\right) = 3.2\ m \tag{26}$$

The results for the steel weight are shown in the following table.

Table VII - Weight, VCG and LCG for Steel.

-	Weight [MT]	Position of the lower edge over L.B. [m]	0,82*h [m]	VCG [m]	LCG [m]	Weight*LCG [MT.m]	Weight*LCG [MT.m]
Hull	880	-	-	3.2	29.2	2826.95	25706.46
Castle deck	120	8.81	2.214	11.024	49	1324.63	5887.78
Upper castle deck	55	11.51	2.214	13.724	48	761.10	2661.98
Wheelhouse	51	14.21	2.214	16.424	46	840.41	2353.81
Total	**1107**	**-**	**-**	**5.2**	**33.1**	**5753.10**	**36610.02**

8.1.2 *Machinery Weight*

In this case, three methods were used to estimate the weight of the machinery.

Table VIII - Machinery weight adopted

Weight machinery			
Method	**Formula**	**Value**	**Unit**
Watson	$0.16 \cdot (BHP)^{0.89}$	279	[MT]
Meridith	$(62.63 \cdot BHP) \cdot 10^{-3}$	274	[MT]
Caldwell	$BHP/16$	274	[MT]
Adopted	279		[MT]

The highest value is adopted to be conservative.

The longitudinal center of gravity of the machinery weight depends on the overall design of the vessel. In the vast majority of general arrangement plans for diesel-electric ships, the engine room is located forward of the midship section. Therefore, the center of gravity will be assumed to lie approximately at the midpoint of the engine room, based on the arrangement plans of comparable vessels.

$$LCG_{Wm} = 33\ m \tag{27}$$

To find the vertical position, the following formula was applied:

$$VCG_{Wm} = 0.17 \cdot H + 0.36 \cdot D = 3.45m \tag{28}$$

8.1.3 *Outfit Weight.*

In this case, three methods were used to estimate the weight of the machinery.

8.1.3.1 Watson's method

$$W_o = 0.23 \cdot LOA \cdot B \tag{29}$$

8.1.3.2 Katsouli's method

$$W_o = k \cdot LOA^{1.3} \cdot B^{0.8} \cdot D^{0.3} \tag{30}$$

- Where 0.045 < k < 0.065
- To be conservative, the value 0.065 is used.

8.1.3.3 Alvariño's method

$$W_o = 0.045 \cdot LOA \cdot B \cdot D \tag{31}$$

Obtaining the following value for the outfitting

Table IX - Outfit Weight Adopted

Weight outfit		
Method	**Value**	**Unit**
Watson	245	[MT]
Katsoulis	250	[MT]
Alvariño	330	[MT]
Adopted	**245**	**[MT]**

Of the three obtained values, one shows a considerable deviation compared to the other two, which are consistent with each other and fall within a reasonable range of variation. In this case, the discrepancy of the third value obtained using Alvariño's formula could be due to the empirical formula having been developed for a different type of vessel with distinct characteristics. Therefore, it is considered appropriate to discard this value to avoid distorting the analysis. The evaluation is consequently performed based on the two consistent values.

The weight of the outfit depends, in part, on the location of the engine room, as a significant portion of this weight is located in that accommodation. The rest of the outfit is distributed along the entire hull.

In the consulted bibliography, a useful approach is proposed to estimate the LCG. It is suggested that 25% of the outfit weight be located at the machinery LCG, 37.5% at the midship section, and the remaining 37.5% at the LCG of the superstructure.

The vertical position will be determined by the following equation, proposed by the author Alvariño Meizoso.

$$VCG_O = D + 1{,}25 \tag{32}$$

- For vessels with a length between perpendiculars less than 125 m.

However, for the vertical position of the percentage distributed in the superstructure area, the corrected draft up to the height of the upper deck (11.51 m) will be used, adopted from the plan of a vessel with similar dimensions and characteristics, since the previous equation does not align with the typical shapes of the type of vessel under development.

Since at this stage of the project we do not have the developed ship's plan, we must estimate the height of the upper deck. Therefore, we will use the height of the upper deck from ships of the same type with similar main dimensions.

Table X - Weights, VCG and LCG for Outfit.

	%	Weight [MT]	VCG [m]	LCG [m]	Weight*VCG [MT.m]	Weight*LCG [MT.m]
	25	61.34	8.12	33.00	498.06	2024.15
	37.5	92.01	8.12	29.89	747.10	2750.09
	37.5	92.01	13.52	48.50	1243.93	4462.34
Total	**100.0**	**245**	**10.1**	**37.6**	**2489.09**	**9236.58**

8.1.4 *Margin*

The values adopted to estimate the lightship weight were obtained using approximate methods based on the main dimensions. Therefore, a 5% margin will be applied to the lightship weight.

8.1.5 *Lightship and center of gravity position.*

The following table will show the weight of the empty vessel and its components.

Table XI - Lightship Weight.

Lightship Weight			
Parameter	**Symbol**	**Value**	**Unit**
Weight of steel	Wst	1107	MT
Weight of machinery	WM	279	MT
Weight of outfit	WO	245	MT
Margin	M	0.05	-
Lightship Weight	**LSW**	**1713**	**MT**

And in the following table, the position of the center of gravity will be shown.

Table XII - Center of Gravity Position.

-	Weight [MT]	VCG [m]	LCG [m]	Weight*VCG [MT.m]	Weight*LCG [MT.m]
Weight of steel	1107	5.20	33.1	5753.10	36610.02
Weight of machinery	279	3.45	33	961.00	9194.88
Weight of outfit	245	10.15	37.6	2489.09	9236.58
Margin	82	-	-	-	-
Total	**1713**	**5.37**	**32.14**	**9203.20**	**55041.47**

8.2 *Deadweight*

The DWT refers to the total cargo capacity that the vessel can carry.

$$DWT = W_{fuel} + W_{lo} + W_{fw} + W_{pw} + W_c + W_f + W_{Required\ load.} \tag{33}$$

8.2.1 *Fuel weight estimation*

As previously calculated in earlier sections, the vessel is expected to carry at least 563 metric tons of methanol and 25 metric tons of MDO for pilot fuel.

8.2.2 *Lube oil weight estimation*

According to the literature consulted, it is estimated to be 4% of the fuel weight.

Table XIII - Lube Oil Weight Estimation.

Lube oil weight	
Value	Unit
23	MT

8.2.3 *Freshwater and potable water weight estimation*

A maximum weight of 20 kg of potable water and 200 kg of freshwater per person per day was estimated.

$$W_{fw} = \frac{0.2\ MT}{Person \cdot Day} \ \&\ W_{pw} = \frac{0.02\ MT}{Person \cdot Day} \tag{34}$$

Table XIV - Fresh Water and Potable Water Weight Estimation.

Fresh water and potable water weight estimation		
Parameter	**Value**	**Unit**
Persons	32	-
Days	15	-
Freshwater weight	**96**	**MT**
Potable weight	**9.6**	**MT**

8.2.4 *Crew weight estimation*

A weight of 80 kg per crew member and passenger was estimated, in addition to 30 kg of luggage.

$$W_c = \frac{0.11\ MT}{Person} \tag{35}$$

Table XV- Crew Weight Estimation.

Crew weight	
Value	Unit
3.52	MT

8.2.5 *Food weight estimation*

A maximum weight of 10 kg of food per person per day is estimated. This weight refers not only to daily consumption but also to reserves.

$$W_{pw} = \frac{0.01\ MT}{Person \cdot Day} \tag{36}$$

Table XVI - Food Weight Estimation.

Food weight	
Value	Unit
4.80	MT

8.2.6 *Required load weight estimation*

Given the estimated deadweight tonnage (DWT) of the vessel and the weights of its components, excluding the operational load, the latter was determined as follows:

$$W_{Required\ load} = DWT - (W_{fuel} + W_{lo} + W_{fw} + W_{pw} + W_c + W_f \tag{37}$$

The operational load includes the weights of drilling water, drilling mud, and cement.

Table XVII - DWT Components.

DWT		
Parameter	**Weight [MT]**	**Volume [m³]**
Fuel weight methanol	563	712
Fuel weight diesel oil	25	30
Lube oil weight	23	25
Fresh water weight	96	96
Potable water weight	9.6	9.6
Crew weight	3.52	-
Food weight	4.80	-
Required load weight	1448	-
DWT	**2178**	**-**

8.3 Displacement

As mentioned earlier, the displacement is given by the sum of the Light Ship Weight and Deadweight.

Therefore, thanks to the development of this section, we can state that:

Table XVIII - DWT Components

Parameter	Value	Unit
LSW	2019	MT
DWT	2178	MT
Δ	**4197**	**MT**

9 MANNING ESTIMATION

The manning estimate for this vessel involves a comprehensive assessment of the personnel required to ensure its safe and efficient operation. The analysis must consider the regulatory requirements of the flag state under which the vessel is registered, along with international conventions.

For an Anchor Handling Tug Supply (AHTS) vessel, the crew composition typically includes operational, technical, and support personnel such as a master, chief officer, second officer, chief engineer, second engineer, electrical engineer, cook, Seafarers, among others. The actual configuration will depend on the complexity of operations, including anchor handling, towing, dynamic positioning, and standby services.

The manning strategy should account for associated costs such as wages, training, rest hours, and welfare in accordance with international standards like the STCW Convention (Standards of Training, Certification and Watchkeeping for Seafarers) and the Maritime Labour Convention (MLC, 2006). In addition, opportunities for automation and technological support may be considered to optimize crew size while maintaining safety and performance standards.

For determining the minimum safe manning levels, the following regulations shall be taken into account:

- Argentina National Coast Guard - Resolution N 03/09 - Chapter 5 - Annex 1.
- Maritime Labor Convention (2006) - Regulation 2.7. Manning Levels.
- International Maritime Organization - Resolution A890 and Amendments.
- International Maritime Organization - The Special Purpose Ships Code (SPS).

According to Argentina's flag authority, the minimum safe manning is as follows:

Table XIX - Minimum Safe Manning Levels.

MINIMUN SAFE MANNING LEVELS				
Position	Tanker vessels		Cargo vessels	
	N.A.T>1600	N.A.T.<1600	N.A.T.>1600	N.A.T<1600
Captain	1	1	1	1
1st Officer	1	1	1	1
2nd Officer	1	1	1	1
3er Officer	1	--	1	--
Seafarers	6	4	6	4
Chief Engineer	1	1	1	1
1st Engineer	1	1	1	1
2nd Engineer	1	--	1	1
3rd Engineer	1	--	--	--
Oilers	2	1	2	1
Radio Officer	(**)	(**)	(**)	(**)

That means that for this vessel, a cargo vessel with a N.A.T. > 1600, the minimum required crew onboard is 16.

The number of passengers will be set at the maximum allowed for the vessel not to be classified as a passenger ship: 12 passengers. In addition, three extra berths will be provided to accommodate either crew members or industrial personnel. Therefore, the vessel's total capacity will be 32 persons.

This additional capacity is intended to support occasional personnel transfers to or from offshore platforms. Although this task is currently dominated by helicopters and fast crafts, the possibility of this vessel performing such operations cannot be ruled out. Furthermore, during standby periods near platforms, the vessel must be prepared to assist platform personnel in case of serious incidents. For this reason, appropriate accommodations and medical facilities must be available not only for the crew but also for potential evacuees.

Based on the above-mentioned regulations and the practices observed in similar vessels, the crew will be composed as detailed in the following table:

Table XX - Manning Onboard Estimation.

Position	Quantity
Captain	1
1st Officer	1
2nd Officer	1
3er Officer	1
Seafarers	6
Chief Engineer	1
1st Engineer	1
2nd Engineer	1
3rd Engineer	1
Electrical Engineer	1
Oilers	2
Medic	1
Cook	1
Passengers	12
Industrial personal	3
Total	32

It is also important to consider the qualifications and experience of the crew to ensure they are capable of safely handling the vessel's specialized operations, particularly given the integration of a methanol-based fuel system.

10 AREA & VOLUME SUMMARY AND FLOODABLE LENGTH ANALYSIS

This section is intended to verify that the design accomplishes the necessary spaces such as accommodation, machinery and the basic outfitting that complies with both the Owners Requirements and the IMO regulations based on the MAXURF model.

10.1 Minimum Bulkheads

The SOLAS Convention establishes that the minimum transverse bulkheads that at least all ships must have, are the following:

a) A collision bulkhead
b) A stern peak bulkhead
c) One at the after end of the Engine Room
d) One at the front end of the Engine Room

In accordance with the local Rules from the Naval Prefecture of Argentina (Maritime Ordinance 08/99) the minimum number of bulkheads, included those mentioned above, based on the length and the position of the Engine Room of the vessel are 4.

Due to both requirements are accomplished with the bulkheads mentioned above, all the other bulkheads are for capacity and compartmentation requirements.

10.1.1 Collision Bulkhead

According to the convention, the longitudinal distance between the bulkhead and the forward perpendicular should be:

- At least 5% of Length on waterline or 10 meters whichever is less
- Not greater than 8% of Length on waterline or 5% of Length on waterline +3 meters whichever is greater

$$L_{min} = \begin{cases} 0.05 * 64.13\ m = 3.2\ m \\ 10\ m \end{cases}$$
$$L_{max} = \begin{cases} 0.08 * 64.13\ m = 5.13\ m \\ 0.05 * 64.13\ m + 3\ m = 6.2\ m \end{cases} \qquad (38)$$

From the equations we have the following limits for the longitudinal distance of the collision bulkhead from the forward perpendicular:

$$3.2\ m < L \quad < 6.2\ m \qquad (39)$$

10.1.2 Stern Peak Bulkhead

In accordance with the SOLAS regulations for the position of the stern peak bulkhead, defined by the shaft tunnel, the stern peak volume needed and the measure to minimize the danger of water penetrating, is positioned at 4.8 m from the stern perpendicular.

10.1.3 Engine Room Bulkheads

The position of the Engine Room Bulkheads is defined by the position of the engines and the volume needed to fit all the required equipment. The position of the Engine Room bulkheads from after perpendicular are:

- After end of the engine room bulkhead: 28.2 m
- Front end of the engine room bulkhead: 43.2 m

10.2 Double Bottom

According to the rules ABS part 3 Chapter 2 section1 4/1.1:

> *"Inner bottoms are to be fitted between the peaks or as near thereto as practicable in vessels of ordinary design of 500 GT or over. The depth of the double bottom measured along the center line parallel to the molded keel line is to be not less than B/20, but not less than 0.76 m (2.5 ft) and need not exceed 2 m (6.6 ft)".*

B/20 is equal to 805mm, and the limits will be:

- $Min\ Depth: h_{DF} - min = 805\ mm$
- $Max\ Depth: h_{DF} - max = 2000\ mm$

The double bottom Depth is not the same along the ship's length but it's between the limits.

10.3 Engine Room Area

The position of the Engine Room is determined by the longitudinal position of the bulkheads that were located to fit all the necessary equipment. The Beam is the distance between the longitudinal bulkheads of the side tanks, and the Depth is the vertical distance between the double bottom and the freeboard deck:

$$A_{ER} = D_{ER} * B_{ER} = 5.7\ m * 13\ m = 74.1 m^2 \tag{40}$$

Where:

- A_{ER}: Area of Engine Room
- D_{ER}: Depth of Engine Room
- B_{ER}: Beam of Engine Room

10.4 Deck Area

Due to the type of vessel, it is important to know the deck area, since it is intended that the vessel may carry supplies and cargo over the main deck. As first approach the deck area is estimated with the regression between the L_{pp}*B and Deck Area in Figure 6.10-1 - (Length Between Perpendiculars * Beam) vs Deck Area obtaining the following area:

$$Deck\ Area = 444.86\ m^2 \tag{41}$$

Taking the measures from the General Arrangement plan we can estimate the area as follows:

$$Deck\ Area_{GA} = B_{Deck} * L_{Deck} = 13m * 37m = 481\ m^2 \tag{42}$$

Where:

- B_{Deck}: Deck Beam
- L_{Deck}: Deck Length

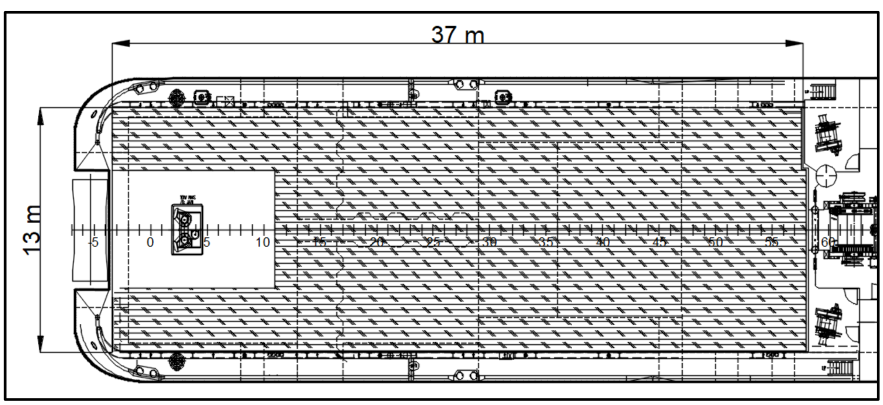


Figure 10.4-1 - Deck Area Estimation.

10.5 Areas Summary Verifications

To verify the estimated cargo spaces, first it is necessary to get the Curve of Areas from the Maxurf Modeler as shown below:

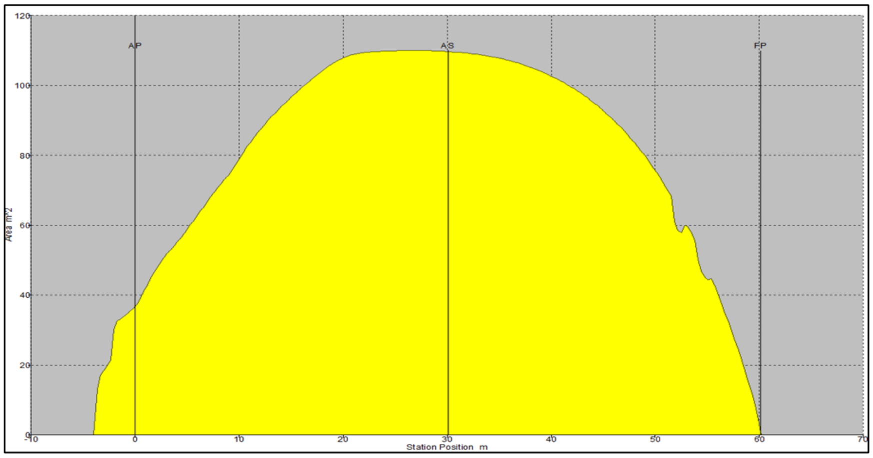


Figure 10.5-1 - Curve of Areas.

The design team obtained the sectional areas of the different spaces such as: Ballast Tanks, Peak Tanks, Azimuthal Room and space for the Bow Thrusters, the resultant curve of areas is shown below:

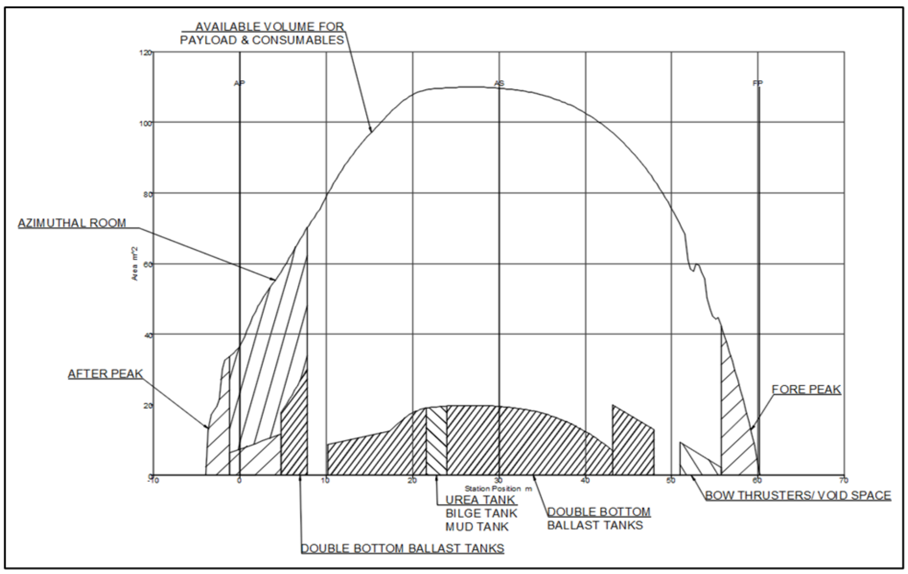


Figure 10.5-2 - Restricted Curve of Areas.

The available volume for payload and consumables is:

$$Available\ volume: 3294.42\ m^3 \tag{43}$$

Summarizing the required spaces for consumables and cargo against those obtained from the General Arrangement plan, the following table is provided:

Table XXI -Required Volumes Vs Estimated from GA Plan.

Required Volumes Vs Estimated from GA		
Name	Required [m³]	From GA [m³]
Methanol	712	727
MDO	30	44
Fresh Water	96	403
Potable Water	9.6	23
Hydraulic and Lube Oil	25	30
Dry Bulk	132	229
Urea	28	32
Total	**1038**	**1488**

Note: as first estimate the dry cargo capacity requirement was obtained based on typical values of existing vessels.

10.6 Offshore Staff Accommodations

In previous sections it was estimated that the vessel can carry 32 offshore staff or technicians and crew.

For the minimum accommodation area, the design is based on the Maritime Work Convention. That establishes:

- *The free height must be adequate for all staff accommodation; the minimum height in all the staff accommodation can't be less than 203 cm*
- *A separate bunk will be provided for each sailor under all the circumstances stated.*
- *The minimum internal dimensions of a bunk bed must be at least 198 centimeters by 80 centimeters.*
- *In cabins with single bunks, the floor area must not be less than: 4.5 square meters on vessels with less than 3,000 gross tonnage.*
- *The captain, the chief engineer, and the chief navigation officer must also have an adjacent lounge, day room, or equivalent additional space; ships with less than 3,000 gross tonnage may be exempt from this requirement by the competent authority after consulting with the interested shipowner and seafarer organizations.*
- *On passenger ships and special purpose vessels, the deck area for sailors performing the functions of ship officers, when a private lounge or day room is not provided, must be no less than 7.5 square meters per person for junior officers and no less than 8.5 square meters per person for senior officers. It is understood that junior officers are at the operational level, and senior officers are at the management level.*
- *In vessels that carry 15 or more seafarers and are on a journey lasting more than three days, hospital accommodation must be provided that is exclusively intended for medical purposes.*

According to the specifications mentioned above, the minimum required area for offshore staff or technician and tribulation is:

$$Captain\ cabin = 8.5\ m^2\ ;\ Chief\ Engineer\ cabin = 8.5\ m^2\ ;\ Crew\ and\ Passangers\ cabin = 7.5\ m^2$$
$$Total = 8.5\ m^2 * 2 + 7.5\ m^2 * 30 = 242\ m^2 \quad (44)$$

And the available area according to the General Arrangement plan is:

Table XXII - Accommodations.

Accommodations	
Deck	Area [m²]
Upper Forecastle	117.28
Main Deck	143.84
Forecastle	169.32
Total	**430.44**

10.7 Floodable lengths

Once the floodable length is determined by the arrangement of watertight bulkheads, the Shirokawa method is applied to verify its adequacy. A permeability of 85 percent is used, in accordance with IMO recommendation MSC 82/24, reflecting that the volume occupied by equipment is consistent with the overall volume of the engine room.

In line with MSC 82/24/Add.2 Annex 3.2.3, any transverse watertight bulkhead extending from the vessel's side to a distance inboard of 760 millimetres or more at the summer load line level, and connecting longitudinal watertight bulkheads, is considered effective for damage stability calculations. In this design, the division of tanks has been employed to establish such transverse watertight bulkheads.

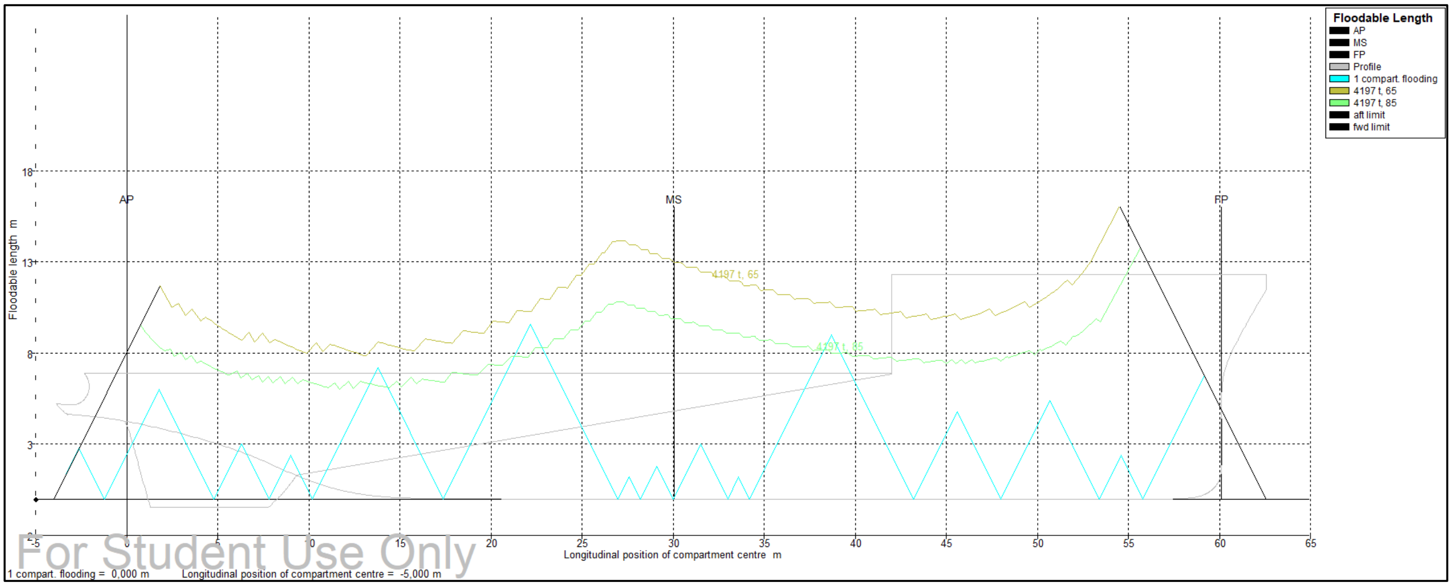


Figure 10.7-1 - Floodable length

The floodable length method has been applied to the AHTS vessel, although it should not be required since it is neither a passenger ship nor a cargo ship over 80 meters in length.. However, the results indicate that the vessel does not meet the criteria at design displacement. This is a known and expected outcome for vessels of this type, and it does not compromise the safety or validity of the design.

The vessel includes an extended engine room and other large longitudinal compartments that reduce the available floodable length. This layout is typical in AHTS vessels and usually results in non-compliance with the floodable length curve under fully loaded conditions.

It is also important to note that the traditional method assumes flooding across the vessel's entire beam, disregarding the contribution of longitudinal bulkheads. In this case, longitudinal subdivision plays a vital role in flood limitation. Consequently, assuming full-beam flooding does not reflect realistic damage scenarios.

In addition, at full load displacement, many compartments are already partially or fully filled with cargo or consumable liquids. Assuming these volumes to be entirely floodable introduces excessive conservatism. If a reduced permeability value is used to represent only the volume that is not already occupied by liquids, the results become more realistic. This is illustrated in the sample curve using a permeability of 65 percent, where the vessel satisfies the floodable length criterion even at maximum displacement.

Although the floodable length method, originally developed by E. G. Frankland in 1903, remains a historic reference, modern design practice relies on direct simulation of damage scenarios using advanced software. This approach, adopted in the present project, offers a more accurate and complete understanding of the vessel's survivability.

Furthermore, the vessel does not fall under the probabilistic damage stability framework defined in SOLAS Part B1, as it is under 80 meters in length and not intended for passenger service. For this reason, deterministic criteria, which are more suitable for this type of offshore support vessel, have been applied.

At lightship condition, the vessel meets the floodable length requirements with a comfortable margin. Non-compliance at design displacement is expected and justified based on the factors outlined above.

In conclusion, although the vessel does not meet the floodable length requirements under standard assumptions at design displacement, its subdivision and floodability characteristics have been validated through more advanced and realistic methods. A comprehensive evaluation of damage scenarios is presented in the Damage Stability section, demonstrating compliance with international standards and confirming the vessel's ability to withstand credible flooding events.

11 POWER PLANT ARRANGEMENTS

There are many different types of power plant arrangements and configurations, depending on the class of vessel, operational requirements, and constraints. Therefore, it is necessary to analyze their advantages and disadvantages in order to identify the propulsion plant that best meets the requirements of this project.

The following table shows different types and combinations of prime movers, transmissions, and propulsors.

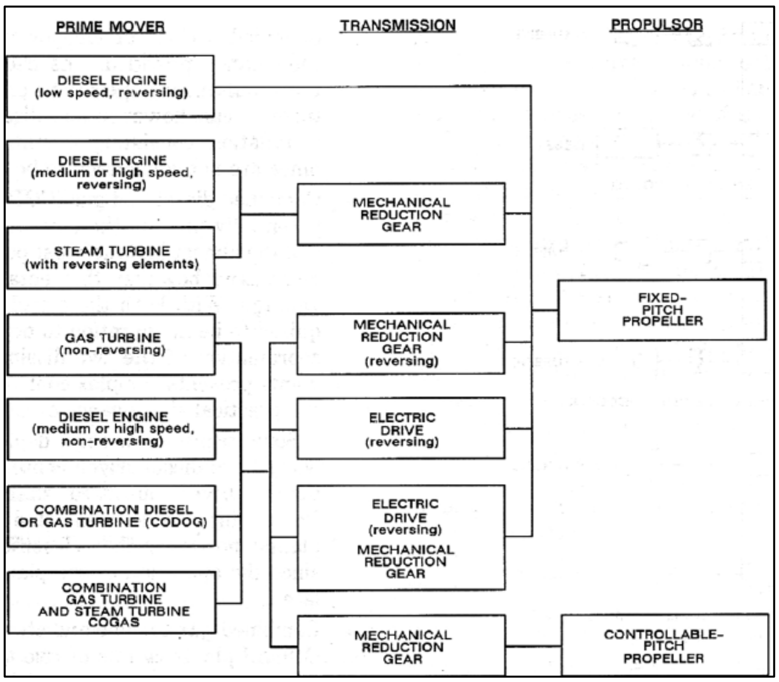


Figure 10.7-1 - principal alternatives in the selection of a propulsion arrangement

11.1 Prime movers

As shown in Figure 10.7-1, there are three types of prime movers: diesel engines (low speed, medium or high speed) and turbines (gas or steam). The table below presents the advantages and disadvantages of each option:

Table XXIII - Comparison Table of Prime Movers for Methanol Use

Prime Mover	**Advantages**	**Disadvantages**	**Available for methanol.**
Low speed Diesel Engine			
	✓ High efficiency in continuous operation: Ideal for prolonged towing phases and constant operation. ✓ High torque at low RPM: Allows direct connection to large-diameter propellers, improving thrust in anchoring maneuvers and heavy towing. ✓ Durability and reliability: Highly resistant to intensive use in offshore operations. ✓ Capability to burn heavy fuel oil: Fuel savings for long-duration operations.	× Large size and weight: Take up a lot of space, which limits available room. × Low flexibility in variable operation: Not optimal for frequent starts/stops or rapid power changes. × Slow response: Not ideal for maneuvers requiring instant power adjustments.	YES
Medium-Hig speed diesel Engine			
	✓ Fast and flexible response: Allow quick power changes, useful in dynamic anchoring and positioning maneuvers. ✓ Compact size: Better use of space in the engine room. ✓ Lower weight: Benefits cargo capacity. ✓ Suitable for generation and propulsion: Enable hybrid configurations with electric generators.	× Lower thermal efficiency compared to slow-speed engines, which may result in higher fuel consumption. × Greater mechanical complexity due to the need for reduction gears. × Specific fuel consumption generally higher than that of low-speed engines.	YES

<table>
<tr><td rowspan="2">Gas Turbine</td><td colspan="3"></td></tr>
<tr><td>✓ High power-to-weight ratio, very compact and lightweight, ideal for maximizing space in AHTS.
✓ Excellent response to rapid power changes, useful for precise maneuvers.
✓ Lower vibration and noise compared to diesel engines.</td><td>× Lower efficiency at partial load, which can increase fuel consumption during prolonged operations.
× High operating and maintenance costs due to high-precision components.
× Require high-quality fuel to avoid turbine damage.</td><td>NO</td></tr>
<tr><td rowspan="2">Steam turbine</td><td colspan="3"></td></tr>
<tr><td>✓ Capable of utilizing residual energy or steam from auxiliary processes, increasing overall energy efficiency.
✓ Smooth and quiet operation with low vibration.
✓ Proven durability and reliability in maritime operations.</td><td>× Require complex auxiliary systems, such as boilers and condensers, which add extra space and weight.
× Lower efficiency compared to modern diesel engines, especially under variable loads.
× Long start-up and shutdown times.
× High investment and maintenance costs due to system complexity.</td><td>NO</td></tr>
</table>

As an additional comparison between different propulsion plants, it can be observed that at lower power ranges, the diesel plant has the lowest specific fuel consumption. This makes it highly attractive for vessels with a long operational lifespan, as it results in lower operating costs over time.

Although the propulsion plant itself is heavier than turbine-based systems, when comparing the combined weight of the plant and the fuel required for a 10,000-nautical-mile range, the geared diesel configuration proves to be the lightest option (excluding nuclear propulsion).

Furthermore, the geared diesel plant also represents the most cost-effective solution among all the evaluated alternatives.

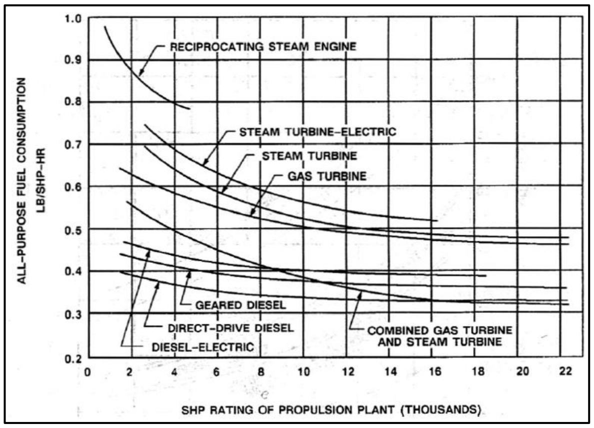


Figure 11.1-1-Fuel Consumption vs. SHP Rating for Different Marine Propulsion Systems.

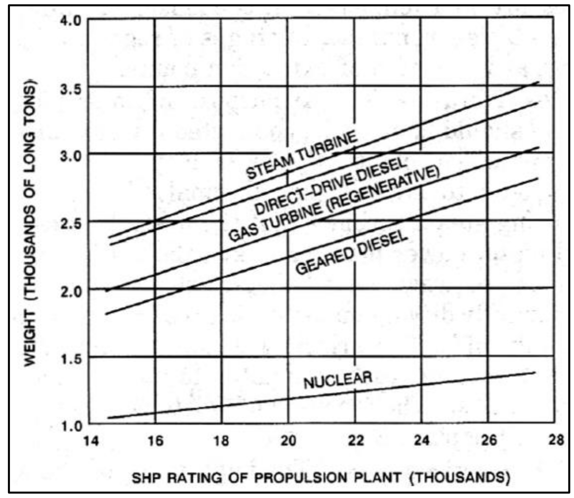


Figure 11.1-2-Weight vs. SHP Rating for Various Marine Propulsion Systems.

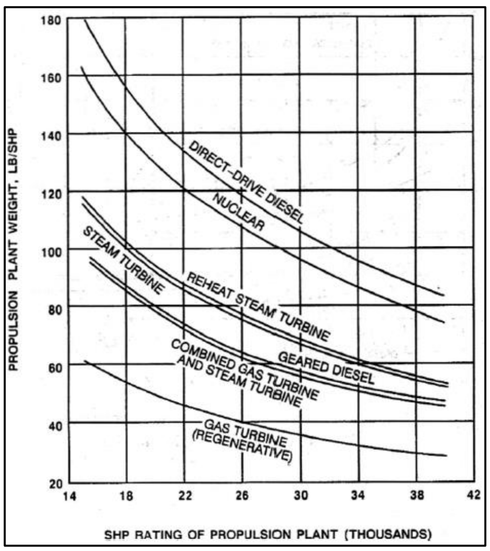


Figure 11.1-3-Propulsion Plant Weight vs. SHP Rating for Various Propulsion Types.

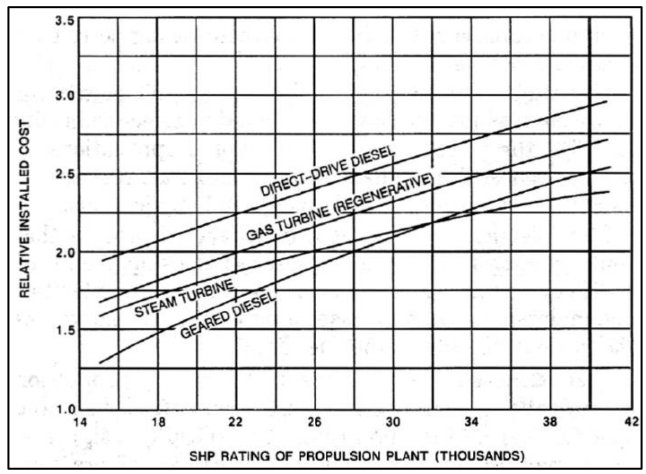


Figure 11.1-4-Relative Installed Cost vs. SHP Rating for Propulsion Plant Types.

Based on the selected fuel, and with the intention of using methanol exclusively for both propulsion and power generation, our study is constrained by the commercial availability of engines and generator sets.

Therefore, considering the current offerings from engine manufacturers, the total power required, and the spatial limitations imposed by the size of the ship's engine room, as well as the objective of selecting the lightest and most affordable plant, the most viable option is to structure the system using 4-stroke medium-speed diesel engines.

The use of gas, steam turbines or 2T diesel engine is neglected in this case due to weights and space requirements and constraints, which makes them no technically nor economically feasible.

11.2 Transmission System

Diesel conventional vs. Diesel electric propulsion:

The selection of a suitable propulsion system for this type of vessel requires a comprehensive evaluation of various technical and operational parameters. Among the most critical aspects to consider are:

- the total cost of machinery
- systems and subsystems

- the size, volume and weight of all machinery components
- the fuel consumption of the prime movers
- emission levels of exhaust gases
- the complexity of the integrated systems
- the associated costs of operation and maintenance.

The vibration and noise characteristics of the system play an important role, particularly in vessels operating under demanding environmental conditions.

Diesel-electric propulsion offers a number of advantages when compared to conventional diesel systems. One of its most relevant features is its capacity to satisfy the vessel's power requirements through one or more generator sets. This arrangement allows for better adaptation to space constraints, reduction of overall machinery weight, and improved vessel stability due to a lower vertical center of gravity. Furthermore, this architecture allows the integration of various types of prime movers, providing flexibility in matching the mechanical output required by the propeller, since all mechanical power is converted into a single medium: electrical power.

In the case of vessels like the one under analysis, where the maximum required power during bollard pull conditions significantly exceeds the power needed during navigation, mechanical transmission would typically require the installation of a shaft generator to maintain main engines operating at efficient loads. Diesel-electric propulsion eliminates the need for such a system, as it allows the plant to meet variable demands through flexible generator configurations, thus simplifying the overall arrangement.

Under normal navigation conditions, it is expected that minimum engines will be required, with some maintained in reserve. During bollard pull or towing operations, where higher power is necessary, the additional installed capacity can be used to meet the increased demand. This approach allows for an efficient and well-distributed use of the engines during both free navigation and high-demand scenarios. Other specific operational modes should be analyzed in detail once the full electrical balance of the vessel is defined.

The diesel-electric configuration grants significant freedom in the layout of the power plant, which enables an optimized use of onboard space and facilitates the arrangement of machinery. Operationally, these systems are typically configured to operate at partial loads by engaging only the necessary number of generators, each running near its optimal efficiency point. This results in lower specific fuel consumption and simplifies maintenance scheduling. Although electric transmission introduces certain losses when compared to direct mechanical systems, these can be offset by the improved efficiency resulting from better load matching and operational flexibility.

From an acoustic standpoint, electric propulsion systems present significant advantages. By eliminating mechanical components such as gearboxes, clutches and couplings, the system reduces the transmission of vibrations and noise through the ship's structure. Electric motors generate significantly lower mechanical noise, and additional isolation using anti-vibration mounts can further minimize structural transmission. While noise mitigation is not the primary driver for adopting this technology, it is an important added value.

This type of propulsion is increasingly used in vessels with variable or high-demand operational profiles, such as AHTS ships. In these applications, the system provides high reliability and availability due to its modular and redundant configuration. Its ability to adapt to frequent and sudden load variations enhances performance and operational safety in challenging conditions.

In terms of lifecycle performance, diesel-electric propulsion offers lower fuel consumption and reduced maintenance costs, especially in vessels with variable load profiles. The flexibility in integrating various types of engines, combined with the optimized use of onboard space, enables efficient operation across different mission profiles.

However, these benefits must be carefully weighed against certain disadvantages. The initial investment cost of diesel-electric systems is generally higher than that of conventional diesel systems. In addition, the presence of intermediate components such as generators, converters and transformers introduces higher transmission losses, particularly under full load conditions.

In addition, these vessels often require significant electrical power for non-propulsion operations such as pumping, cargo handling or anchor management, making diesel-electric systems especially advantageous during periods of low propulsion demand.

While the reduction of underwater radiated noise (URN) is not the main objective of adopting electric propulsion, it represents a significant environmental benefit. According to the guidelines issued by the International Maritime Organization (IMO), ship-generated underwater noise can interfere with marine fauna, affecting their communication, navigation and survival behaviors. Electric propulsion contributes to mitigating these impacts through reduced mechanical vibration, smoother torque delivery, and optimized propeller performance, which together reduce cavitation and noise emissions. Furthermore, hybrid configurations that incorporate energy storage systems allow for silent operation during specific tasks, ensuring compliance with IMO environmental guidelines.

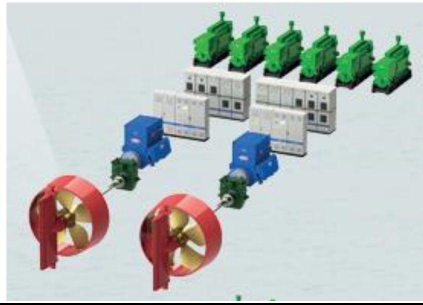
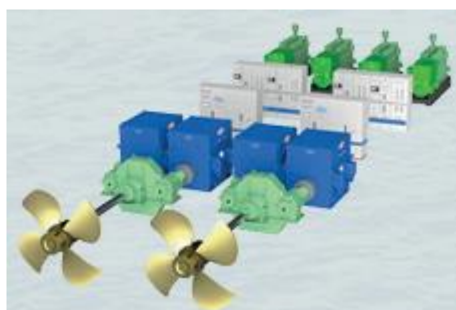
In summary, diesel-electric propulsion represents a technically robust and operationally flexible alternative to conventional diesel systems. Its advantages in terms of efficiency, space optimization, noise reduction, and system redundancy make it particularly suitable for vessels with high variability in power demand. Although it involves higher initial costs and certain energy losses, these are often compensated by the operational and environmental benefits over the vessel's service life.

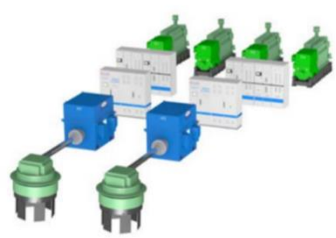
In the specific case of our design, adopting a diesel-electric propulsion system offers an additional advantage: it allows the elimination of the conventional shaft line. This configuration enables us to avoid routing the shaft tunnel through the methanol fuel tanks, which would otherwise introduce considerable construction challenges. These challenges arise from the strict coating requirements applicable to methanol tanks, as well as from the need to minimize structural welds and intersections in these areas to reduce the risks. Ensuring methanol tank surfaces that are as flush and flat as possible is a priority in our design, and the absence of a shaft tunnel directly contributes to this objective by simplifying internal geometry, improving integrity, and facilitating compliance with safety and classification standards for alternative fuel storage.

11.3 Transmission systems:

This section describes the most common types of diesel-electric transmission system configurations. The most relevant alternatives are summarized in the table below:

Table XXIV-Transmission System.

Transmission System	Advantages	Disadvantages
Hybrid with reduction gear box		
	✓ High operational flexibility and good efficiency at partial load. ✓ Improved maneuverability and power control, ideal for dynamic positioning (DP) and towing operations. ✓ Lower noise and vibration levels, enhancing onboard comfort. ✓ Generators can be placed flexibly, not constrained to the shaft line. ✓ Easy integration with hybrid systems or batteries. ✓ Electrical redundancy enhances operational safety.	× Higher system complexity and requires specialized maintenance. × Energy losses due to multiple energy conversions (typically 10–15%). × Higher initial investment compared to mechanical propulsion systems. × Requires additional space for electrical equipment and systems. × Still needs a reduction gearbox, adding weight and maintenance needs.
Hybrid with frequency converter		
	✓ High operational flexibility: allows efficient variation of propeller speed. ✓ Good maneuverability: ideal for dynamic positioning (DP) operations. ✓ Better efficiency at partial loads compared to direct mechanical systems. ✓ Lower noise and vibrations: beneficial for crew and marine life. ✓ Enables integration with alternative energy sources (e.g., batteries or methanol).	× Higher installation and electrical equipment costs. × Greater system complexity: requires more specialized maintenance. × Overall efficiency lower compared to simple mechanical systems at full load. × Additional energy conversion losses (mechanical electrical mechanical).

<table>
<tr><td rowspan="2">Hybrid with Azipod propellers</td><td colspan="2"></td></tr>
<tr><td>✓ Reduce fuel consumption by up to 20% compared to traditional shaft line systems. More efficiency and flexibility in operation.
✓ Smaller engine rooms.
✓ High maneuverability.
✓ Integration of multiple energy sources.
✓ Gearless system limits mechanical losses.
✓ Minimized engine noise and vibration.
✓ Fast installation.
✓ Less cavitation.</td><td>× More complex than other systems.
× Expensive to install, especially retrofitting existing vessels.
× To fully utilize its capabilities, crew members need specialized training</td></tr>
<tr><td rowspan="2">Hybrid with azimuth stern thruster</td><td colspan="2"></td></tr>
<tr><td>✓ Excellent maneuverability and directional control.
✓ Fast and flexible power response.
✓ Less noise and vibration.
✓ Lower mechanical maintenance.</td><td>× High initial cost.
× Complex electrical system.
× Can be less energy efficient than direct propulsion.
× Requires good electrical management to prevent failures.</td></tr>
<tr><td rowspan="2">Hybrid with Voith propellers</td><td colspan="2"></td></tr>
<tr><td>✓ .Smooth and instant thrust changes.
✓ Compact design that saves space in the engine room.
✓ Less noise and vibration.
✓ Lower mechanical wear due to fewer moving parts.
✓ Ideal for dynamic positioning and complex maneuvers.</td><td>× High initial costs.
× More complex control and electrical systems.
× Potentially lower overall efficiency compared to direct drive systems.
× Requires specialized maintenance and proper management.</td></tr>
</table>

The decision to adopt Azipod propulsion in our vessel design was made after a comprehensive evaluation of all propulsion alternatives. The design team selected Azipod as the optimal choice due to the wide range of technical, operational, and environmental advantages that this system offers over traditional shaft line propulsion.
Although the initial investment and the complexity of Azipods are major drawbacks, the reduction in fuel consumption, and therefore emissions, as well as its capacity to be integrated with multiple energy sources, cannot be ignored. Its maneuverability is also a key benefit, especially in ports where tug services are limited. In the end, the environmental benefits of Azipods over a conventional shaft line were the key factors that influenced the decision of the design team.
With Azipod propulsion, the full propeller thrust can be directed freely in any direction, whereas in fixed shaftline-rudder arrangements, thrust decreases rapidly as helm angle increases. A conventional rudder can produce about 40% side thrust compared to maximum ahead bollard pull thrust. In contrast, a freely turning Azipod can apply full thrust in any direction, giving 150% more side thrust than a conventional rudder. The superior maneuverability of Azipods has been demonstrated in full-scale trials between sister ships: MS Fantasy, with conventional propulsion, and MS Elation, with Azipods, showing a 38% reduction in tactical diameter. Similar results have been replicated in model experiments. Mechanically, Azipods feature a simple and robust drivetrain. The electric motor is installed directly on the propeller shaft, eliminating mechanical gears.

Figure 11.3-1-Azipod

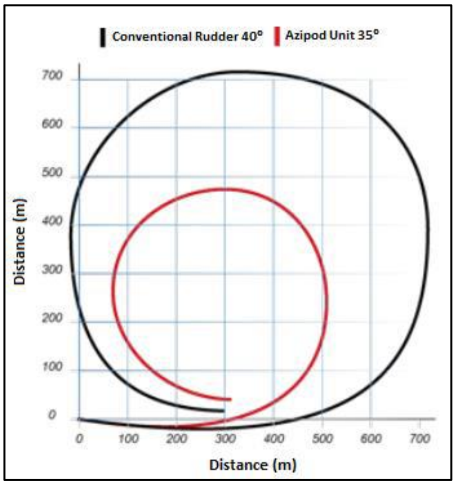


Figure 11.3-2-Azipod turning

Table XXV-Azipod Benefits

Design Benefits	Constructional Benefits	Operational Benefits
✓ Added cargo volume ✓ Lower weight ✓ One-lift installation ✓ Shorter building time ✓ Smaller engine rooms ✓ Simplified Casing	✓ One unit replaces gearbox, thrust bearing, shaftline, sterntube with sealing, lube-oil system, rudder, and steering gear ✓ Simplified steel structure ✓ No shaft alignment needed ✓ Reduced dry-dock building time	✓ Improved hydrodynamic efficiency ✓ Less cavitation ✓ Reduced vibrations and noise ✓ Lower exhaust emissions ✓ Enhanced navigational safety due to redundancy and steerability ✓ Reduced fuel consumption ✓ Optimal maintenance scheduling ✓ Reduced maneuvering time in port

Additionally, the Azipod's electric motor is housed in a submerged pod outside the hull, sealed with a robust shaft seal system using four rings and monitored for leaks. This eliminates the need for a rudder and long mechanical shaftline, saving onboard space

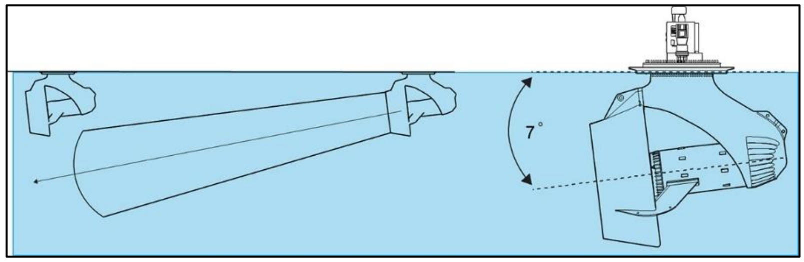


Figure 11.3-3-Hydrodynamic Design of the Azipod DZ with Tilted Shaftline

and improving safety and efficiency. The result in fuel saving, enhanced hydrodynamic performance, and reduced vibrations, making Azipods the preferred choice in cruise ships and vessels where comfort and efficiency are paramount. From a hydrodynamic standpoint, the Azipod DZ offers high thrust efficiency at low ship speeds thanks to its pushing configuration and optimized nozzle profile. The strut placement improves inflow conditions, and the 7-degree tilted shaftline reduces interaction with the hull, boosting effective thrust during dynamic positioning operations. Mechanically, Azipod D features near-perfect efficiency due to its gearless design with only two bearings. Electrically, the use of permanent magnet motors enhances efficiency to 98%, compared to 96% in induction motors, with even greater advantages at partial loads. The passive seawater cooling system eliminates the need for auxiliary pumps and fans, further increasing overall system efficiency.

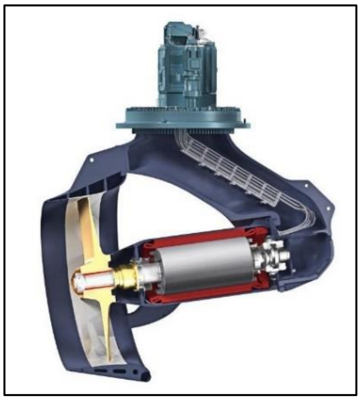


Figure 11.3-4-Azipod Propulsion Unit, Internal Configuration.

In addition, savings are gained due to the absence of other auxiliary systems that are present in a conventional propulsor, including a bevel gear lubrication system and possible steering hydraulics Figure Typical auxiliary systems needed for the Azipod C propulsor (left) and conventional geared propulsor. In terms of reliability and maintenance, Azipods have proven durability with minimal wear after years of operation. Maintenance intervals can be extended, and underwater replacement is feasible, as demonstrated in offshore operations. Another critical advantage in our specific design is that by using a diesel-electric propulsion system with Azipods, we eliminate the need for a conventional shaft line.

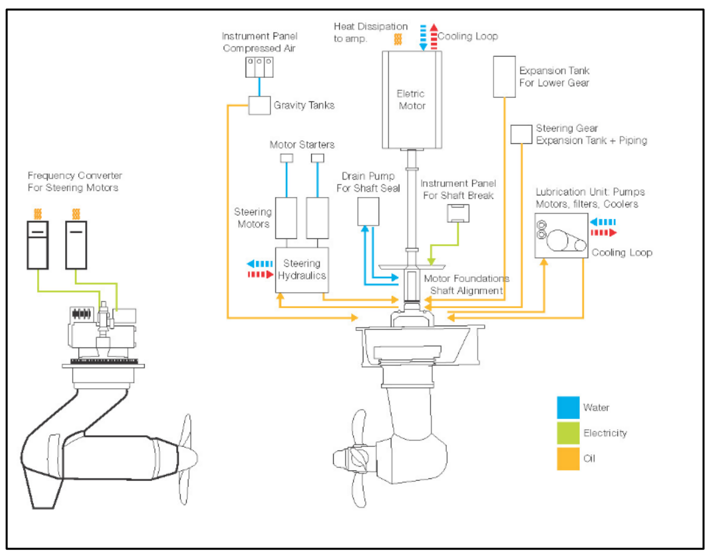


Figure 11.3-5-Auxiliary Systems in Conventional vs. Azipod Propulsion

This allows us to avoid running the shaft tunnel through the methanol tanks, which would otherwise pose significant construction challenges due to the strict coating requirements and the need to minimize welds and structural intersections. Reducing these interactions helps lower the risk of leaks or contamination. In our design, maintaining flat and flush surfaces within the methanol tanks is a key objective, and the absence of the shaft tunnel supports this goal by simplifying internal arrangements and enhancing structural integrity.

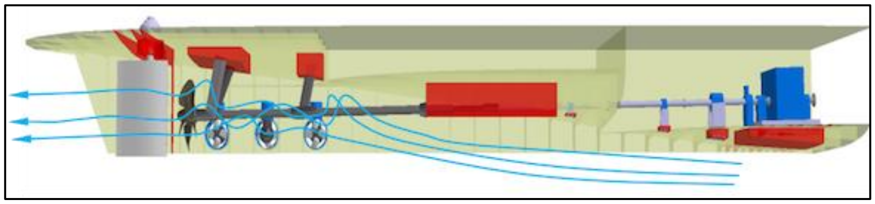


Figure 11.3-6- Azipod System Reliability and Underwater Maintenance Capability.

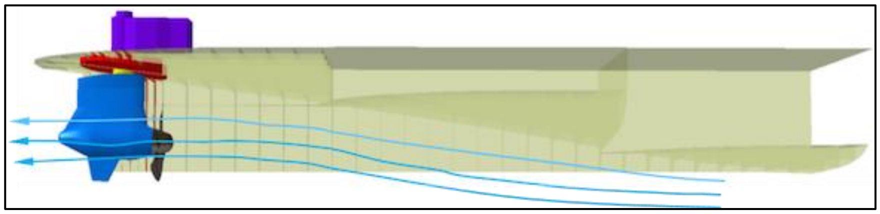


Figure 11.3-7-- Elimination of Shaft Tunnel Using Azipod Propulsion for Enhanced Tank Integration.

Finally, the Azipod system contributes to reduced hull resistance by removing appendages such as shaftlines, rudders, and tunnel thrusters, and by allowing for smoother hull lines and optimized stern geometry. These factors, combined with improved payload capacity and layout flexibility, make Azipod propulsion the ideal solution for our vessel.

12 HULL MODELING

The creation of the hull forms is a critical aspect of ship design, as it has a significant impact on multiple areas of the project. From a hydrodynamic perspective, the optimal hull shape is the one that allows the vessel to operate at its service speed with minimal power consumption resulting in lower fuel usage and improved range.

The objective of this section is to obtain a 3D model of the ship's hull using MAXSURF, specifically its Maxsurf Modeler module. This software utilizes NURBS (Non-Uniform Rational B-Splines), a mathematical model widely used in computer graphics to accurately represent complex curves and surfaces.

The hull has been primarily analyzed from a hydrodynamic point of view. Nonetheless, other essential factors such as seakeeping, intact and damage stability, and commercial operational efficiency must also be considered, as they directly influence the final hull design.

In particular, the ship's performance at sea requires special attention. A decision must be made between prioritizing platform stability or minimizing speed reduction and acceleration in waves. This trade-off will significantly shape the final hull geometry.

This translates into a design approach focused on reducing calm water resistance and limiting ship motions in waves.

Developing a detailed 3D hull model will enable further refinement of the ship’s design through various analyses using dedicated software tools, including:

- Hydrostatics and displacement calculations, using MAXSURF Stability.
- Intact and damaged stability analysis, using MAXSURF Stability.
- Resistance prediction, using MAXSURF Resistance and CFD. (Computational Fluid Dynamics)
- Seakeeping performance, using Maxsurf Motions.
- Geometric and operational analysis, including hold volumes, machinery spaces, and tank capacities.

Because we are designing an Anchor Handling Tug Supply (AHTS) vessel, we do not have access to as much standardized reference data as is typically available for merchant ships. However, we can rely on a selection of proven designs from existing AHTS vessels, using them as a baseline to be adapted and refined according to the specific operational requirements of our project. This approach enables us to strike a balance between technical reliability and tailored innovation, ensuring that the final hull form meets the demands of both performance and functionality in offshore environments.

12.1 Stern form analysis

The stern hull forms must take into account the influence of water inflow to the propeller, aiming to achieve the most laminar flow possible. This is essential to minimize vibrations on both the propeller and rudder configurations. To ensure optimal flow quality, the wake coefficient must be reduced to a minimum. One of the most effective strategies to achieve this is to reduce the hull section in the vicinity of the propeller, thereby minimizing flow distortion and turbulence.

The skeg, a vertical, tapering structural projection located aft, typically along the vessel's centerline was incorporated into the design. This component offers several well-documented benefits:

- Enhanced propeller efficiency, due to improved flow guidance and stabilization.
- Reduced turbulence in the aft region, as the skeg helps transition chaotic flow into more laminar patterns.
- Improved hydrodynamic separation of Azipod flows, especially when centrally aligned, minimizing flow interference between units.
- Assists with maneuvering and braking, particularly after sharp turns, by generating additional resistance at the stern.

The length and geometry of the skeg were carefully designed to avoid interference with the transverse thrust flow generated by the Azipods when operating in lateral mode.The shape of the stern is inherently influenced by the type of propulsion system selected. After careful evaluation, the design team opted for Azipod Electric Propulsion by ABB, a choice extensively justified in the Transmission System section. The decision was based not only on performance data but also on integration flexibility and lifecycle benefits.

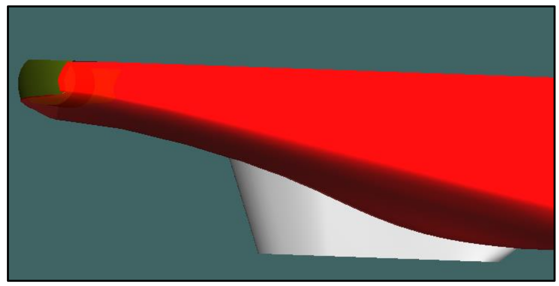


Figure 12.1-1-Stern Hull Form.

During the propulsion integration study, it was identified that a flat and robust mounting surface is required at the stern to accommodate the Azipods securely—akin to a well-leveled platform. This surface is not only essential for structural integrity but also for the proper alignment and operational efficiency of the units.

In summary, the stern hull form has been designed not just as a structural necessity, but as a refined hydrodynamic feature that harmonizes with the selected propulsion system, ensuring optimal performance, maneuverability, and energy efficiency throughout the vessel's operational profile.

12.2 Bow Analysis.

The first decision to be made regarding the bow is whether to install a conventional bow or an X-Bow.

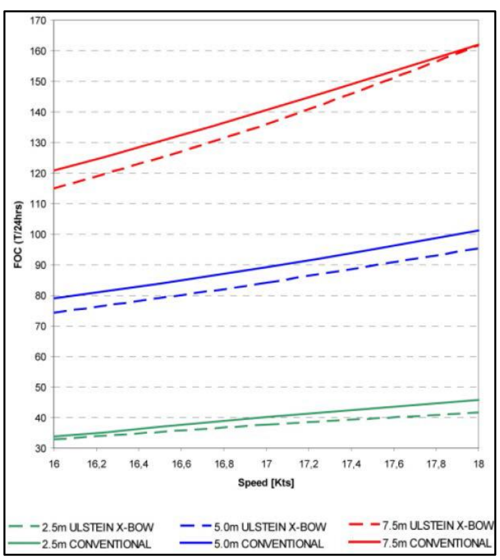


Figure 12.2-1- Fuel Consumption Comparison: X-Bow vs. Conventional Bow Designs.

The possibility of using an X-Bow type bow was analyzed, based on the results of tests carried out by the Norwegian Marine Technology Research Institute (MARINTEK). The graph indicates that for waves under 5 meters and speeds below 16 knots, the reduction in fuel consumption tends to be negligible. Therefore, the implementation of the X-Bow is not considered, given that our service speed is only 12.5 knots.

The second decision to be made regarding the bow is whether to install a bulbous or a straight bow.

Based on the hull shapes of reference vessels, it is noted that both bulbous and straight bows are used, so their application must be investigated more thoroughly. Based on research into vessels in the industry, motivated by the significant number of ships with conventional bows, it was found that the conventional bow performs adequately, considering the specific dimensions, speeds, and sea conditions of our intended route.

At this point, a decision must be made regarding whether to implement a conventional or a bulbous bow. Alvariño Meizoso outlines a set of conditions for the application of a bulbous bow: if all conditions are met, a bulbous bow should be implemented; if even one condition is not met, the implementation is not confirmed, but neither is it ruled out.

Table XXVI - Criteria for Bulbous Bow Implementation According to Meizoso

Condition	Condition	Value	Verify
A	$0.65 < C_B < 0.815$	0.735	YES
B	$5.5 < L_{pp}/B < 7.0$	3.71	NO
C	$0.24 < F_N < 0.57$	0.26	YES
D	$C_B.B/L_{PP} > 0.135$	0.2	YES

In our case, 3 out of 4 conditions are met, with Condition B being the exception. Therefore, to determine whether or not to implement a bulbous bow, a resistance analysis of both hulls will be carried out using CFD.

The selection of the bulbous bow type will be based on the hull forms of reference vessels that have already been built and demonstrated satisfactory performance. Given the absence of specific literature for this type of vessel and the fact that a detailed study of various bulb shapes under different loading conditions is beyond the scope of this report, it is considered reasonable to adopt a proven design approach.

The analyzed bows are shown in their profile view

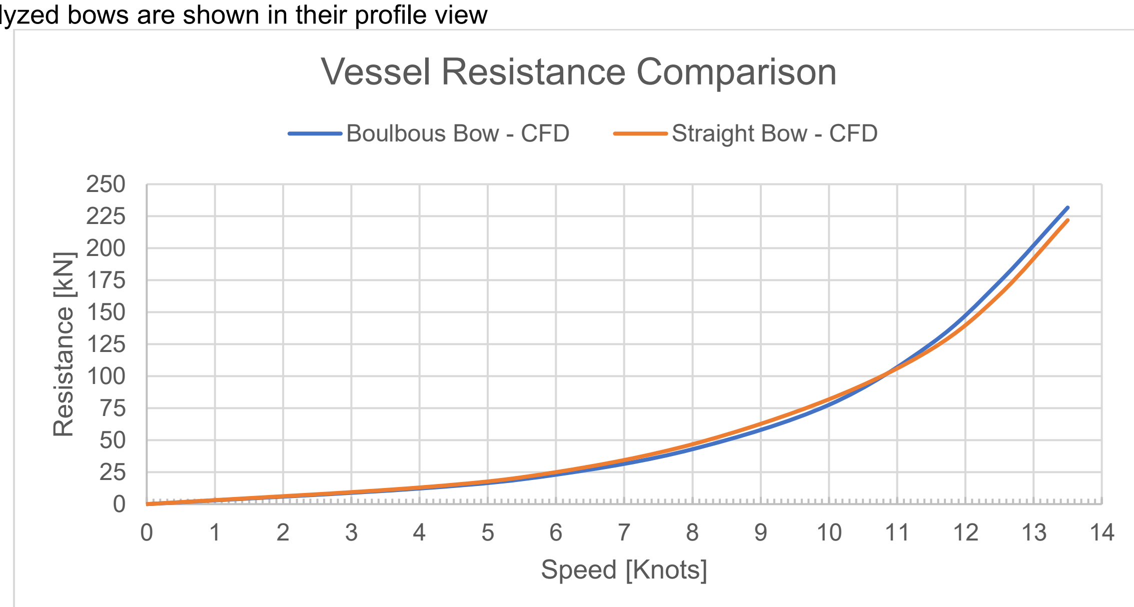


Figure 12.2-2-Vessel Resistance Comparison.

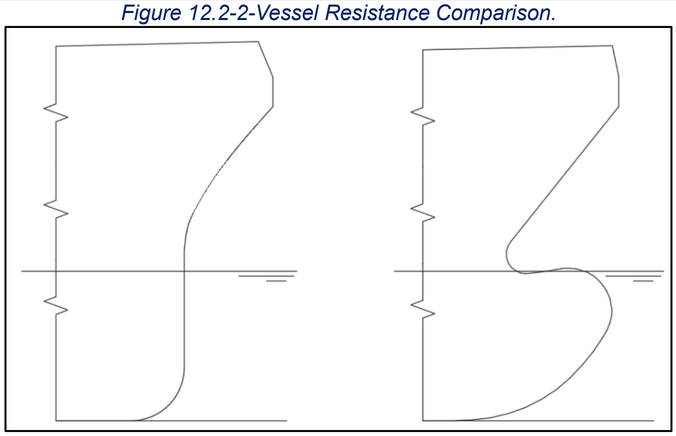


Figure 12.2-3-Bow Analyzed.

Table XXVII - Resistance Comparison, Straight Bow vs. Bulbous Bow.

Speed	Straight Bow CFD	Boulbous Bow CFD	Difference
[Knots]	[kN]	[kN]	%
0	0	0	0
4	13.0	12.2	6%
6	25.0	23.0	8%
8	46.8	42.9	8%
10	81.9	77.6	5%
11,5	121.0	125.4	-4%
12,5	163.6	173.7	-6%
13,5	221.9	231.7	-4%

To estimate the resistance of both hulls, a CFD analysis was carried out, showing a slight reduction in resistance for the bulbous bow at low speeds, whereas at speeds close to and at the service speed, the straight bow resulted in lower resistance. Therefore, the team decided to adopt the straight bow, as it proved to be more efficient at the service speed, requiring less fuel consumption, and also due to its simpler construction and shorter build time compared to the bulbous bow.

12.3 Fairing, Curvature and Surface Analysis

As a result, a fair and hydrodynamically efficient hull was achieved. Minor fairness refinements will be addressed in a later stage of the modeling process; however, none of the current imperfections are expected to significantly impact performance during the conceptual design phase.

Once the hull form and principal dimensions were established, curvature and surface analysis tools were used to verify and refine the continuity of the hull. To ensure a smooth surface, the defining curves must also exhibit smooth transitions.

The following images present an initial assessment of the hull curvature. For clarity and conciseness, midship sections, and an overall view of the vessel displaying longitudinal ans transverse curvature are shown.

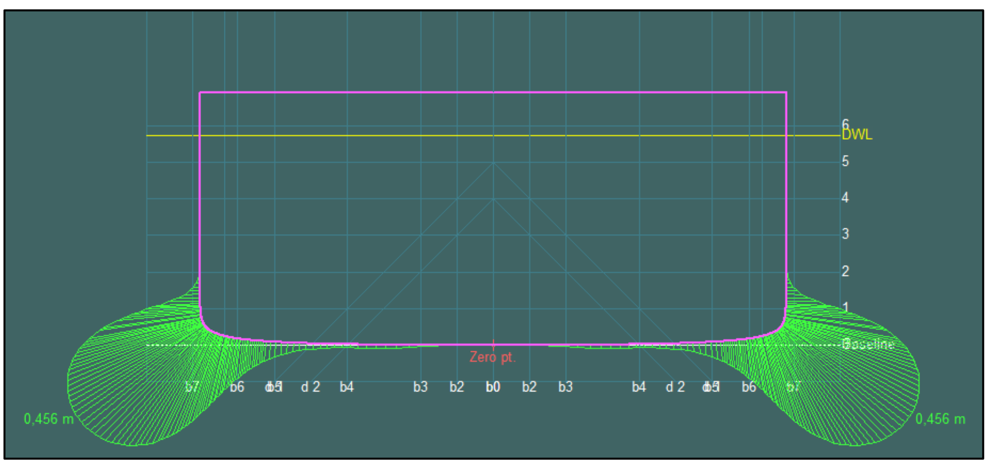


Figure 12.3-1 - Hull Surface Fairing and Curvature Assessment.

The design team used renderings (Figure 12.3-2 & Figure 12.3-3) to evaluate both transverse and longitudinal curvature, identifying any abrupt changes that could lead to irregularities on the hull surface.

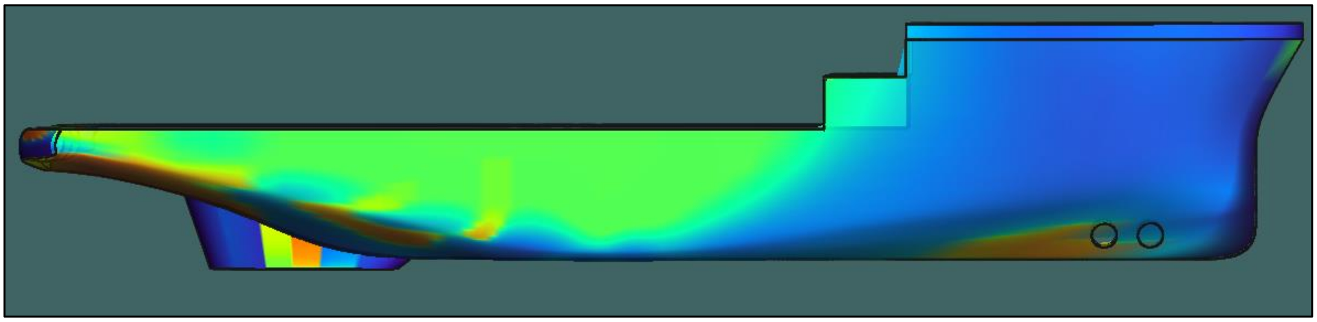


Figure 12.3-2-3D modeling - rendering longitudinal curvature.

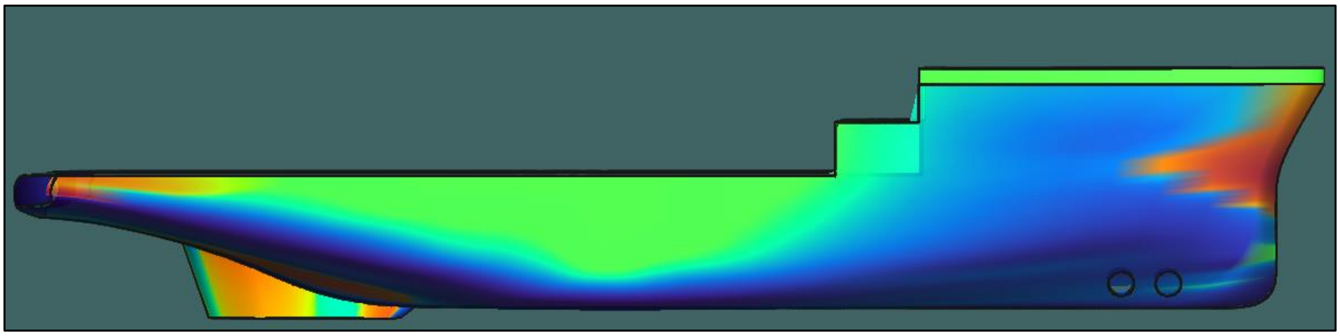


Figure 12.3-3-3D modeling - rendering transversal curvature.

Some areas exhibit consistent reddish tones, indicating longitudinal curvature with slight variations. Green areas represent flat regions with zero curvature. Additionally, color gradients help distinguish between surface characteristics: blue tones indicate concavity, while red tones indicate convexity.

Following this analysis, the team concluded that the hull surface is fair. Minor fairness issues will be addressed in the next phase of modeling, but none are expected to affect the outcomes of the current design stage.

13 HULL RESISTANCE

To estimate the effective resistance of the hull, a combined approach was adopted using both the Holtrop method and Computational Fluid Dynamics (CFD). These complementary techniques allowed for a balance between empirical prediction and numerical simulation during the preliminary design phase.

The Holtrop method was selected as the initial predictive tool due to its established reliability for conventional ship designs. It is a statistical model developed through regression analysis of model test data and full-scale measurements carried out at the Netherlands Ship Model Basin. Although widely applied in early-stage resistance prediction, the method has known limitations when unconventional parameter combinations are used. To address this, the original model has been extended by calibrating its prediction formulas with additional test data, broadening its applicability.

In parallel, the design team conducted CFD simulations to enhance the accuracy of the resistance estimation. While a full hull optimization study was outside the scope of this phase, obtaining a reliable prediction of the Effective Horsepower (EHP) was essential for preliminary propeller selection and ensuring high propulsive efficiency.

13.1 Holtrop Method

The following section presents the applicability range of the Holtrop method, alongside the principal characteristics of the vessel under development. It can be observed that all conditions required for the method's application are met.

Table XXVIII - Validation of Hull Parameters for Holtrup Method Application.

Parameter		Limitation	Actual value	Verify
Prismatic Coefficient	C_P	0.55 to 0.85	0.696	YES
Lenght Breath relation	L/B	3.9 to 15	3.98	YES
Breath draught relation	B/T	2.1 to 4.0	2.80	YES

The implementation was carried out using Maxsurf Resistance, based on the 3D model of the hull. The resulting resistance values will be presented in the following sections and compared against those obtained through CFD analysis.

13.2 CFD configuration

The CFD simulations were conducted using the 3D hull model developed in Maxsurf. Input parameters included the vessel's trim and displacement at service draft, and the hull was evaluated across a range of speeds.

The simulations were performed in the commercial CFD code STAR-CCM+, under an academic license granted through a partnership between UTN and SIEMENS, provided by the partner X-Plan. To optimize computational resources, only half of the hull was modeled, following standard CFD best practices.

The configuration parameters were as follows:

- A grid consisting of 3.5 million elements was created.
- The simulations employed the Reynolds-Averaged Navier-Stokes (RANS) methodology.
- Turbulence closure was handled using the k-epsilon model, suitable for moderately streamlined hull shapes.
- A time step of 0.017 seconds was chosen to meet the stability requirements dictated by the Courant number.
- The fluid interface was represented using the Volume of Fluid (VOF) technique, with the free surface identified at a phase fraction value of 0.5.
- To accurately resolve turbulence near the hull, prism layers extending up to 0.07 meters from the hull boundary were incorporated, applying wall treatment to control y+ values.
- The grid was constructed through a combination of prism layer meshing, surface remeshing, and trimming operations. The resulting volume deviation was 0.0%, demonstrating excellent mesh integrity and aiding the convergence of the numerical solution.
- Targeted mesh refinement was applied in the bow, skeg, and stern areas to improve accuracy in regions with complex flow.

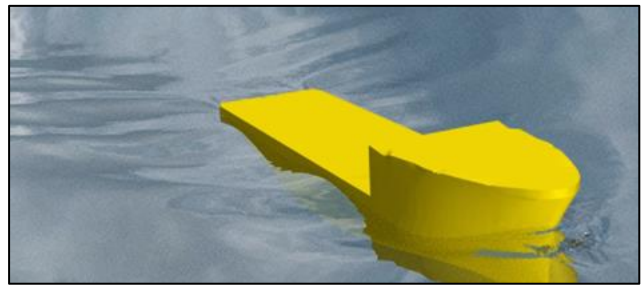


Figure 13.2-1 - 3D Hull Model Used for CFD Simulations.

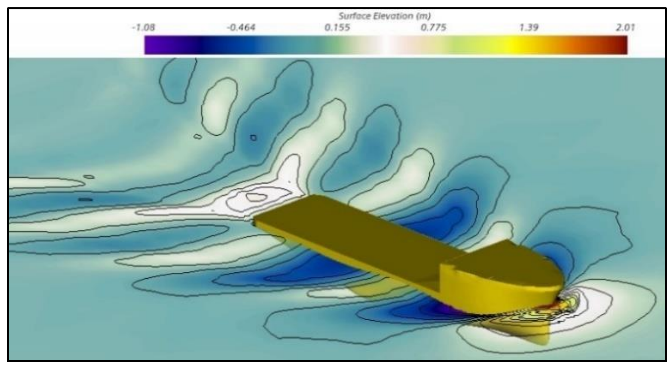


Figure 13.2-2 - CFD Results, Pressure and Wake Field Distribution.

The simulation proceeded until convergence criteria were satisfied. Once the solution stabilized, resistance values were exported to Excel, and average results from the final stabilized portion of each run were calculated for every tested speed.

13.3 Resistance result

The results obtained from both the Holtrop method and the CFD simulations, performed at the vessel's design draught, are shown below.

Table XXIX - Resistance Comparison CFD vs. Holtrop Method.

Speed	Straight Bow CFD	Holtrop Method	
[Knots]	[kN]	[kN]	Difference %
0	0	0	0
4	13.0	16.5	21%
6	25.0	35.0	29%
8	46.8	59.7	22%
10	81.9	94.6	13%
11,5	121.0	137.6	12%
12,5	163.6	180.0	9%
13,5	221.9	239.8	7%

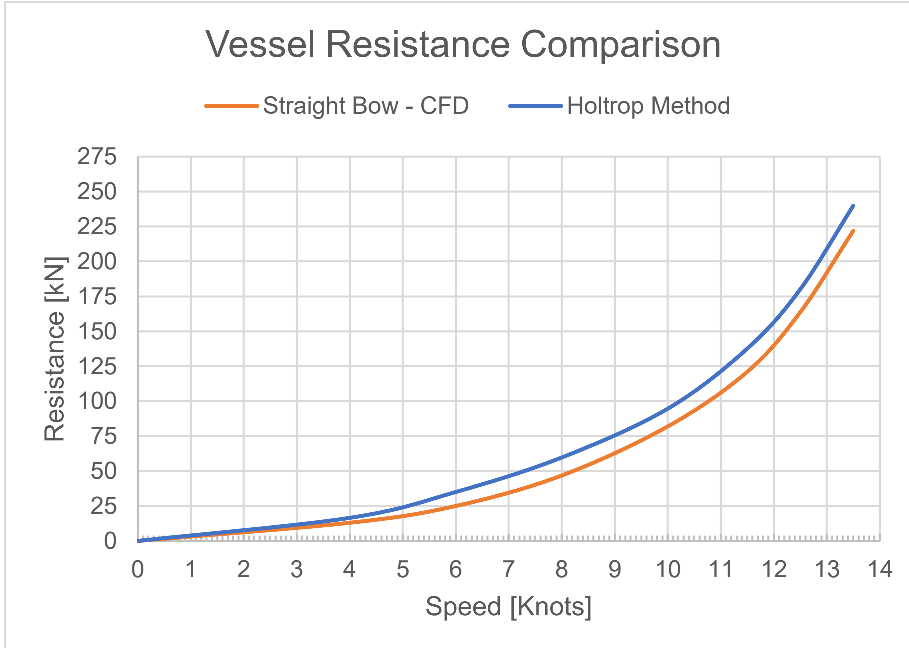


Figure 13.3-1-Vessel Resistance Comparison.

Given that the Holtrop method was not originally developed for vessels of this type and based on prior experience from the university's hydrodynamics laboratory, it is known that this method tends to overestimate resistance for vessels of similar length. This overestimation becomes less pronounced at higher speeds, as illustrated Figure 13.3-1.

The Holtrop method is based on empirical regression of model test data and relies on potential flow theory, which does not account for viscous flow effects in detail. As such, it may not accurately capture flow separation, wave interference, or viscous pressure drag in unconventional hull forms or low-speed regimes. These simplifications are often acceptable for traditional ship types within the method's calibrated range, but they can lead to discrepancies when applied to other designs.

In contrast, Computational Fluid Dynamics (CFD) solves the Navier-Stokes equations numerically, providing a more accurate representation of the fluid behavior around the hull, including viscous and turbulent effects. Although CFD simulations require significantly more computational time and resources, they offer improved fidelity in predicting resistance.

Therefore, considering the expected overprediction from the Holtrop method, the design team ultimately relied on the results obtained from CFD simulations for the final resistance prediction.

13.4 Appendage Resistance

The bilge keel and the nozzle intended for the propeller were not included in the resistance simulations; therefore, the additional resistance generated by these appendages must be estimated. For this purpose, the formula proposed by Holtrop will be applied.

$$R_{App} = \frac{1}{2}.\rho.V^2.S_{App}.(1+K_2).C_F \tag{45}$$

Where S_{App} is the wetted area of the appendages, $(1+K_2)$ the appendage resistance factor and C_F the coefficient of frictional resistance of the ship according to the ITTC

According to this method, the resistance of appendages is evaluated independently, ignoring both the influence these appendages exert on the flow over the hull and the influence of the hull on the velocity field around the appendages.

The appendage resistance factor is calculated as follows:

$$(1+K_2) = \frac{\sum(1+K_2)S_{App}}{\sum S_{App}} \tag{46}$$

The table below shows the tentative $(1 + K_2)$ values assigned to each appendage, along with the calculated total appendage resistance factor.

Table XXX -Appendage Resistance Factor Calculation.

	S_{APP}	$1+k_2$	$(1+k_2)*S_{APP}$	Effective length
Unit	**[m²]**	**[-]**	**[m²]**	**[m]**
Nozzle	78.70	2.00	157.4	3.0
Bilge Keel	48	1.4	67.2	80.0
Total	**126.7**	**1.773**	224.6	83.0

Approximate $1 + k_2$ values	
rudder behind skeg	1.5 – 2.0
rudder behind stern	1.3 – 1.5
twin-screw balance rudders	2.8
shaft brackets	3.0
skeg	1.5 – 2.0
strut bossings	3.0
hull bossings	2.0
shafts	2.0 – 4.0
stabilizer fins	2.8
dome	2.7
bilge keels	1.4

Figure 13.4-1- Typical Values for Marine Appendages.

For the service speed, the appendage resistance is calculated as follows: $R_{App} = 8.345kN$

13.5 Bow Thruster Resistance

The total resistance must be increased by the resistance due to the bow thruster tunnel openings, calculated as follows:

$$R_{BTO} = \rho.V^2.\pi.d^2.C_{BTO} \tag{47}$$

where d is the tunnel diameter. The coefficient C_{BTO} ranges from 0.003 to 0.012. To be conservative, the maximum value of this range will be adopted.

Given that the diameter of each tunnel opening is 1.3 meters and there are two bow thrusters, the additional resistance due to the tunnels is: $R_{BTO} = 5.4kN$

13.6 Surface Roughness Resistance

Considering the vessel's length and construction details (welded steel), an average hull roughness (AHR) of 150 micrometers is deemed acceptable, according to the Specialist Committee on Powering Performance Prediction in their publication, "Final Report and Recommendations to the 25th ITTC."

Based on the length between perpendiculars and the average hull roughness, the friction coefficient (Cf) is calculated using Townsin et al.'s formula:

$$C_F = 0.044\left(\left(\frac{AHR}{L_{PP}}\right)^{\frac{1}{3}} - 10 * Rn^{-1/3}\right) + 0.000125 = 8.3 * 10^{-5} \tag{48}$$

This non-dimensional coefficient is influenced by wetted surface area, water density, and vessel speed, and is subsequently added to the resistance values obtained from the CFD analysis. The corresponding resistance is calculated as:

$$R_{SR} = \frac{1}{2}.C_F * \rho * S * V^2 = 2.63kN \tag{49}$$

Finally, the total resistance at service speed is obtained by summing the CFD resistance, the additional appendage resistance, and the bow thruster resistance, resulting in a final value of 180 kN.

14 PROPELLER AND ENGINE SELECTION

14.1 Coefficient

14.1.1 Wake coefficient

This value can be calculated based on the relationships provided in Gaykovich (2014b), with the appropriate corrections applied for Supply-type vessels.

$$w = k_W * 0.165 * C_B^2 . \frac{(L_{WL}.B.T.C_B)^{\frac{1}{6}}}{\sqrt{D}} - 0{,}1.C_B.(F_N - 0.2) = 0.175 \quad (50)$$

- $k_W = 1$ For Supply-type vessels.

14.1.2 Thrust deduction coefficient.

It can be calculated based on the relationships provided in Gaykovich (2014b), with the necessary corrections applied for Supply-type vessels.

$$t = k_T.(0.7 * w + 0.06) = 0.182 \quad (51)$$

Where: $k_T = 1$ For Supply-type vessels.

The referenced table (Table XXXI) provides the value of the thrust coefficient at zero advance ratio, which has been set to 0.05.

Table XXXI- Thrust deduction coefficient

Configuration	t
Single-screw ships of great fullness	0.20-0.25
Slender single-screw ships	0.16-0.22
Twin-screw ships, normal fullness	0.10-0.15
Slender twin-screw ships	0.07-0.12
In bollard condition (V = R = 0!)	0.02-0.05
Astern	2*t_{ahead}

14.2 Efficiency

14.2.1 Relative rotative efficiency

Using the expression recommended by Holtrop, this efficiency depends on P/D, a parameter that is currently unknown and subject to variation due to the use of a controllable pitch propeller:

$$\eta_{rr} = 0.9737 + 0.111 * (C_P - 0.0225.LCB) - 0.06325\ P/D = 0.981 \quad (52)$$

However, to gain an initial understanding of the expected value, the calculation is performed over a representative range of P/D ratios typical for this type of vessel.

14.2.2 Mechanical efficiency

A mechanical efficiency of 88.5% is considered, as it corresponds to an electric propulsion system.

$$\eta_m = 0.885 \quad (53)$$

14.3 Propeller selection

The objective of this study is to analyze and define the preliminary optimum propeller to satisfy the different operating conditions.

14.4 Discussion of type of propeller

In this section, it is clarified that although the Azipod manufacturer provides an efficient and well-tested propeller and nozzle design, for academic purposes we will design these components ourselves, as the detailed information is understandably confidential.

The following graph can be used to determine the propeller with the highest efficiency based on the thrust coefficient. The velocity used for this calculation will not be the free-running speed but a lower speed (6 knots), representative of towing operations such as pulling a platform, which is more characteristic for this type of tug vessel. Additionally, the RPM values were estimated based on similar vessels and will be confirmed later to fall within the expected range.

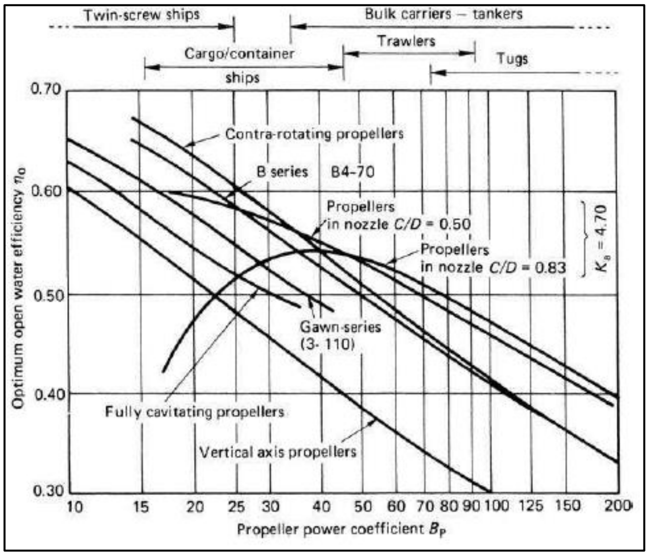


Figure 14.4-1 - Optimum Open Water Efficiencies for Various Propeller Types.

$$B_P = \frac{\sqrt{DHP} * N}{Va^{2,5}} = \frac{\left(\sqrt{\frac{BHP}{2} * \eta_m . \eta_{rr}}\right) * N}{\left(V * (1 - w)\right)^{2,5}} = 129.5 \tag{54}$$

Where:

- BHP = 3620 HP. Estimated based on statistical data discussed in the previous step.
- N = 140 RPM. Estimated propeller speed, based on benchmark data from vessels with similar operational profiles.
- S = 6 knots. Proposed towing speed for this vessel

Taking into account the limits defined in the chart for tugboats, and based on the analysis of comparable vessels, it can be concluded that the Kaplan 4.70 series propeller with 19Anozzle is predominantly used.

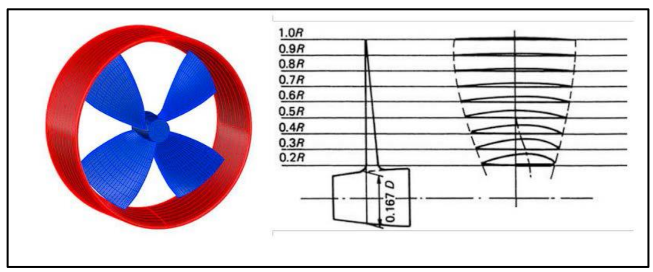


Figure 14.4-2 - Ducted Propeller (Nozzle) with Blade Section and Geometry Details.

14.5 Propeller size

Whether aiming for the most efficient propeller to generate the necessary thrust to reach a specific design speed, or the most efficient configuration for the "bollard pull" condition, the propeller diameter should generally be as large as possible within the constraints of the stern tube opening.

Based on the overall arrangement, the maximum allowable dimensions for the nozzle will be determined considering the ballast arrival condition at port. To ensure that the propeller remains fully submerged, the draft used for this assessment corresponds to the vessel's lightship draft plus an additional 20%, accounting for various loads expected in the ballast condition. This is a conservative approximation intended to ensure adequate submergence under all operational scenarios. The resulting nozzle diameter must then be verified against the commercially available sizes of Azipod units. Subsequently, during the intact stability analysis, it will be verified that the propeller remains submerged under every loading condition, according to the corresponding draft and trim.

For this design, the propeller diameter is set at 3 meters.

14.6 Calculation Procedure

The thrust and torque coefficients, K_T, K_{TN} (Thrust coefficient of the nozzle), and K_Q, were expressed as polynomial functions of the advance coefficient J and the pitch-to-diameter ratio P/D. The formulas and their corresponding coefficients are presented in the following figures, (Figure 14.6-1-K_T Formulation, Figure 14.6-2-K_{TN} Formulation & Table XXXII – Coefficients for K_T and K_{TN} calculation).

$$
\begin{aligned}
K_T = {} & A_{0,0} + A_{0,1}\, J + \text{-----------} + A_{0,6}\, J^6 + \\
& + A_{1,0}\left(\frac{P}{D}\right) + A_{1,1}\left(\frac{P}{D}\right) J + \text{-----------} + A_{1,6}\left(\frac{P}{D}\right) J^6 + \\
& + A_{2,0}\left(\frac{P}{D}\right)^2 + A_{2,1}\left(\frac{P}{D}\right)^2 J + \text{-----------} + A_{2,6}\left(\frac{P}{D}\right)^2 J^6 + \\
& \text{-----------------------------} \\
& + A_{6,0}\left(\frac{P}{D}\right)^6 + A_{6,1}\left(\frac{P}{D}\right)^6 J + \text{-----------} + A_{6,6}\left(\frac{P}{D}\right)^6 J^6
\end{aligned}
$$

Figure 14.6-1-K_T Formulation

$$
\begin{aligned}
K_{TN} = {} & B_{0,0} + B_{0,1}\, J + \text{-----------------} \\
& \text{-----------------------} + B_{6,6}\left(\frac{P}{D}\right)^6 J^6 \\
K_Q = {} & C_{0,0} + C_{0,1}\, J + \text{-----------------} \\
& \text{-----------------------} + C_{6,6}\left(\frac{P}{D}\right)^6 J^6
\end{aligned}
$$

Figure 14.6-2-K_{TN} Formulation

Table XXXII – Coefficients for K_T and K_{TN} calculation

x	y	Axy	Cxy	Bxy
0	0	0,03055	0,006735	0,076594
0	1	-0,148687		0,075223
0	2		-0,016306	-0,061881
0	3	-0,391137		-0,138094
0	4		-0,007244	
0	5			-0,37062
0	6			0,323447
1	0			-0,271337
1	1	-0,432612		-0,687921
1	2		-0,024012	0,225189
1	3			
1	4			
1	5			
1	6			-0,081101
2	0	0,667657		0,666028
2	1			
2	2	0,285076	0,005193	0,734285
2	3			
2	4			
2	5			
2	6			
3	0	-0,172529	0,046605	-0,202467
3	1			
3	2			-0,54249
3	3			
3	4			
3	5			
3	6			-0,016149
4	0		-0,007366	
4	1			
4	2			
4	3			0,099819
4	4			
4	5			
4	6			
5	0			
5	1			0,030084
5	2			
5	3			
5	4			
5	5			
5	6			
6	0		-0,00173	
6	1	-0,017293	-0,000337	
6	2		0,000861	-0,001876
6	3			
6	4			
6	5			
6	6			

From the following relationship, the efficiency curves are derived.

$$\eta_0 = \frac{J.K_T}{2.\pi.K_Q} \tag{55}$$

In order to automate the propeller sizing process, the curves were plotted using MATLAB.

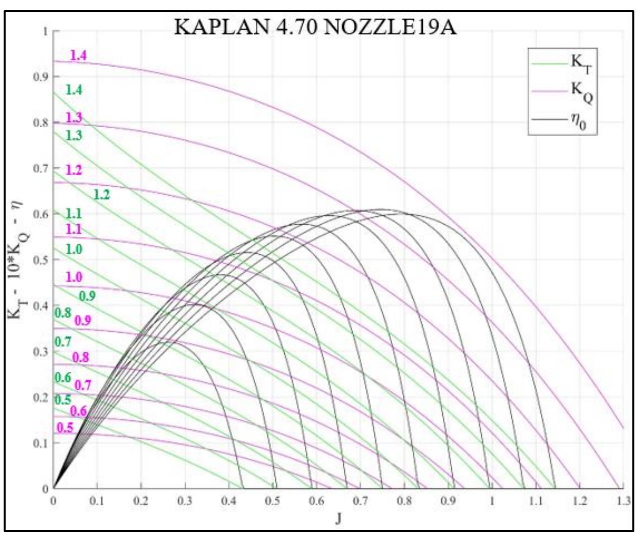


Figure 14.6-3-Kaplan 4.70 Nozzle 19A.

Note: *The curves corresponding to the nozzle thrust coefficient (KT_N) have been excluded from the figure, as they are intended only for cavitation verification and including them would visually clutter this important section.*

14.7 Service Speed

We know the thrust T, the advance speed V_A, and the diameter D. Since the diameter is fixed, the objective is to find the combination of rotational speed (RPM) and pitch-to-diameter ratio (P/D) that yields the best propeller efficiency η_0

Due to the abundance of unknown variables, the thrust coefficient at constant diameter KT_D is introduced to eliminate the dependency on the rotational speed.

Since the loading condition and speed correspond to service conditions, the power used in this formula must include the service margin. This ensures that the propeller design point lies on the loaded propeller curve.

$$K_{TD} = \frac{\left(EHP_{Service} * (1+MS)\right)/(No.of\ Shafts)}{(1-t)(1-w)^2.V^3.\rho.D^2} = \frac{K_T}{J^2} \tag{56}$$

Where:

- $EHP_{Service}$: *Effective horsepower under service speed condition*
- MS: *Service margin, considered to be 25%*
- V: *Service speed*

This simplification allows determining the optimal number of revolutions for the estimated diameter, meaning the number of revolutions at which the propeller efficiency reaches its maximum. The values of K_T are determined for various advance coefficients J, Then the curve is plotted alongside the open water test curves, and the intersections with the K_T curves are identified. For each abscissa, the corresponding ordinates from both the K_T curve and the K_Q and efficiency η_0 curves are obtained. Resulting in the following:

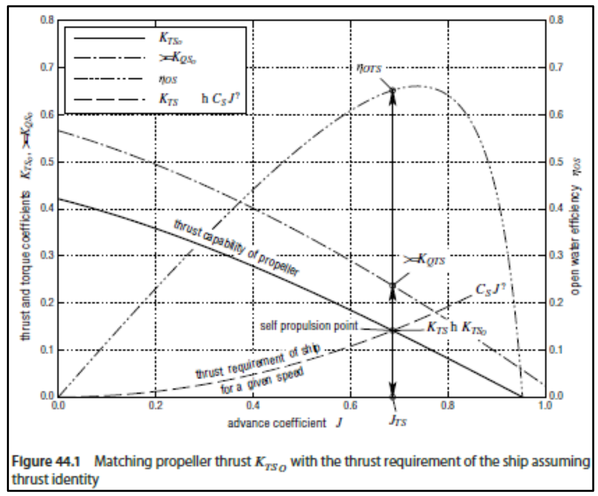


Figure 14.7-1-Matching Propeller.

Table XXXIII-Coefficient Ktd.

K_{TD}		
0.5214		
no	**J^2**	**K_T**
0	0	0.00
0.1	0.01	0.01
0.2	0.04	0.02
0.3	0.09	0.05
0.4	0.16	0.08
0.5	0.25	0.13
0.6	0.36	0.19
0.7	0.49	0.26
0.8	0.64	0.33
0.9	0.81	0.42
1.0	1.00	0.52
1.1	1.21	0.63
1.2	1.44	0.75
1.3	1.69	0.88

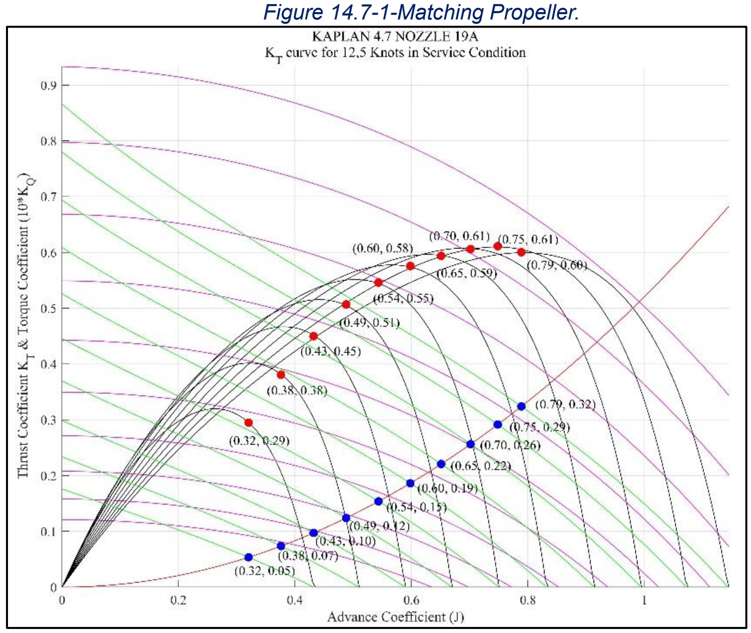


Figure 14.7-2 - KT curve for service speed.

For each pitch-diameter ratio, the propeller's revolutions per minute are calculated using the following expression:

$$N[rpm] = \frac{V_A}{J * D} * 60 = \frac{V.(1-w)}{J * D} * 60 \tag{57}$$

The brake power for each pitch-diameter ratio is calculated using the following expression:

$$P[W] = \frac{2.\pi.\rho.N[rps]^3.D^5.K_q}{\eta_{rr}.\eta_m} \tag{58}$$

And the torque required by the propeller is determined using the following expression:

$$Q = k_Q * N[rps]^2 * \rho * D^5 \tag{59}$$

Obtaining the following results, organized in the table below.

Table XXXIV - Propeller Efficiency in Terms of Revolution Speed.

P/D	J	K_T	K_Q	η_0	N1=VA/Ji.D [rps]	N1 [rpm]	PB [kW]	Q [kN.m]
0.5	0.3202	0.0534	0.0092	0.295	5.5260	332	2809	70
0.6	0.3759	0.0736	0.0116	0.381	4.7080	283	2177	64
0.7	0.4319	0.0972	0.0149	0.450	4.0970	246	1842	62
0.8	0.4878	0.1240	0.0190	0.507	3.6280	218	1635	62
0.9	0.5433	0.1537	0.0243	0.546	3.2580	196	1518	64
1	0.5978	0.1861	0.0308	0.576	2.9600	178	1439	67
1.1	0.6508	0.2206	0.0385	0.594	2.7190	164	1395	71
1.2	0.7014	0.2562	0.0472	0.606	2.5230	152	1367	75
1.3	**0.7480**	**0.2914**	**0.0568**	**0.611**	**2.3660**	**142**	**1356**	**79**
1.4	0.7885	0.3239	0.0677	0.600	2.2440	135	1380	85

From this table, it is clear that for the service speed and the initially selected diameter, the pitch-to-diameter ratio that offers the highest efficiency is P/D = 1.3.

14.8 Bollard pull

It is necessary to verify the bollard pull, the required revolutions to achieve this pull, and the power needed to accomplish it. For this verification, the propeller curves at the point where the advance coefficient is zero (J=0) will be used to obtain the values of Kq_0 and Kt_0. Subsequently, the power required to meet this requirement will be calculated.

$$N_0 = \sqrt{\frac{\frac{BP}{Lineas\ de\ eje}}{(1-t_0).\rho.D^4.K_{T0}}} \tag{60}$$

Where: BP: represents the Bollard Pull, equal to 75 metric tons of force, i.e., 735,498 Newtons.

- t_0: is the thrust deduction factor at zero advance ratio (J = 0), taken as 0.05.

The required power is given by the following expression:

$$P[W] = \frac{2.\pi.\rho.N_0[rps]^3.D^5.K_{q0}}{\eta_{rr}.\eta_m} \tag{61}$$

Obtaining the following results, organized in the table below:.

Table XXXV - Propeller Efficiency in Terms of Revolution Speed

P/D	J	K_{T0}	K_{Q0}	N_0[rps]	No [rpm]	PB [kW]	Q [kN.m]
0.5	0	0.1759	0.0121	5.148	309	2965	80
0.6		0.2336	0.0158	4.467	268	2530	78
0.7		0.2985	0.0207	3.952	237	2305	81
0.8		0.3695	0.0271	3.552	213	2188	85
0.9		0.4456	0.0350	3.235	194	2130	91
1		0.5257	0.0442	2.978	179	2103	98
1.1		0.6088	0.0549	2.767	166	2095	105
1.2		0.6938	0.0668	2.592	156	2095	112
1.3		**0.7798**	**0.0797**	**2.445**	**147**	**2098**	**119**
1.4		0.8657	0.0933	2.321	139	2098	125

P/D = 1.1 corresponds to the lowest required power in the bollard pull condition. However, the difference in required power for higher P/D values is negligible. Additionally, the necessary RPM for these higher ratios is closer to the RPM associated with maximum efficiency in open water conditions, which is merely anecdotal given that the vessel uses a variable-speed electric motor. For these reasons, a pitch-to-diameter ratio of P/D = 1.3 is selected.

The operating points (without applied margins) obtained are:

Bollard pull condition:
RPM: 147
P: 2098 kW
Q: 119 kN.m

Free Running (Service Condition):
RPM: 142
P: 1356 kW
Q: 79 kN.m

The required power, considering the applicable margins, is given by:

$$P' = P * \frac{(1 + MS)}{(1 - MM)} \tag{62}$$

Where:

- P: Power without applied margins, previously calculated
- MS: Service margin
- MM: Mechanical margin

The RPM corresponding to the increased power is calculated using the relation:

$$\frac{P'}{P} = \left(\frac{P_{RPM}'}{P_{RPM}}\right)^3 \tag{63}$$

Since at higher loads the heavy propeller has greater slip, it produces the required thrust at lower revolutions than the light propeller. These optimal RPM values can be estimated by applying the slip margin:

$$P_{RPM}'' = P_{RPM}' * (1 - MR) \tag{64}$$

Where: MR: Slip margin

In the free running condition, the total service margin is already included in the calculation of K_{TD} , Therefore, neither the service margin nor the slip margin should be applied again (since when working with the loaded propeller curve, the slip margin is already considered). Only the mechanical margin and the resulting RPM are taken into account.

The required power is determined from the bollard pull test conducted in sheltered waters at zero advance speed. For this reason, the service margin is not applicable. As this test aims to reach 100% of the nominal power, no motor margin is applied. However, a 5% “safety margin” is established to cover uncertainties related to the parameters involved in the calculation and the resistance method.

The resulting operating points are:

- Bollard pull condition:
  - RPM: 147
  - P: 2098 kW
  - Q: 119 kN.m
- Free Running (Service Condition):
  - RPM: 142
  - P: 1356 kW
  - Q: 85 kN.m

Therefore, the azipod selected must support at least the following power and RPM and diameter of propeller:

$$BHP = 2208kW \quad @\ N = 147rpm\ @\ Q = 119kN.m \quad @\ D = 3m \tag{65}$$

Based on the required power and the available propeller diameter, the selected azipod with nozzle was chosen from ABB's catalog of standard models. Although detailed information regarding the rotational speed of these units is not publicly available, a review of similar vessels equipped with this type of propulsion confirms that the selected model can operate at, or above, the required RPM. In comparable applications, azipods typically operate within a maximum range of 250-400 RPM, which comfortably covers the design requirement of 147 RPM.

To further ensure compatibility and confirm that the operating point lies within the performance limits of the selected unit, it would be useful to obtain the power output versus propeller RPM curve provided by the manufacturer. This information would help validate that the selected azipod can deliver the required power at the intended speed without overloading the system.

MAIN DIMENSIONS:	POWER [kW]
Azipod® DZ980A	2100
Azipod® DZ980P	2400
Azipod® DZ1100A	2500


Azipod DZ for high thrust applications for powers 1.5–7MW

Figure 14.8-1- Azipod Selection.

Note: Now, with the final dimensions of the adopted propulsion unit and based on the available space in the azimuthal room, the azimuth thruster will be positioned in accordance with the clearance requirements recommended by the manufacturer. As a result, the vertical axis of the azimuth unit will be located on frame #2. Therefore, from this point forward, the length between perpendiculars (LPP) will be reduced by 1.2 meters, resulting in a final **L_{PP} of 57.8** meters. This adjustment was anticipated, as the initial layout was based on vessels with a conventional shaft line and rudder configuration. This modification does not negatively impact the overall design.

14.9 Sea Trial — Speed Verification

Whenever possible, tests will be conducted at the design load draft condition. However, due to ballast capacity limitations, sea trials are often performed at different drafts. In all cases, the bow and stern drafts at the time of testing must be recorded. The trial should be carried out at drafts as close as possible to the design conditions.

That said, considering the vessel's towing role and its high available power for free-running, the following requirements will be adopted for the sea trial:

- Due to insufficient ballast to reach the design draft, the trial will be performed at a test condition, which will be planned to achieve the greatest possible draft with a slightly positive trim close to neutral.
- The test speed will be set at 1.5 knots above the service speed.
- The trial will be conducted with wind conditions of Beaufort scale level 2 (maximum 6 knots).

For this case, the mean draft at test condition is 5.09 meters.

The resistance to advance will be determined via CFD using STAR-CCM+.

At the contractual speed of 13.5 knots, with a headwind of 6 knots and calm sea conditions, considering appendages, bow thruster openings and surface roughness as in the service condition, the total resistance is estimated to be 253 kN.

No service margin is necessary in this case since, as mentioned earlier in the report, the trial will be conducted in calm sea conditions with a clean hull. The calculated resistance thus represents the hydrodynamic resistance plus the aerodynamic resistance due to wind at the time of the trial (6 knots)

The same procedure used for the service speed condition will be repeated, leading to the following results.

Table XXXVI- Results for service speed condition

P/D	J	K_T	K_Q	η_0	Ni=VA/Ji.D [rps]	Ni [rpm]	PB [kW]	Q [kN.m]
0.5	0.3206	0.0532	0.0092	0.294	5.928	356	3462	81
0.6	0.3764	0.0733	0.0116	0.380	5.050	303	2685	74
0.7	0.4325	0.0968	0.0147	0.453	4.395	264	2251	71
0.8	0.4885	0.1235	0.0190	0.506	3.891	233	2017	72
0.9	0.5441	0.1532	0.0243	0.545	3.494	210	1872	74
1	0.5987	0.1855	0.0308	0.575	3.175	190	1775	77
1.1	0.6519	0.2199	0.0385	0.593	2.916	175	1721	82
1.2	0.7025	0.2554	0.0469	0.609	2.706	162	1675	86
1.3	**0.7492**	**0.2905**	**0.0568**	**0.610**	**2.537**	**152**	**1672**	**91**
1.4	0.7899	0.3229	0.0677	0.599	2.407	144	1701	98

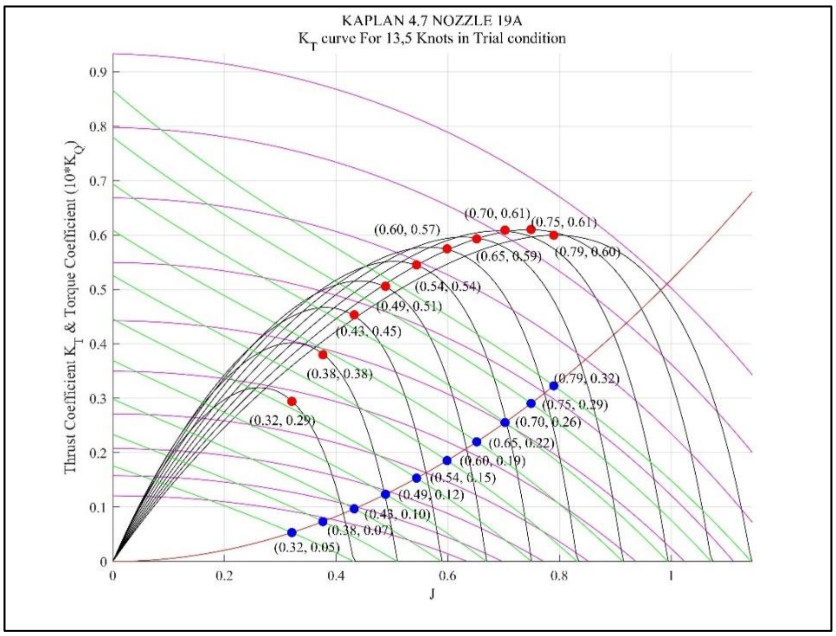


Figure 14.9-1 - Advance Coefficient.

From these results it can be observed that for the adopted P/D ratio the required power is 1672 kW, which is lower than that required under bollard pull conditions, and the corresponding RPM is 152. Both parameters can be met by the selected azipod unit.

14.10 Constant Speed and Constant P/D Curves

Procedure:

The process for obtaining the K_T curve will be repeated for each advance speed under the service condition, considering the service margin.

By plotting the Power-RPM curves corresponding to each evaluated speed on the same graph, we obtain the constant speed curves. By connecting the points corresponding to the selected P/D ratio across the different curves, the constant P/D curve is derived.

Note: At lower speeds, the curves do not show a significant increase in required power, which limits their usefulness for graphical representation. Furthermore, these low speeds are not meaningful from an operational perspective, as they cannot be reached at a continuous rated engine power.

Although it may appear that higher speeds could be reached based on the 2500 kW capacity of the azipod, it must be noted that, due to the diesel-electric propulsion system, the generators will be sized according to the total power demand from both propulsion and hotel loads. Therefore, only after performing the electrical balance will it be possible to determine how much power remains available for propulsion under open water conditions at service speed, based on the requirements and the engine or engines selected for this operational profile.

The following graph, Figure 14.10-1 shows the RPM and power consumption under the service condition at different speeds.

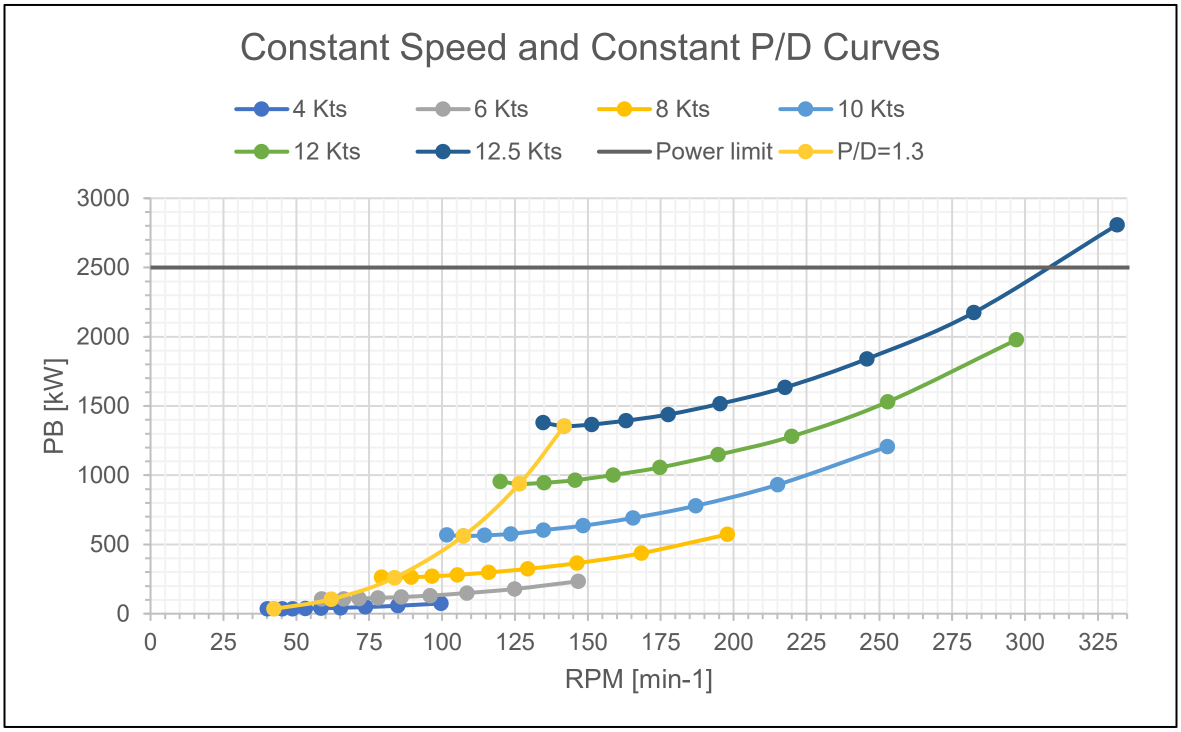


Figure 14.10-1- Constant Speed & Constant P/D curves

15 MAJOR MISSION-RELATED SYSTEMS AND EQUIPMENT

In this section, the ship's specific equipment is described, as it enables the vessel to carry out its intended functions such as anchor handling, oil spill response, fire-fighting, dynamic positioning, and the transportation of cargo including mud and dry bulk. The selection and specification of this equipment are based on statistical data from similar vessels, engineering calculations, and information obtained from vendors and manufacturers' catalogs.

15.1 Dry Cargo

Due to is intended to transport cement to supply the platforms, the ship is equipped with 4 dry cargo tanks, air compressors and air dryer.

15.1.1 Dry Bulk Air Compressors

Air compressors are essential for the operation of cement tanks on ships designed for the transport of dry bulk cargo. Their main function is to generate the necessary pressure inside the tanks to push the cement through the pipeline system to its discharge point, such as an offshore platform. This pneumatic transport system allows the cement to be moved efficiently, continuously, and in a controlled manner, ensuring fast operations and reducing the risk of blockages or interruptions in the material flow.

Table XXXVII - Dry bulk Air compressors

Maker/ Model	Max pressure [bar]	Noise level [db(A)]	Dimensions [mm]		
			D	W	L
Atlas Copco/ GA 200-75	5.5	77	1310	890	1790

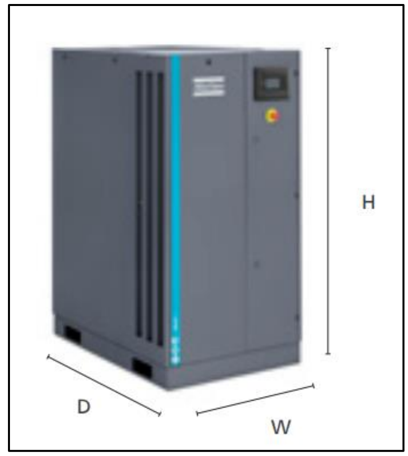


Figure 15.1-1 - Dry Bulk Air Compressor

15.1.2 Dry Bulk Air Dryer

An appropriate air dryer must be installed to prevent condensation water from entering the dry cargo system. This is especially important because cement is highly sensitive to moisture; contact with water can cause it to clump or harden inside the tanks or pipelines, leading to blockages and affecting the quality of the product. By removing moisture from the compressed air, the air dryer ensures a safer, more efficient transport system, free from contaminants that could compromise the operation.

Table XXXVIII -Dry Bulk Air Dryer

Maker/Model	Pressure drop [bar]	Flow rate [l/s]	Dimensions [mm]		
			Large	Width	Height
Atlas Copco/ND 300 A	0.14	300	1515	1293	1701


Figure 15.1-2 - Dry Bulk Air Dryer

15.2 Liquid mud pump

On an AHTS (Anchor Handling Tug Supply) vessel, the mud pump plays a crucial role in supporting offshore platform operations. This equipment is designed to handle heavy fluids with suspended solids, such as drilling mud, which are essential in hydrocarbon exploration and extraction tasks.

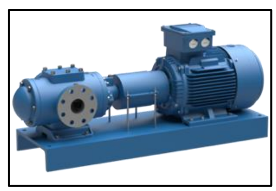


Figure 15.2-1 - Liquid mud pump

The primary function of the mud pump is to transfer these fluids from the ship's tanks to the offshore platform or vice versa.These muds are vital to drilling operations as they help lubricate and cool the drill bit, maintain pressure in the well, and transport cuttings to the surface. Due to the high density and viscosity of these fluids, it is necessary to use robust and reliable pumps capable of operating under demanding conditions.

In addition, the mud pump can be used for other onboard tasks such as discharging contaminated waste tanks, handling oily mixtures, or cleaning cargo tanks through fluid recirculation. Its versatility makes it an indispensable component for ensuring the vessel's operational efficiency during offshore logistical support missions.

15.3 Mud recirculation pump

Mud recirculation pumps play a crucial role in the drilling fluid management system onboard the vessel. Their primary purpose is to keep the mud continuously circulating within the tanks and piping system, preventing suspended solids from settling and ensuring the fluid maintains its rheological properties. Rheological properties refer to the fluid's behavior under stress, such as its viscosity and ability to flow and transport solids, which are essential for the mud to perform effectively during drilling operations.

These pumps enable tasks such as homogeneous mixing of the mud, conditioning prior to transfer to a platform, and during loading and unloading processes, ensuring the fluid meets the required specifications.

15.4 Fire Fighting system

This system provides the vessel with the capability to combat fires quickly and effectively. The FIFI (Fire Fighting) Class I system is a high capacity firefighting system designed for vessels operating in high risk environments, such as offshore platforms. This system includes pumps dedicated exclusively to fire-fighting, each equipped with its own independent seawater suction line, ensuring a constant and reliable supply. The pumps and piping that feed the water monitors for fire extinction must be used solely for this purpose and must not be shared with any other systems onboard.

The sea chests used for fire-fighting are designed for exclusive use and must not be employed for any other function. Likewise, the seawater intakes and sea chests must be positioned as low as possible in the hull to avoid blockages caused by debris or the ingestion of oil from the sea surface. The location of these intakes must ensure that water suction is not affected by the vessel's motion or by the flow generated by propellers or thrusters, guaranteeing a continuous and efficient supply.

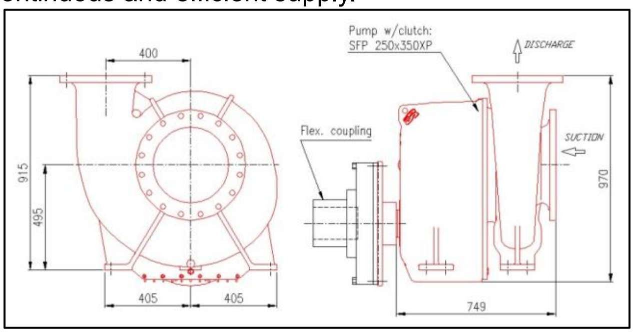


Figure 15.4-1 – FIFI Pumps

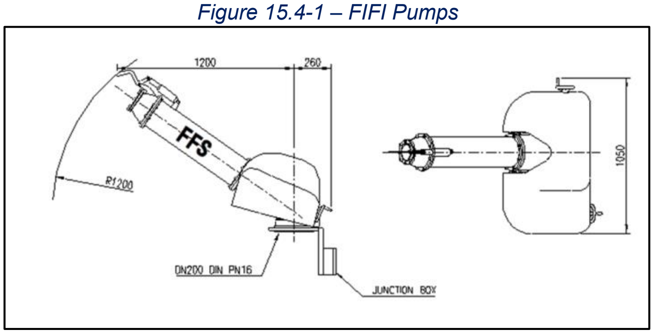


Figure 15.4-2 - Monitor

Additionally, the pumps must be installed below the waterline to ensure a positive suction head, improving the system's efficiency and reliability.Two fire pumps will be installed on board, each one coupled to the main generators and located on opposite sides (port and starboard) of the vessel. These are SFP 250X350XP type pumps, which come equipped with a gearbox for direct coupling to the generators, and have a nominal flow rate of 1850 m³/h at 166 meters.

The fire-fighting system will include two high-capacity fire monitors, strategically located above the vessel's bridge. This position allows optimal reach and coverage to direct powerful water jets quickly and accurately toward the fire source. The monitors can be operated manually or automatically and are designed to withstand extreme conditions, ensuring a reliable response in emergency situations.

Table XXXIX - Monitor's characteristics

Monitor type	FFS 1200 LB
Nominal Flow	1200 m³/h
Nominal pressure	10 bar
Rotarion	300°
Elevation	-20° to 80°

15.5 Oil Spil System

To carry out hydrocarbon spill recovery operations, the AHTS will be equipped with a V-shaped multi-barrier system known as the Moss Sweeper. This system is one of the most effective, as the V-shaped barrier channels the oil present on the water surface towards a floating tank located at the end of the barrier. The collected oil will then be pumped and stored in designated tanks, utilizing liquid mud tanks as permitted by the ABS classification society standard 5D-3-1.

Additionally, Moss Sweeper systems offer higher oil recovery speeds and better maneuverability compared to other methods. This is essential to reduce response time during spills and minimize the impact on wildlife in environmental emergency situations.

Figure 15.5-1-Oil Spill Recovery Operation

15.5.1 Dispersant pumps

The primary function of the dispersant pumps is to quickly and efficiently distribute the dispersant agent over the spilled oil, facilitating the breakup of surface layers into small oil droplets. This helps disperse the hydrocarbon within the water column, reducing the concentration on the surface and preventing the oil from reaching coastal areas, thereby minimizing the environmental impact.

15.6 Bow thruster

The bow thruster is a fundamental piece of equipment in vessels such as AHTS (Anchor Handling Tug Supply), as it significantly enhances their maneuvering capability in confined spaces or under demanding operational conditions, such as those encountered near offshore platforms. This type of vessel must maintain precise positioning during critical operations like anchor handling or platform supply, where relying solely on the rudder or main engines is not sufficient. Two bow thrusters have been installed to allow for immediate lateral adjustments to the vessel's position, contributing to greater stability and control. In this case, high-performance models have been selected that are compatible with the requirements of the DP2 dynamic positioning system, ensuring fast response, high reliability, and increased operational safety.

Thruster type	Maximum Power [1] Manoeuvring AUX (kW)	Dynamic Positioning DP (kW)	Propeller Diameter (D) (mm)	Length (L) (mm)	Weight [2] (kg)
CT/FT 125 H	614	603	1250	1550	2820
CT/FT 150 H	880	789	1500	1800	4200
WTT-11	1100	1000	1750	1970	5672
WTT-14	1450	1300	2000	2195	8050
WTT-16	1650	1475	2200	2115	11300
WTT-18	1850	1825	2200	2275	12250
WTT-21	2100	1825	2400	2275	12975
WTT-24	2400	2150	2600	2390	13775
WTT-28	2800	2400	2800	2970	20029
WTT-32	3200	2800	3000	3150	25142
WTT-36	3600	3200	3200	3350	29530
WTT-40	4000	3600	3400	3520	30500
WTT-45 [3]	4500	4050	3600	3950[4]	35350[4]
WTT-55 [3]	5500	4900	4000	4300[4]	47650[4]

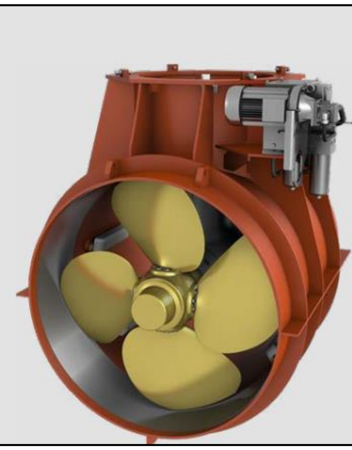


Figure 15.6-1 – Bow thruster's characteristics

15.7 Anchor handling and towing system

The anchor handling and towing winch is an essential piece of equipment located on the ship's main deck. Its primary function is to hold and manage the anchor chains during anchor handling operations, as well as to control the towing lines during towing operations. This equipment enables precise and safe maneuvers to position and secure heavy loads, such as platforms and other offshore structures. According to the reference vessels and the information provided by their owners, a detailed investigation was carried out to determine the appropriate specifications for the equipment to be installed.

Figure 15.7-1 -Anchor handling and towing winch

During this comparative analysis, it was observed that vessels with similar dimensions and functions typically have a maximum static brake holding force of around 250 MT for the winch.

This figure is considered adequate to ensure safety and efficiency in anchor handling and towing operations, allowing precise control of the anchor chains and towing lines under significant loads. Additionally, this capacity helps maintain the vessel's stability and control during critical maneuvers in adverse maritime conditions.

The selection of a winch with these characteristics responds to a combination of technical, regulatory, and operational criteria, ensuring that the equipment can withstand the demands of the tasks assigned to the vessel without compromising safety or operability at sea.

16 MAJOR HULL, MACHINERY, & ELECTRICAL SYSTEMS AND EQUIPMENT

16.1 Anchor and mooring system

To design the system and select the respective equipment it is necessary to obtain the Equipment Number. In accordance with the ABS rules Part 3 Ch. 5 Sec. 1- 3.3 is:

$$EN = \Delta^{\frac{2}{3}} + 2 * \left(B * a + \sum b * h\right) + 0.1 * A \quad (66)$$

Where:

- Δ(t)= molded displacement
- B(m)= molded breadth
- h(m)= height of each tier of deckhouse or superstructure having a width of B/4 or greater. In the calculation of h, sheer, camber and trim may be neglected.
- b(m)= breadth of the widest superstructure or deckhouse on each tier.
- a(m)= vertical distance at hull side, in m, from the Summer Load waterline amidships to the upper deck.
- A(m^2)= side projected area of the hull, superstructures, houses and funnels above the Summer Load waterline which are within the Rule length of the ship and also have a breadth greater than *B*/4.

Therefore, the Equipment Number is:

$$EN = 910 \quad (67)$$

According to tables 1A, 2 and 3 from the rule:

Table XL - Table 1A from ABS (Anchor and Chain)

Equipment Numeral	Equipment Number	Stockless Bower Anchors: Number	Stockless Bower Anchors: Mass per Anchor, kg	Chain Cable Stud Link Bower Chain*: Length, m	Diameter: Ordinary-Strength Steel (Grade 1), mm	Diameter: High-Strength Steel (Grade 2), mm	Diameter: Extra High-Strength Steel (Grade 3), mm
U22	910	2	2850	495	54	48	42

Table XLI - Table 2 from ABS (Mooring Lines)

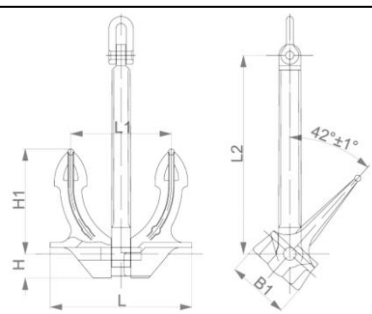
Equipment Number: Exceeding	Equipment Number: Not Exceeding	Mooring Lines: Number	Minimum length of each line *: (m)	Minimum length of each line *: (fathoms)	Ship design minimum breaking load **: (kN)	Ship design minimum breaking load **: (kgf)	Ship design minimum breaking load **: (lbf)
910	980	4	170	93	235	24000	52800

Table XLII – Table 3 from ABS Tow line

Equipment Number: Exceeding	Equipment Number: Not Exceeding	Tow Lines: Minimum length of each line: (m)	Minimum length of each line: (fathoms)	Ship design minimum breaking load *: (kN)	Ship design minimum breaking load *: (kgf)	Ship design minimum breaking load *: (lbf)
910	980	190	104	559	57000	125600

16.2 Anchor

According to the equipment number and the rule requirements, the design team selected the two same hall anchors from Damen Marine Components:



Nominal weight (kg)	L	L1	L2	H	H1	B1
2640	1590	1120	2230	270	1180	690
2850	1630	1150	2280	277	1210	700

Figure 16.2-1-Anchor selection

16.3 Anchor Chain

The chain length is 495 m and the steel grade will be 2 with a diameter of 48 mm. The proof load is 908 kN and the breaking load is 1280 kN.

16.4 Mooring Lines

There are required by rule at least 4 mooring lines of 170m and a breaking load of 235 kN

16.5 Towing Lines

There are required by rule at least a line of 190m and a breaking load of 559 kN

16.6 Anchor Windlass

The anchor windlass is an essential piece of equipment for a ship's anchoring operations. Its main function is to hoist and lower the anchor by precisely controlling the anchor chain.

Table XLIII – Anchor windlass characteristics

Anchor chain diameter	48 mm
Working load	61.4 kN
Holding capacity	365 kN
Speed	9 m/min
Motor power	37 kW

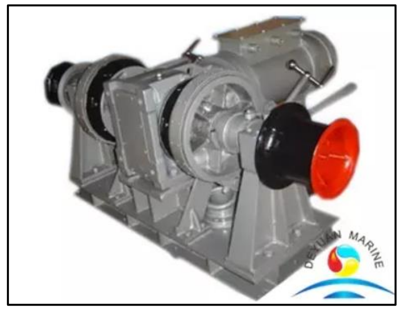


Figure 16.6-1 – Anchor windlass

16.7 Towing bitt

Regarding the SWL (Safe Working Load) of the bitts, as indicated in circular MSC.1/Circ.1619 – SOLAS, a 25% increase over the line's breaking load must be considered as the SWL of the bitt.

$$SWL = 293.75\ kN$$

Figure 16.7-1-Towing bitt

16.8 Stern winch

Stern winches are used for various tasks. With their help, it is possible to move cargo on deck and secure it. During towing preparation, they are used to lay out the towing line over the deck.

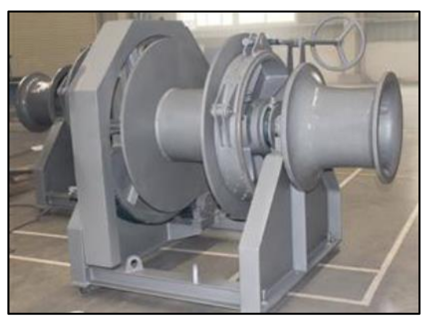


Figure 16.8-1-Stern winch

Table XLIV-Stern winch characteristics

Model No	Pull [MT]	Speed [M/MIN]	Drum Capacity (MAX)	Manual Brake Holding (1st Layer) [MT]	Warping Head Dia.[mm]	Power [kW]
UW-10T	10	15	28mmx280m	15	380	37

16.9 Shark Jaw

The shark jaw is a fundamental system on the vessel. Its main function is to secure anchor chains or towing wires, preventing unwanted movements during operations. Additionally, it supports loads during anchor or towing connection and disconnection maneuvers, reducing the strain on the winch. It works in coordination with towing pins, guide rollers, and stop pins to ensure proper alignment and control of the heavy equipment.

The design team selected the appropriate shark jaw to meet the required Safe Working Load (SWL) and to fit the corresponding chain and wire size; for this reason, the HI-SEA SJ-200 was chosen.

Working pressure	18 Mpa
Capacity	200 MT
Max. Rope size	50 to 75 mm
Max.Chain size	28 to 77 mm

Figure 16.9-1 – Shark Jaw

16.10 Vertical capstan

Its main function is to hoist heavy loads and tension cables during various operations carried out on the ship's deck, facilitating maneuvers such as anchor handling, towing lines, and other heavy equipment. These capstans allow precise control of the tension and movement of the loads, ensuring efficiency and safety during operations. To meet the specific requirements of the vessel and guarantee optimal performance, the following model was selected:

Figure 16.10-1 – Vertical capstan

Type	Working Load (kN)	Mooring Speed (m/min)	Motor Power (kW)
5kN	5	15	2.2
10kN	10	15	4
15kN	15	15	7.5
20kN	20	12	7.5
30kN	30	12	11
50kN	50	12	18.5
70kN	70	12	22
100kN	100	12	37

Figure 16.10-2 – Vertical capstan selection.

16.11 Stern roller

The stern roller is an essential component on AHTS (Anchor Handling Tug Supply) vessels, located transversely at the aft end of the main deck. Its main function is to facilitate the handling of anchors, chains, towing wires, and other heavy equipment during offshore operations, reducing friction and protecting the ship's structure. This rotating cylinder allows loads to slide in a controlled manner over the stern, minimizing wear on both the equipment and the deck. In many cases, the stern roller may be motorized or equipped with braking systems, enhancing safety and efficiency during demanding maneuvers.

Figure 16.11-1-AHTS Stern View Showing Stern Roller

16.12 Cranes

On an AHTS vessel, a light deck crane is essential for loading provisions and small equipment, facilitating logistical operations in port with greater autonomy and efficiency.

Additionally, a dedicated crane was selected to handle the fast rescue boat, ensuring its safe deployment and recovery when needed.

Table XLV - Crane's characteristics

Model	SWL	Work radius [m]		Hosting Speed [m/min]	Luffing Speed [m/min]	Slewing Speed [rpm]	Electric Motor [kW]	A [mm]	B [mm]	C [mm]	T [mm]	Weight [kg]
		Max	Min									
HPC-03-12	3	12	2.5	10	59	0.5	18.5	1500	1575	950	16	6300
HPC-02-06	2	6	1.5	10	45	0.5	11	1500	1575	800	14	3600

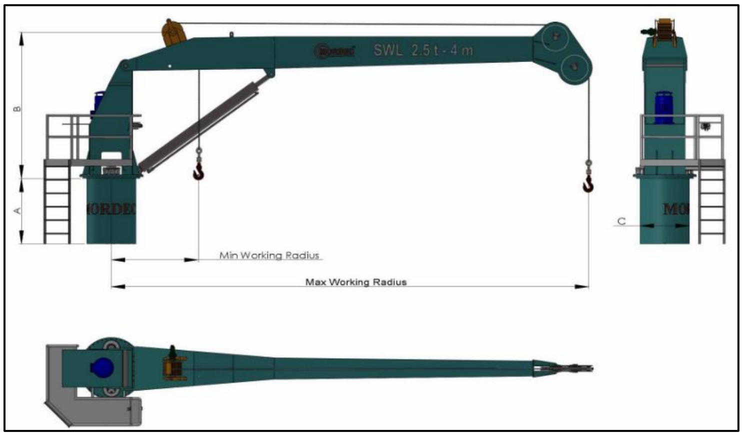


Figure 16.12-1 -Deck Crane dimensions

16.13 Rescue boat

A fast rescue boat (Fast Rescue Boat) is available on the forecastle deck, equipped with a diesel engine and waterjet propulsion system. The choice of this system is due to its increased safety during rescue operations, as it does not have exposed rotating elements in the water like conventional propellers.

The specific model selected is the "Merlin 615 MKI Waterjet."

Figure 16.13-1-Merlin 615 MKI Waterjet

1. REGULATION AND CERTIFICATION

Applicable rules and regulations	In accordance with IMO/ SOLAS requirements, LSA Code and European Council Directive 2014/90/EU on Marine Equipment (MED)
Certificate	MED
Other certificate	Class certificate or flag acceptance on request

2. BOAT SPECIFICATION

2.1. GENERAL BOAT

Type	**Fast Rescue Boat**
Model	Merlin-615 MKI, Waterjet
Length overall	6,25 m
Length on fender	6,17 m
Breadth	2,45 m
Height	2,50 m
Capacity, SOLAS	6 Persons
Weight, fully equipped	1.563 kg
Davit load, with 6 pers@82,5 kg	2.058 kg
Color	Orange (RAL 2004)
Operation temperature:	-15°C till +40°C
Hull/deck material	Fire retardent glass reinforced polyester (GRP)
Buoyancy material	Polyurethane foam
Bollards/towing	Aft bollard P & S, painter hook in bow
Steering	Mechanical
Fender	Polyethylene closed cell foam fender with double skinned heavy duty PVC cover
Deck	Self-bailing
Console cover	PVC
Loose equipment	According to SOLAS

Figure 16.13-2-Merlin 615 MKI Waterjet specifications

16.14 Methanol Pac

MethanolPac is a solution provided by Wärtsilä, designed to process and condition methanol onboard a methanol-fueled vessel to supply energy to the generators. MethanolPac systems are made up of several interconnected modules; some are standard modules, while others are custom-designed according to the specific project needs and customer requirements.

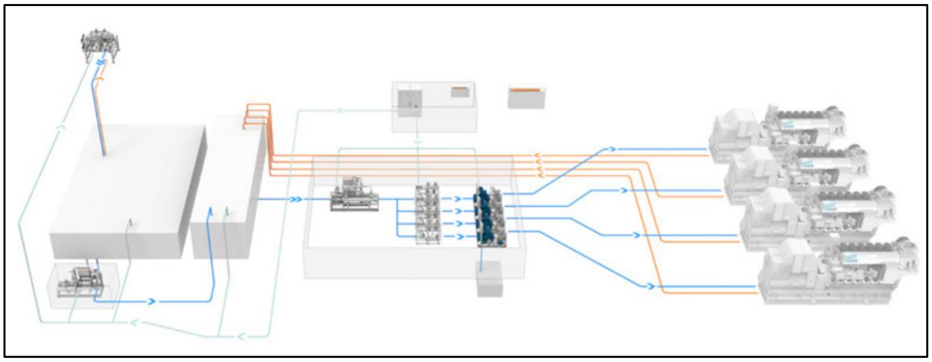


Figure 16.14-1-Complete MethanolPac system

As shown in the Figure 16.14-1, in a MethanolPac system, the fuel is pumped at low pressure from the storage tanks to the high-pressure pumps or Methanol Fuel Pump Units (MFPU). Between the storage tanks and the MFPUs is the low-pressure section of the system, which includes the low-pressure fuel pumps with related equipment and the fuel valve trains (FVT) that filter the methanol before it reaches the MFPU and isolate or purge the lines when necessary. One MFPU is required for each engine. The unit raises the liquid pressure to meet the engine's requirements. After the low-pressure pumps, a return line to the service tank is installed to regulate the minimum flow. Each engine has a discharge line, which is only used for specific purposes, such as ensuring the safe shutdown of the system.

The two main functions of MethanolPac are to manage the transfer of methanol from, to, and between the storage tanks and the service tanks on board, and to supply fuel to the methanol consumers on board. Figure 16.14-2 provides a simplified overview of a MethanolPac system, highlighting these two functions and showing the main modules of the system.

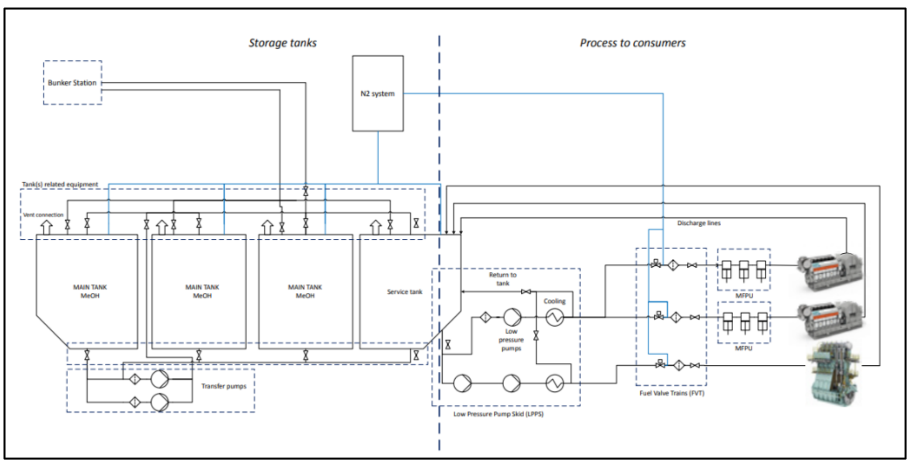


Figure 16.14-2- Simplified overview of a typical MethanolPac system

To simplify, a methanol system can be logically divided in two main subsystems: storage and transfer, and processing for consumers.

16.14.1 Storage and transfer

This subsystem handles bunkering of the methanol on board, transfer between the storage tanks, monitoring of the tank level and pressure, tank blanketing operations and safety features.

16.14.2 Bunkering station

The bunkering station is the main interface between the receiving vessel and the methanol supplier for fuel transfer. There are usually one or two bunkering stations on board, one on each side of the vessel. The bunkering interfaces for liquid fuel and vapor return are preferably supplied on two separate skids or units. This means that the system is designed to handle, on one side, the incoming liquid methanol to the vessel's storage tanks, and on the other side, independently manage the return of methanol vapors generated during the transfer. This separation improves safety and process control by preventing the accumulation of flammable vapors and allowing for a more efficient and safer fuel handling process.

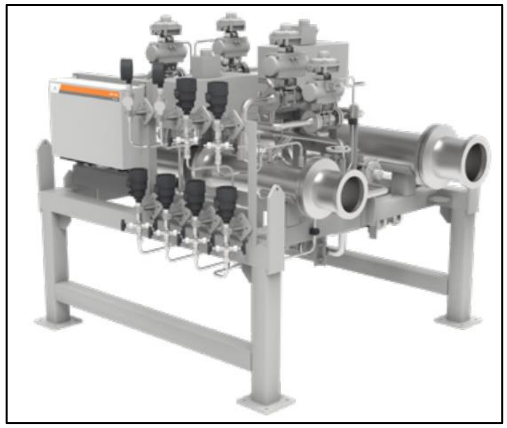


Figure 16.14-3-Methanol bunkering station skid with vapour return

16.14.3 Transfer pump skid

It is essential to have a reliable and efficient system to transfer fuel between the different tanks when multiple tanks are present on board. For this purpose, a transfer pump skid is used, consisting of two pumps: a primary unit that operates continuously and a backup unit that ensures process continuity in case of failure or maintenance of the main pump. This system also includes the necessary valves and instruments to control and monitor the fuel flow during transfer, thus ensuring safe and precise handling of the process. The redundancy and control provided by this skid are key to maintaining operational capability and avoiding interruptions during fuel management.

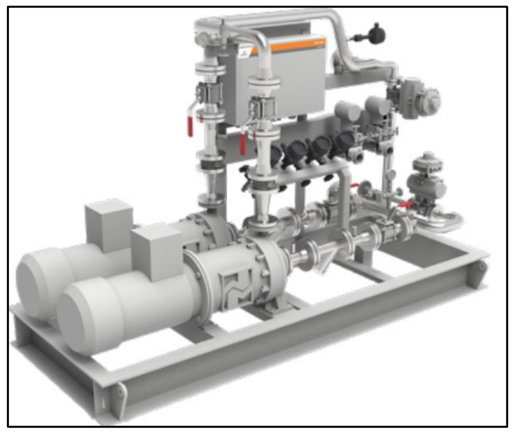


Figure 16.14-4-Transfer pump skid

16.14.4 Processing for consumers

Processing for the fuel consumers on board is the most critical function of the system regarding ensuring continuous power generation on board. This subsystem consists of different standardized skids or modules, each with a specific purpose.

16.14.5 Low pressure pump skid (LPPS)

The LPPS (Low Pressure Pumping System) contains the recirculation pumps that supply both the FVT (Fuel Viscosity Treater) and the MFPU (Marine Fuel Processing Unit) for the supply lines of four-stroke engines at a pressure above the Net Positive Suction Head (NPSH) of the MFPU, or only the FVT for the supply lines of two-stroke main engines. The low-pressure pumps recirculate part of the flow back to the service tank.

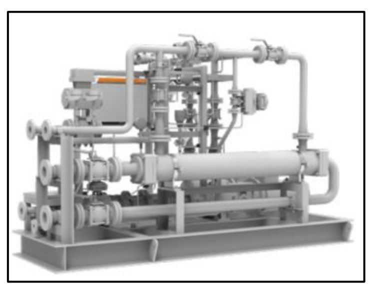


Figure 16.14-5-Low pressure pump skid (LPPS)

16.14.6 Fuel valve train (FVT)

The FVT is a compact module (skid) installed just before the Methanol Fuel Pump Unit (MFPU). Its main function is to allow isolation of the fuel lines and inerting of the pipes by filling them with inert gas to prevent the formation of explosive atmospheres. This ensures system safety and minimizes the risk of fire or explosions.
Additionally, certain maritime classification rules require this skid to have double block and bleed systems, which allow complete shut-off of the flow and purging of fuel from the lines, ensuring no pressure or hazardous residues remain.

Figure 16.14-6 - Fuel valve train (FVT)

The filters that clean the fuel before it reaches the MFPU can be installed on this same FVT skid or on the low-pressure pump skid (LPPS), depending on the system design. This ensures that the fuel arrives clean and in optimal condition for injection into the engines.

16.14.6.1 Methanol Fuel Pump Unit (MFPU)

Methanol engines require a Methanol Fuel Pump Unit (MFPU), which increases the fuel pressure according to the engine load. The MFPU software is developed and configured in accordance with the engine's requirements.
Although the MFPU cannot be installed directly inside the engine room, it should be located as close as possible to it in order to minimize the total piping distance.

Figure 16.14-7-Methanol fuel pump unit

16.14.7 Control system

According to the IGF Code, a methanol fuel supply system must have its own safety system. Software is an essential component of any MethanolPac system, as safety requirements are embedded in the automation system, whose interface must be designed to enable safe and easy system operation.

The modules described above are delivered with their own built-in automation cabinet (UNIC). The automation of each module is integrated into a single complete automation system.

For the overall methanol storage and supply system, the automation consists of a main programmable logic controller (PLC) that manages all normal operations of the system and a safety PLC that handles emergency procedures. Two operator stations are provided to control the system. Typically, one station is installed in the engine control room (ECR) and the other on the bridge.

The PLC connects to the vessel's integrated automation system (IAS) via a Modbus network. Each module or skid of the MethanolPac system is supplied with I/O and isolator boxes connected by cables to the main PLC.

The main valves of the system are pneumatically actuated and remotely controlled via solenoid cabinets supplied for the main modules of the system.

The human-machine interface (HMI) is user-friendly and can operate in automatic, semi-automatic, or manual mode.

16.14.8 Auxiliary systems

The auxiliary systems of the MethanolPac are key components that support the safe and efficient supply of methanol on board, ensuring the proper operation and safety of the main system.

16.14.8.1 Nitrogen (N_2) generator

All methanol systems require the process lines to be inerted and purged, which means having an onboard N_2 supply. Additionally, a continuous flow of nitrogen must be supplied to the storage tanks to keep them blanketed, prevent vacuum formation, and maintain an inert atmosphere inside the tanks.

To achieve this, Wärtsilä supplies a membrane-type N_2 generator, accompanied by air compressors, a control cabinet for the nitrogen generator, and a buffer tank. The nitrogen supplied must have a purity greater than 95%.

16.14.8.2 Gas and liquid leak detection system

Gas and liquid leak detection systems are essential and mandatory components on all methanol-fueled vessels, ensuring the safety and reliable operation of the fuel system. These systems are an integral part of the WärtsiläPac package, which includes the supply, installation, and configuration of the necessary equipment for early and effective leak detection, thereby minimizing potential risks to the crew and the vessel.

16.14.8.3 Cooling system

Methanol must never reach its boiling point during the feeding process. For this reason, a heat exchanger is installed downstream of the low-pressure pumps to regulate the fuel temperature before it enters the Methanol Fuel Pumping Unit (MFPU) and before its return to the service tank. The heat exchanger can use glycol or fresh water. The cooling circuit for the heat exchanger mounted on the Low-Pressure Pumping System (LPPS) is included in the WärtsiläPac.

16.14.8.4 Ship-to-shore link (SSL)

The safety link for bunkering operations, known as the SSL (Safety Shutdown Link), ensures effective communication between the fuel supplier and the receiving system on board. This link guarantees that any emergency shutdown triggered by an anomaly during the fuel transfer is executed simultaneously and in a coordinated manner by both parties.

The SSL may consist of a simple shared shutdown signal, but it can also transmit additional data such as liquid level and pressure.

Since the fuel transfer operation will be below 150 m^3/h, ISO 20519 requires the use of a pneumatic emergency shutdown (ESD) link. For this type of operation, a more comprehensive system is recommended to enable continuous and automatic communication between both parties, using a 5-pin SIGTTO electric cable along with a pneumatic signal as backup.

16.14.8.5 Control and sealing oil pump unit (OPU)

The OPU (Oil Pump Unit) is an auxiliary system that supplies the oil required for both the injector control system and the fuel sealing in certain Wärtsilä engines. This system is essential to ensure precise and safe methanol injection operation, as well as to prevent external fuel leaks. One OPU is required per engine, and it can be installed in a safe area within the engine room, outside of hazardous zones.

Figure 16.14-8-Control and sealing oil pump unit

16.14.8.6 Alcohol resistant foam

The Methanol PAC provided by Wärtsilä includes a fixed alcohol resistant foam (AR-foam) extinguishing system, specifically designed to combat fires caused by methanol. This system complies with the requirements of the FSS Code and IMO circular MSC.1/Circ.1621.

The system consists of a foam pump, a concentrate tank, a proportioning unit, and a network of fixed nozzles that discharge foam over the bilge area and under the methanol tanks, including category A machinery spaces and fuel preparation areas. Activation can be manual or automatic, integrated with the PAC's fire detection system.

Being integrated into the Methanol PAC, the system ensures a compact, efficient, and reliable installation, optimizing onboard space and guaranteeing a rapid response to alcohol-based fuel fire emergencies.

17 ELECTRICAL BALANCE

To determine the onboard equipment, power requirements, and efficiency data, the design team consulted various manufacturers and industry suppliers. Demand and utilization factors were established based on the necessary equipment and services identified for all operational conditions under analysis.

The electrical load analysis was conducted across a range of operational scenarios. For each case, a utilization factor was applied to account for the power demand of each system based on its nominal power rating. According to the American Bureau of Shipping (ABS), the key conditions considered include sea-going operations, cargo handling, harbor and anchoring situations, and emergency modes.

This process is not an exact calculation, but rather a result of the designer's experience and benchmarking with similar vessels operating under comparable conditions. The design team compiled a comprehensive list of all onboard equipment related to power, lighting, and communication systems. The nominal power of each device was scaled by the installed quantity and further adjusted according to operational conditions.

Three main factors were used to determine the actual power required for each service:

- **Load factor (F_L):** Ratio between the absorbed power in a specific condition and the nominal power.
- **Simultaneity factor (F_{SI}):** Ratio between the total installed units of a system and the number of units expected to be operating in each condition.
- **Service factor (F_{SE}):** Percentage of time a service is active under a given operational state.

The total utilization coefficient (F) for each system is obtained by multiplying these three factors:

$$F = F_L . F_{SI} . F_{SE} \quad (68)$$

This factor adjusts the nominal power to reflect realistic usage, providing a more accurate basis for the electrical balance in each condition.

The actual power demand for each system is calculated by multiplying the nominal power by the total factor (F). All system loads and the total electrical requirements per condition are detailed in APPENDIX F: ELECTRIC LOAD BALANCE.

17.1 Operational conditions

The vessel operates under nine primary service conditions throughout its lifespan. Each state, unless it involves an emergency, is analyzed during both day and night periods. These scenarios were chosen as the most demanding or representative of real operations. The selected generator sets must meet the power demands associated with these cases.

17.1.1 Service Speed

This condition involves navigation with all essential systems operating, including propulsion, hotel loads, cargo control, and safety equipment. The propulsion power demand was estimated in previous sections.

17.1.2 Harbor / Anchored

Although Harbor and Anchored are operationally distinct, they are grouped together in the electrical load analysis due to their similar low power demand profiles. In both cases, the vessel remains stationary and operates under reduced load conditions.

While docked, the ship may rely partially on shore power, which is typically preferred due to its lower cost. However, shore-side electricity is not always available. Therefore, at least one auxiliary generator must remain in operation to ensure a continuous and reliable power supply.

When anchored, the vessel is typically waiting for further instructions or favorable weather. Electrical consumption in both scenarios is limited to essential services, communication, and basic hotel loads.

17.1.3 Towing

This condition involves reduced forward speed but significant thrust. It is one of the most critical conditions in the vessel's operational life due to its high power requirements.

17.1.4 Bollard Pull

A key condition for contract performance, this mode produces the vessel's maximum thrust at zero speed in calm waters. Engines are pushed to their maximum output for a short period, allowing higher loads than in continuous operations.

17.1.5 Charge and Discharge DPII

During loading and unloading, the vessel uses dedicated cargo pumps in a staggered sequence for safety and monitoring. Dynamic positioning is activated to maintain a fixed location throughout the operation.

17.1.6 Anchor Handling operation

One of the vessel's core missions. This operation requires low propulsion power, just enough to maintain position using dynamic positioning. However, the anchor handling winch demands full power.

17.1.7 FIFI DPII

Though not frequently used, this mode is essential. Fire-fighting pumps coupled to the engines are operated at full capacity while propulsion remains minimal. Dynamic positioning ensures the vessel holds its location.

17.1.8 Emergency

In case of critical failure, the emergency generator must supply all vital systems including crew communication, lighting, and lifeboat davit operation. This generator must be capable of independently handling this load with additional margin for future growth, wear, and system losses.

17.2 Operational profile

To estimate electrical consumption, the design team referenced data from comparable vessels, manufacturer specifications, and efficiency figures. Demand and usage factors were defined based on service needs identified under the analyzed conditions. Power profiles were developed for all operational phases, including navigation and port activities. An important observation was the inverse relationship between propulsion and auxiliary power demands: when one increases, the other typically decreases.

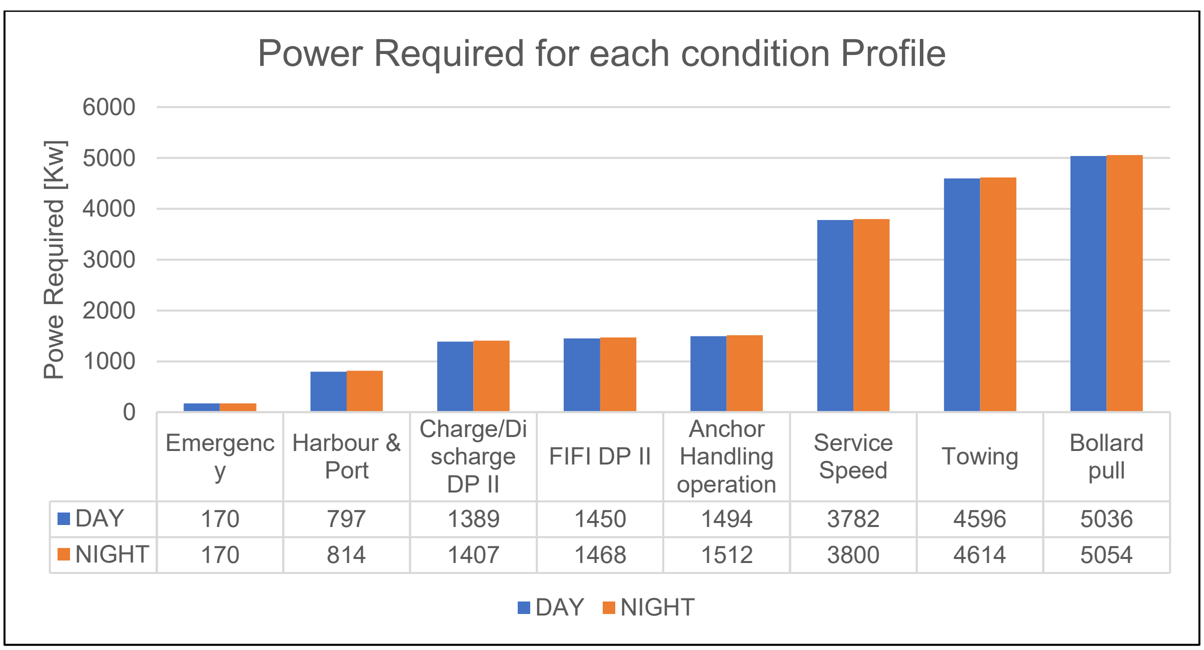


Figure 17.2-1-Power Requirement

An estimate of the annual distribution of operating hours across the different service conditions is provided in the following table.

Table XLVI-Service conditions operating hours

Condition	Navigation at service speed	Harbor / Anchored	Towing	Bollard Pull	Charge & Discharge DPII	Anchor handling operation	FIFI DPII	Emergency
Hours / Year	3600	480	1080	24	1584	1800	120	72
Days / Year	150	20	45	1	66	75	5	3
%/Year	41.1%	5.5%	12.3%	0.3%	18.1%	20.5%	1.4%	0.8%

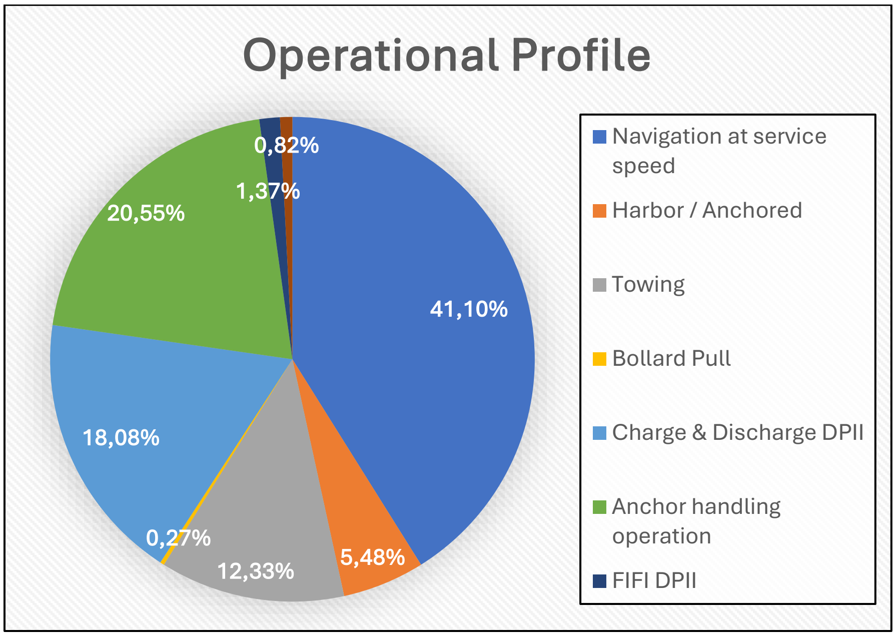


Figure 17.2-2-Operational profile

17.3 Main and emergency genset selection

Based on the results of the Electrical Load Analysis (see APPENDIX F: ELECTRIC LOAD BALANCE), both the main and emergency generator sets were selected. The emergency generator must be capable of independently supplying its designated load, while also allowing sufficient margin for future increases in consumption, equipment degradation, and system losses.

The configuration of the power plant was defined for each operational condition in such a way that the thermal engines operate within an optimal efficiency range, generally between 75 and 90 percent of their rated power. This criterion is based on performance data provided by Wartsila for methanol-fueled engines. Operating configurations that meet this efficiency requirement are highlighted in green, indicating that no additional engines are needed to support the load in those conditions.

The electric plant includes:

- Main Gensets = 3 x Wärtsilä 9L20 Methanol with alternator; 3 x1800 (Gen 1730kW) at 50Hz
- Emergency Genset = 1 x Caterpillar C9.3 IMO TIER III; 1 x 250 kW at 50Hz

- **Main Genset**

Wärtsilä provides the engine together with the generator

Table XLVII-Main Genset.

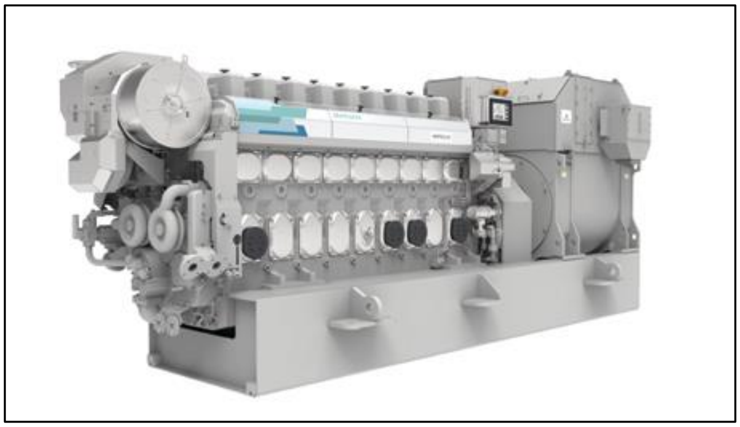


Figure 17.3-1- Wärtsilä 9L20 Methanol Genset.

Wärtsilä 9L20 Methanol Genset		
Fuel	-	Methanol + diesel Pilot
Engine	kW	1800
Gen	kW	1730
Frequency	Hz	50
Cylinder Bore	mm	200
Piston Stroke	mm	280
Speed	rpm	1000/1200
Dry Weight	Kg	23910

- **Auxiliary Genset**

Caterpillar provides the engine together with the generator

Table XLVIII-Auxiliary Genset.

Figure 17.3-2- CATERPILLAR C9.3 IMO TIER III.

CATERPILLAR C9.3 IMO TIER III		
Fuel	-	Diesel
Gen	kW	250
Frequency	Hz	50
Cylinder Bore	mm	114.3
Piston Stroke	mm	147.32
Speed	rpm	1800
Dry Weight	Kg	1122

The following table presents the generator load percentage and the number of gensets required to meet the power demand under each operational condition, both during day and night scenarios.

Table XLIX- Power demand on different scenarios

Condition	Navigation at service speed		Harbor / Anchored		Towing		Bollard Pull		Charge & Discharge DPII		Anchor handling operation		FIFI DPII		Emergency
Day/ Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night	-
Power required [kW]	3782	3800	797	814	4596	4614	5036	5054	1389	1407	1494	1512	1450	1468	170
Load 1 Genset	219%	220%	46%	47%	266%	267%	291%	292%	80%	81%	86%	87%	84%	85%	-
Load 2 Genset	109%	110%	23%	24%	133%	133%	146%	146%	40%	41%	43%	44%	42%	42%	-
Load 3 Genset	73%	73%	15%	16%	89%	89%	97%	97%	27%	27%	29%	29%	28%	28%	-
Emergency Genset	-	-	-	-	-	-	-	-	-	-	-	-	-	-	68%

As shown in the table, all the proposed operating conditions ensure an adequate load on the gensets. In particular, the harbour/port condition presents a load percentage slightly below the recommended threshold. However, this is not considered problematic due to the limited number of hours per year this condition is expected to occur. Throughout the year, the active genset will be rotated to prevent issues such as carbon buildup and other problems associated with prolonged low-load operation.

On the other hand, a high load percentage on the three gensets is observed under the bollard pull condition. This should not be a cause for concern, as this operational mode represents an even smaller portion of the vessel's service life. Moreover, it is a scenario that inherently demands maximum engine power. The values are presented in the table to demonstrate that the required power can be achieved while still maintaining a small power margin.

18 STRUCTURAL DESIGN

This section will detail the analyses and sizing calculations of the vessel, considering its operational profile and dimensions.

Given that the vessel has an approximate length of 66 meters, its longitudinal strength is not significantly critical. Therefore, the transverse construction method will be employed, except for the working deck, which will be reinforced longitudinally to support higher loads, and the tween deck, given its shape, to facilitate construction.

18.1 Regulations

The design and sizing will adhere to the rules established by ABS, following the standards and sections outlined below:

- *ABS Rules for Building and Classing - Part 3 - Chapter 1 - General*
- *ABS Rules for Building and Classing - Part 3 - Chapter 2 - Hull Structures and Arrangements*
- *ABS Rules for Building and Classing - Part 5D - Offshore Support Vessels for Specialized Services*

18.2 Materials

18.2.1 Hull

Since this vessel is not intended to operate in regions with extreme cold climates, high-strength or low-temperature resistant steel grades will not be required for the hull. Considering the vessel's material requirements, Grade A steel has been selected for the hull.

18.2.2 Profiles

For their availability and practicality, L and T profiles made from the same material as the hull plates were used.

18.3 Longitudinal Strength

The next step of the analysis is to calculate the mid-ship section modulus and the minimum hull girder moment of inertia. These values must be verified to ensure they meet the minimum requirements established by ABS:

18.3.1 Mid-ship section modulus

Table L - Hull Girder Section Modulus Calculation.

ABS 3-2-1/3.7.1 b): Hull Girder Section Modulus for Vessels 61 m (200 ft) in Length and Over	
$\boldsymbol{SM = C_1 \cdot C_2 \cdot L^2 \cdot B \cdot (C_b + 0.7)[cm^2 - m]}$	
C_1	30.839
C_2	0.01
$L\ [m]$	61.565
$B\ [m]$	16.10
C_b	0.67
$\boldsymbol{SM[sm^2 - m]}$	**2511.5**

18.3.2 Hull girder moment of inertia

Table LI - Hull Girder Moment of Inertia Calculation.

ABS 3-2-1/3.7.2: Hull Girder Moment of Inertia	
$I = L \cdot SM/33.3\ [cm^2 - m^2]$	
$L\ [m]$	61.565
$SM[sm^2 - m]$	2511.5
$I\ [cm^2 - m^2]$	**47535.3**

18.4 Scantling

The next step consists in calculating the minimum dimensions that the structural members must meet according to the aforementioned standards. Subsequently, plate thicknesses, profiles, and stiffeners are selected to comply with these requirements. A summary of the structural calculations, including both the ABS minimum requirements and the dimensions ultimately adopted, is presented in APPENDIX H: STRUCTURAL CALCULATION

To fulfill the minimum deck load capacity of 7.5 Metric tons/m² as required by the owner, it is noted that this value is verified using the formulas provided by ABS. These apply specifically to the main cargo deck, midship frame section, pillars at midship, as well as the supporting beams and longitudinals.

18.5 Verification

With all structural members dimensioned, it is necessary to verify the compliance with the requirements for midship section modulus and hull girder moment of inertia. This analysis considers only the stiffeners and plating that contribute to longitudinal strength, listed below:

Table LII-Minimum and Adopted Thicknesses for Longitudinal Strength Structures.

Plating and structures that apports longitudinal strength	Minimum required thickness [mm]	Adopted Thickness [mm]
Shell Plating		
Bottom and keel plating	9.58	10
Bilge plating	9.58	10
Side plating	8.57	9.5
Deck plating		
Double bottom (at machinery room)	9.2	9.5
Double bottom (out of machinery room)	8.5	9.5
Main deck	9.15	9.5
Double bottom structures		
Center girder	8.9	9.5
Side girders	6.9	8

Table LIII-Section Modulus Requirements and Adopted Profiles for Longitudinals.

Longitudinals	Required minimum section modulus [cm^3]	Adopted profile	Adopted profile modulus [cm^3]
Main deck Longitudinals (out of tanks)	203	L 150x100x12	232
Main deck Longitudinals (inside tanks)	511	L 200x150x15	570

Using direct calculation methods, we obtain the following values for the midship section modulus and hull girder moment of inertia (refer to APPENDIX H: STRUCTURAL CALCULATION).

Table LIV-Comparison of Required vs. Calculated Hull Girder Strength Values.

Item	Units	Minimum required	Direct calculation result
Section moment of inertia	cm^2*m^2	19534.13	76400
Section modulus	$m*cm^2$	10565.88	53500

18.6 Steerable Thrusters Hull Support

Since this vessel is equipped with steerable thrusters, ABS specifies certain requirements for their hull support as outlined in the following rule:

- *ABS Rules for Building and Classing - Part 3 - Chapter 2 - Section 14: Rudders and Steering Equipment.*

The rule indicates that structural support must adhere to the following arrangement:

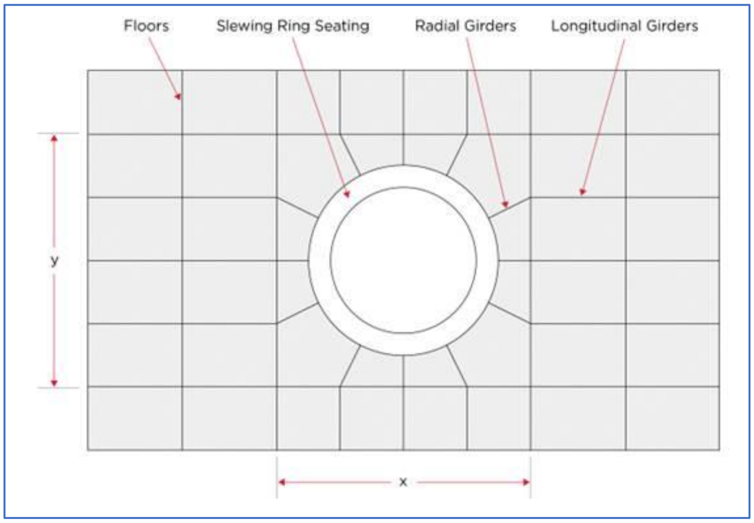


Figure 18.6-1-Structural Arrangement for Steerable Thruster Hull Support (ABS Requirements).

And with the following required thicknesses for the structural reinforcements:

Table LV-Required Structural Thickness for Hull Support.

ABS 3-2-14/25.15.3 Hull Support, iii)	
$t = 0.85 \cdot (0.056 \cdot L + 5.5)[mm]$	
$L\ [m]$	61.565
$t\ [mm]$	**7.60**

Additionally, the following hull plating thickness must be met:

Table LVI-Minimum Shell Plating Thickness for Primary Support Areas.

ABS 3-2-14/25.15.3 Hull Support, v): *Shell plating thickness in way of hull primary support structure is to be at least 50% thicker than as required for the adjacent shell plating.*	
$t_{shell\ aft}[mm]$	10
$t\ [mm]$	15

18.7 Engine Foundation

The scantling and sizing of engine foundation involves considering both static and dynamic loads arising from various factors, including:

- Vibrations of the vessel structure.
- Variable thrust or torque.

- Dead weight of the engine.
- Vessel motions due to wave action.
- Thermal deflections.

To address these, we use the following formulation established by the classification society Bureau Veritas:

Table LVII-Net Cross-Sectional Area of Engine Bedplate.

Net cross-sectional area, in cm², of each bedplate of seatings		
$A = 40 + 70 \cdot \frac{P}{n_r \cdot L} [mm]$		
Item	**Symbol**	**Value**
Maximum power of the engine [kW]	P	1800
Number of revolutions per minute of the engine shaft at power equal to P [rpm]	n_r	1200
Effective length of the engine foundation plate required for bolting the engine to the seating, as specified by the engine manufacturer [m]	L_f	5.55
Net cross-sectional area [cm²]	$\boldsymbol{A}$	58.9

Table LVIII-Net Thickness of Engine Bedplate Scantlings.

Net thickness, in mm, of each bedplate of the scantlings		
$t = 5 + \sqrt{240 + 175 \cdot \frac{P}{n_r \cdot L}} [mm]$		
Item	**Symbol**	**Value**
Maximum power of the engine [kW]	P	1800
Number of revolutions per minute of the engine shaft at power equal to P [rpm]	n_r	1200
Effective length of the engine foundation plate required for bolting the engine to the seating, as specified by the engine manufacturer [m]	L_f	5.55
Net thickness of each bedplate of the scantlings [mm]	$\boldsymbol{t}$	21.9

Table LIX-Web Thickness of Girders Under Engine Bedplates.

Web net thickness, in mm, of girders fitted in way of each bedplate of the seatings		
$\boldsymbol{t_1 = \sqrt{95 + 65 \cdot \frac{P}{n_r} \cdot L_f} [mm]}$		
Item	**Symbol**	**Value**
Maximum power of the engine [kW]	P	1800
Number of revolutions per minute of the engine shaft at power equal to P [rpm]	n_r	1200
Effective length of the engine foundation plate required for bolting the engine to the dhe seating, as specified by the engine manufacturer. [m]	L_f	5.55
Web net thickness of girders fitted in way of each bedplate of the seatings [mm]	$\boldsymbol{t_1}$	24.6

Table LX-Web Thickness of Transverse Members Under Engine Bedplates.

Web net thickness, in mm, of transverse members fitted in way of bedplates of the seating		
$\boldsymbol{t_3 = \sqrt{55 + 40 \cdot \frac{P}{n_r \cdot L_E}} [mm]}$		
Item	**Symbol**	**Value**
Maximum power of the engine [kW]	P	1800
Number of revolutions per minute of the engine shaft at power equal to P [rpm]	n_r	1200
Effective length of the engine foundation plate required for bolting the engine to the dhe seating, as specified by the engine manufacturer. [m]	L_f	5.55
Web net thickness of girders fitted in way of each bedplate of the seatings [mm]	$\boldsymbol{t_1}$	19.7

Additionally, the manufacturer recommends the following minimum dimensions and thicknesses for the engine foundation:

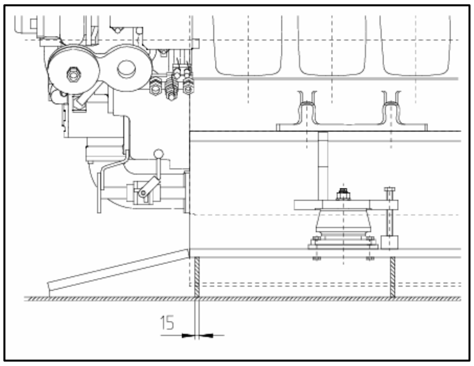


Figure 18.7-1 - Transverse Section of Engine Mounting on Foundation.

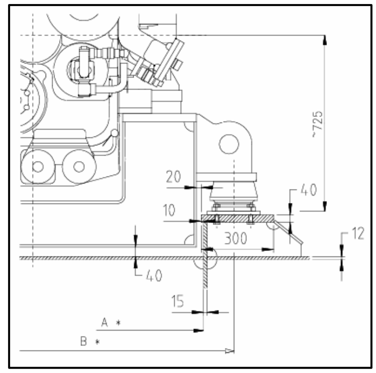


Figure 18.7-2 - Detail View of Engine Mounting Dimensions.

Engine type	A*	B*
4L	1330 / 1480	1580 / 1730
6L	1330 / 1480	1580 / 1730
8L	1480 / 1630	1730 / 1880
9L	1480 / 1630 / 1860	1730 / 1880 / 2110

Figure 18.7-3 - Engine Mounting Dimensions A* *and B* by Engine Type.*

For this ship, the engine is the 9L model, so the dimensions A* and B* are 1480 mm and 1730 mm, respectively. Therefore, the manufacturer's recommended dimensions are as follows:

Table LXI - Manufacturer's Recommended Dimensions for 9L Engine Installation.

Dimension	Magnitude [mm]
Distance between the double bottom and the bottom of the engine	40
Distance between the engine side and the edge of the flat bar:	20
Distance between the edge of the flat bar and the girder of the foundation:	10
Width of the bedplate	300
Thickness of the foundation girder	15
Thickness of the bedplate	40
Thickness of the double bottom plate adjacent to the foundation	12
Thickness of the floor plate beneath the foundation	15
Distance between the faces of the foundation girders (A*)	1480
Distance between the support centers of the foundation (B*)	1730

Finally, a verification of the values must be done to ensure compliance with the requirements of both sets of specifications.:

Table LXII - Comparison of Bureau Veritas, Manufacturer, and Adopted Engine Foundation Dimensions.

Item	Unit	Bureau Veritas Formulae	Engine Manufacturer minimum recommendation	Adopted
Distance between the double bottom and the bottom of the engine	mm	-	40	40
Distance between the engine side and the edge of the flat bar:	mm	-	20	20
Distance between the edge of the flat bar and the girder of the foundation:	mm	-	10	10
Width of the bedplate	mm	-	300	300
Thickness of the foundation girder	mm	24.6	15	24.6
Thickness of the bedplate	mm	21.9	40	40
Thickness of the floor plate beneath the foundation	mm	19.7	15	19.7
Thickness of the double bottom plate adjacent to the foundation	mm	-	12	12
Net cross-sectional area of each bedplate of seatings	cm^2	58.9	120	120
Distance between the faces of the foundation girders (A*)	mm	-	1480	1480
Distance between the support centers of the foundation (B)*	mm	-	1730	1730

19 WEIGHT ESTIMATION (STAGE II)

This section is dedicated to a more detailed estimation of the vessel's weight, an essential aspect that requires high accuracy from the early stages of the design process. Initially, a preliminary calculation was carried out to define the general dimensions. Now, with the main characteristics already determined, including the selection of the propulsion system and the arrangement of onboard equipment, there is sufficient information to perform a more rigorous weight calculation that accurately reflects the vessel’s final configuration.

19.1 Steel Weight

The steel weight of the vessel mainly depends on the weights of the plates, reinforcements, bulkheads, decks, welds, and paint. The plates form the surfaces of the hull and superstructures. The reinforcements provide stiffness and strength against loads. The bulkheads divide the internal compartments and also contribute to the total weight. The decks support loads and equipment, increasing the structural weight. Additionally, the welds add extra material to join the parts, and the paint, although light, protects the structure and contributes to the final weight. All these elements combined determine the vessel’s total steel weight.

19.1.1 Plating of hull

The hull plating is calculated from the 3D model developed in Maxsurf, using the "Structure" module tool. The calculation includes the main deck, the forecastle deck, the upper forecastle deck, and the skeg as parts of the hull. For the weight estimation, an average thickness of 10 mm was adopted, obtained through a weighted average.

Likewise, using the same procedure in Maxsurf, the weight of the Superstructure was estimated, adopting an average thickness of 8 mm, also determined through a weighted average.

Finally, the weights of the modeled cylindrical tanks were also calculated using the same methodology.

Table LXIII - Plating of hull.

Steel Item	Area [m^2]	Thickness [mm]	Weight [MT]	LCG [m]	TCG [m]	VCG [m]
Hull	3754.9	10	293	32.150	0.00	6.660
Superstructure	596	8	37	48.700	0.00	16.000
Cylindrical Tank	302	9	21	31.6	0.00	4.057
Total	**4653**	**-**	**351**	**34.24**	**0.00**	**7.69**

19.1.2 Transverse stiffeners

The design team divided the vessel into five zones: the aft section of the engine room, the engine room section, the forward section of the engine room, the superstructure, and the Superstructure. The first three are considered up to the main deck. This division was made due to changes in thicknesses depending on the location and the presence of an intermediate deck in the engine room area.

Additionally, it was considered that every 2.4 meters there is a reinforced section, which was calculated by zone and added to the weight of the transverse stiffeners.

The base weights of the five sections were calculated. These base weights are multiplied by a correction factor that depends on the longitudinal position along the vessel. This means that each section's position on the ship has a corresponding factor which, when multiplied by the base weight, provides the transverse structural weight at that specific position. Then, the values obtained for each section are summed to obtain the total weight of the transverse structure.

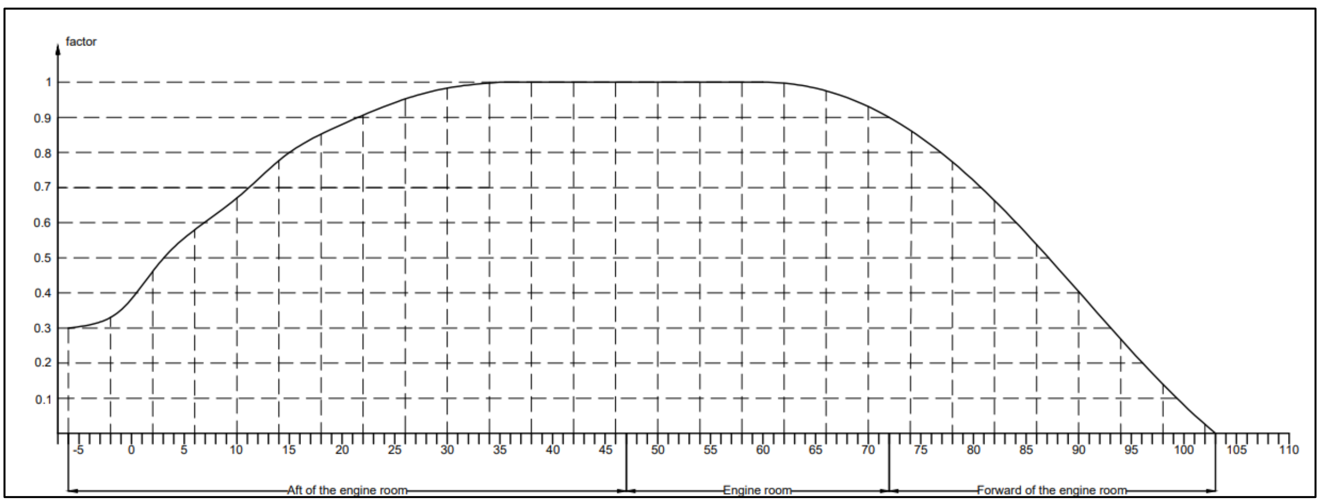


Figure 19.1-1 - Area factor.

The weights of the superstructure and the Superstructure were adjusted in the same way, applying a factor based on the area according to the longitudinal position along the vessel.

The weight of the reinforcements is calculated by multiplying the cross-sectional area of the profile by its length and by the density of the steel.

19.1.2.1 Sections aft of the engine room

Below are the calculated weights for the ordinary section in the aft of the engine room.

Table LXIV - Weight for Ordinary Section Aft of the Engine Room.

Transverse stiffeners	Quantity	Area per unit [m²]	Total Area [m²]	Thickness/Large [m]	Weight [MT]	VCG [m]	TCG [m]
Floor	1	0.00839	0.00839	16.01	1.048	0.6	0
Frame between the double bottom and the main deck	2	0.003	0.006	5.7	0.267	3.45	0
Main deck beam	1	0.002	0.002	15	0.234	6.81	0
Total			**0.02**		**1.55**	**2.03**	**0.00**

Below are the calculated weights for the reinforced section in the aft of the engine room.

Table LXV - Weight for Reinforced Section Aft of the Engine Room.

Transverse stiffeners	Quantity	Area per unit [m²]	Total Area [m²]	Large [m]	Weight [MT]	VCG [m]	TCG [m]
Floor	1	0.00944	0.00944	16.01	1.179	0.6	0
Reinforced beam	2	0.004	0.008	5.4	0.337	3.9	0
Main deck beam	1	0.0038	0.0038	13	0.385	5.4	0
Total			**0.02**		**1.90**	**2.16**	**0.00**

19.1.2.2 Sections in the engine room

Below are the calculated weights for the ordinary section in the engine room.

Table LXVI - Weight for Ordinary Section in Engine Room.

Transverse stiffeners	Quantity	Area per unit [m²]	Total Area [m²]	Large [m]	Weight [MT]	VCG [m]	TCG [m]
Floor	1	0.00839	0.00839	16.01	1.05	0.6	0
Frame between the double bottom and the tween deck	2	0.003	0.006	2.85	0.1334	1.4	0
Frame between the tween deck deck and the main deck	2	0.00132	0.00264	2.85	0.059	5.48	0
Total			**0.02**		**1.24**	**0.92**	**0.00**

Below are the calculated weights for the reinforced section in the engine room.

Table LXVII - Weight for Reinforced Section in Engine Room.

Transverse stiffeners	Quantity	Area per unit [m²]	Total Area [m²]	Large [m]	Weight [MT]	VCG [m]	TCG [m]
Floor	1	0.0095	0.0095	16.01	1.18	0.6	0
Reinforced frame	2	0.004	0.008	5.4	0.34	3.9	0
Reinforced beam	1	0.0034	0.0034	5.3	0.141	3.9	0
Main deck beam	1	0.0038	0.0038	13	0.39	5.4	0
Tween deck beam	1	0.0034	0.0034	13	0.35	4.1	0
Pillar between the double bottom and the tween deck	2	0.00395	0.0079	2.5	0.15	2.47	0
Pillar between the tween deck and the main deck	2	0.00395	0.0079	2.5	0.15	3.184	0
Total			**0.04**		**2.69**	**2.57**	**0.00**

19.1.2.3 Sections forward of the engine room

Below are the calculated weights of the ordinary section forward of the engine room.

Table LXVIII - Weight Ordinary Section Forward of the Engine Room.

Transverse stiffeners	Quantity	Area per unit [m²]	Total Area [m²]	Large [m]	Weight [MT]	VCG [m]	TCG [m]
Floor	1	0.00839	0.00839	16.01	1.048	0.6	0
Frame between the double bottom and the main deck	2	0.003	0.006	5.7	0.267	3.45	0
Main deck beam	1	0.002	0.002	15	0.234	6.81	0
Total			**16.82**		**1.55**	**2.03**	**0.00**

Below are the calculated weights of the reinforced section forward of the engine room.

Table LXIX - Weight for Reinforced Section Forward of the Engine Room.

Transverse stiffeners	Quantity	Area per unit [m²]	Total area [m²]	thickness or large [m]	Weigth [MT]	VCG [m]	TCG [m]
Floor	1	0.0095	0.0095	16.01	1.179	0.6	0
Reinforced beam to main deck	2	0.004	0.008	5.4	0.337	3.9	0
Main deck beam	1	0.0038	0.0038	13	0.385	6.9	0
Pillar to Main Deck	1.00	0.0027	0.0027	4.7	0.099	4.40	0.00
Total			**0.02**		**2.00**	**3.13**	**0.00**

19.1.2.4 Main deck & forecastle deck

Below are the weights of the ordinary section of the superstructure.

Table LXX - Weights of Transverse Stiffeners in the Ordinary Superstructure Section.

Transverse Stiffeners	Quantity	Area per unit [m²]	Total area [m²]	Large [m]	Weight [MT]	VCG [m]	TCG [m]
Frames between the main deck and the forecastle deck	2	0.00098	0.00196	2.60	0.0398	8.25	0
Forecastle deck beam	1	0.00165	0.00165	16.01	0.206	9.67	0
Frames between the forecastle deck and the upper forecastle deck	2	0.00098	0.00196	2.60	0.0398	10.9	0
Upper forecastle deck beam	1	0.0014	0.0014	10.60	0.116	12.3	0
Total			**0.01**		**0.40**	**10.41**	**0,00**

Below are the weights of the reinforced section of the superstructure.

Table LXXI - Weights of Transverse Stiffeners in the Reinforced Superstructure Section.

Transverse Stiffeners	Quantity	Area per unit [m²]	Total area [m²]	Large [m]	Weight [MT]	VCG [m]	TCG [m]
Reinforced frame between the main deck and the forecastle deck	2	0.00405	0.0081	2.6	0.164	8.25	0
Reinforced beam of the forecastle deck	1	0.0024	0.0024	13	0.243	9.45	0
Reinforced frame between forecastle deck and upper forecastle deck	2	0.0024	0.0048	2.6	0.097	10.9	0
Reinforced beam of upper forecastle deck	1	0.0028	0.0028	15.2	0.332	11.7	0
Pillar in the Superstructure	2	0.0036	0.0072	2.4	0.135	8.1	0
Pillar in the upper Superstructure	2	0.0036	0.0072	2.4	0.135	10.8	0
Total			**0.03**		**1.11**	**10.07**	**0.00**

19.1.2.5 Upper forecastle & bridge deck

Below are the weights of the ordinary section of the upper part superstructure.

Table LXXII - Weights of Transverse Stiffeners in the Ordinary Section of the Superstructure.

Transverse Stiffeners	Quantity	Area per unit [m^2]	Total area [m^2]	Large [m]	Weight [MT]	VCG [m]	TCG [m]
Bridge deck beam	1	0.00072	0.00072	10.60	0.0595	15	0
Bridge ceiling beam	1	0.0012	0.0012	11.4	0.107	17.7	0
Frames between the upper forecastle deck and bridge deck	2	0.001	0.002	2.7	0.042	13.65	0
Frames between the bridge deck and bridge ceiling	2	0.001	0.002	2.7	0.042	13.65	0
Total			**0.01**		**0.25**	**15.70**	**0.00**

Below are the weights of the reinforced section of the upper part of superstructure.

Table LXXIII - Weights of Transverse Stiffeners in the Reinforced Section of the Superstructure.

Transverse Stiffeners	Quantity	Area per unit [m^2]	Total area [m^2]	Large [m]	Weight [MT]	VCG [m]	TCG [m]
Reinforced beam in the bridge deck	1	0.0024	0.0024	10.60	0.199	14.85	0
Reinforced beam in the bridge ceiling	1	0.0024	0.0024	10.60	0.199	17.55	0
Pillar in the wheelhouse	2	0.0036	0.0072	-	0.134784	13.5	0
Reinforced frames between the upper forecastle deck and bridge deck	2	0.0024	0.0048	2.7	0.101088	13.65	0
Reinforced frames between the bridge deck and bridge ceiling	2	0.00268	0.00536	2.7	0.1128816	13.65	0
Total			**0.02**		**0.75**	**14.98**	**0.00**

19.1.3 Longitudinal stiffeners

For the longitudinal stiffeners, the design team divided the vessel in a similar manner as with the transverse stiffeners, considering the areas where the stiffeners were continuous and those where they were interrupted. The weights of the longitudinal stiffeners between the reinforced structures were calculated, taking into account the reinforced bottom longitudinals, the plating of intermediate and internal decks, and the longitudinals supporting those decks.

Table LXXIV - Longitudinal Stiffeners Weight.

Sections	Area [m^2]	LCG [m]	VCG [m]	TCG [m]	Factor	Weight [MT]
-4 to 0	36.6	-1.2	6.21	0	1	5.70
0 to 4	45.6	1.2	5.81	0	1	5.70
4 to 8	45.6	3.6	4.61	0	1	5.70
8 to12	45.6	6	4.31	0	1	5.70
12 to 16	45.6	8.4	3.21	0	1	5.70
16 to 20	87.2	10.8	2.71	0	1	5.70
20 to 24	87.2	13.2	2.41	0	1	5.70
24 to 28	87.2	15.6	2.31	0	1	5.70
28 to 32	106.22	18	2.31	0	1	5.70
32 to 36	106.22	20.4	2.31	0	1	5.70
36 to 40	109.66	22.8	2.76	0	1	8.70
44 to 48	109.66	25.2	2.76	0	1	8.70
48 to 52	109.66	27.6	2.76	0	1	8.70
52 to 56	109.66	30	2.76	0	1	8.70
56 to 60	106.22	32.4	2.76	0	1	8.70
60 to 64	185.34	34.8	9.76	0	1	13.63
64 to 68	185.34	37.2	9.76	0	1	13.63
68 to 72	185.34	39.6	9.76	0	1	13.63
72 to 76	167.2	42	9.76	0	1	13.63
76 to 80	167.2	44.4	9.76	0	1	13.63
80 to 84	127	46.8	9.76	0	1	13.63
84 to 88	126.2	49.2	2.31	0	1	13.63
88 to 92	126.2	51.6	9.76	0	1	13.63
92 to 96	126.2	54	9.76	0	1	13.63
96 to 100	126.2	56.4	9.76	0	1	13.63
Total	**2760.12**	**33.01**	**6.38**	**0.00**	**-**	**236.79**

19.1.4 Bulkheads

This section presents calculations related to the ship's bulkheads, focusing on the determination of their weights. It includes the weights of both transverse and longitudinal bulkheads, which are key components of the ship's structure. The main objective of this analysis is to obtain an accurate and reliable estimate of the total bulkhead weight, taking into account the different characteristics and types of bulkheads present in the design. This information is essential for assessing the overall structural weight of the vessel.

19.1.4.1 Transverse Bulkheads

Transverse bulkheads, which can be flat or corrugated, are calculated based on determining their surface area using sections and drawings made in AutoCAD. From this area, the corresponding thickness is applied to obtain the volume, which is then multiplied by the material's specific weight to calculate the total weight of the bulkhead.

Flat bulkheads include an additional weight for stiffeners, calculated by referencing vessels with similar characteristics. In contrast, corrugated bulkheads do not require additional stiffeners, although their total surface area is larger due to the corrugated shape.

Table LXXV - Transverse Bulkhead Weight.

Transverse Bulkheads	Type	Semi Area [m^2]	Weight added by stiffeners [MT]	Weight [MT]	LCG [m]	TCG [m]	VCG [m]
Collision Bulkhead	Flat	28.64	1.47	6.83	55.80	0.00	5.30
Bulkhead #80	Flat	42.70	2.19	10.18	48.00	0.00	5.00
Bulkhead #72	Flat	43.60	2.23	10.40	43.20	0.00	4.10
Bulkhead #47	Flat	45.80	2.35	10.92	28.20	0.00	2.85
Bulkhead #29	Flat	45.30	2.32	10.80	17.40	0.00	4.05
Bulkhead #13	Flat	34.60	1.77	8.25	7.80	0.00	5.00
Bulkhead #-2	Flat	23.30	1.19	5.56	-1.20	0.00	5.70
Bulkhead corrugated	Corrugated	45.16	0.00	5.64	11.40	0.00	4.70
Total		**309.10**	**-**	**68.57**	**28.24**		**4.43**

19.1.4.2 Longitudinal Bulkheads

Since these bulkheads are symmetrically arranged on both the port and starboard sides, the area of only one side (semi-area) is calculated first. This value is then multiplied by two to obtain the total weight, accounting for both bulkheads. This methodology allows for a clear and accurate estimation of the contribution of the longitudinal bulkheads to the ship's total structural weight.

Table LXXVI - Longitudinal Bulkheads Weights.

Longitudinal Bulkheads	Type	Semi Area [m^2]	Weight added by stiffeners [MT]	Weight [MT]	LCG [m]	TCG [m]	VCG [m]
Longitudinal bulkhead #80-#93	Flat	39.20	1.01	6.21	53.40	0.00	4.45
Longitudinal bulkhead #72-#80	Flat	23.50	0.61	3.72	47.40	0.00	4.45
Longitudinal bulkhead #47-#72	Flat	105.30	2.71	18.32	35.70	0.00	3.45
Longitudinal bulkhead #17-#29	Flat	74.52	1.92	12.96	23.40	0.00	3.45
Longitudinal bulkhead #29-#48	Flat	47.42	1.22	8.25	13.80	0.00	4.10
Longitudinal bulkhead #-2-#13	Flat	38.20	0.98	6.65	3.60	0.00	4.70
Longitudinal Bulkhead corrugated	Corrugated	45.90	0.00	5.01	13.80	0.00	4.90
Total		**218**	**-**	**61.12**	**27.36**	**0.00**	**3.96**

After completing the calculations previously mentioned, the design team is now in a position to present the total steel weight of the vessel.

A 3% increase over the total steel weight was considered to account for the presence of reinforcements and brackets that were not included in the previous calculations. Additionally, the deposited weld metal and the paint scheme were not considered, for which the consulted literature recommends adding 1% of the total steel weight.

Finally, an additional 1% is added, also suggested by the specialized literature, to account for local reinforcements in the hull where thickness increases are required. These areas correspond to locations with concentrated loads, such as azipods, mooring and anchoring equipment, as well as other equipment necessary for the vessel's operation.

In total, these increments represent an additional 5% over the initially calculated total steel weight.

Table LXXVII - Steel Weight.

Steel Item	Weight [MT]	LCG [m]	Horizontal Mom. [MTm]	TCG [m]	VCG [m]	Vertical Mom. [MTm]
Plating	348.24	34.66	12069.61	0.00	7.69	2677.38
Transverse Bulkheads	66.96	28.68	1920.76	0.00	4.43	296.39
Longitudinal Bulkheads	62.10	27.73	1722.15	0.00	3.96	246.07
Longitudinal stiffeners	236.79	33.01	7816.41	0.00	6.38	1510.62
Transverse stiffeners	161.92	32.82	5314.84	0.00	4.04	654.68
Margin 5%	43.80					
Total	**920**	**31.36**	**28843.77**	**0**	**5.85**	**5385.14**

19.2 Machinery weight

To determine the machinery weight, a list of propulsion and auxiliary equipment was compiled, including their respective weights and locations within the vessel. The weight values were obtained from commercial catalogs. Since the project is still in a preliminary stage, the weights corresponding to various complementary systems, although essential for the vessel's operation, have not been included in this phase. These systems comprise electrical wiring, piping systems, ventilation, control and automation systems, among others. Due to the difficulty of accurately estimating these components at this stage of the design, the team decided to include a percentage of the total machinery weight as a representative estimate for these elements.

The bibliography used for the weight estimation, particularly the authors Watson and Gilfillan, suggests considering up to 30% of the total machinery weight to account for complementary elements. However, after an exhaustive analysis and a detailed listing of the equipment in the engine room with their weights and locations, the design team considers that this information allows for a more accurate estimate and therefore decided to adopt a value of 5% as an additional margin for the machinery. This reduced percentage reflects confidence in the thoroughness and accuracy of the analysis performed. Additionally, this decision was supported after consultations with expert university professors and shipowners of vessels similar to the project ship, who kindly shared confidential information about their vessels.

Table LXXVIII - Machinery weight.

N°	DESCRIPTION	Qty	Unit weight [kg]	Weight [MT]	LCG [m]	Hor. Mom. [MTm]	TCG [m]	Trans. Mom. [MTm]	VCG [m]	Vertical Mom. [MTm]
1	Azipods & equipment	2	53350	106.7	1.4	149.4	0	0	2.4	256.84
2	Ballast/drill water pump	1	210	0.21	24.6	5.166	1.7	0.357	1.6	0.336
3	Bilge & fire pump	1	210	0.21	25.2	5.292	3.2	0.672	1.6	0.336
4	Bow thruster	2	3800	7.6	53.4	405.84	0.0	0	2.0	15.2
5	Bow thruster cooler	2	350	0.7	49.8	34.86	-2.5	-1.75	2.5	1.75
6	Bow thruster cooling pump	2	25	0.05	52.2	2.61	-2.5	-0.125	2.1	0.105
7	Bow thruster hydraulic power unit	2	30	0.06	55.8	55.8	0	0	2.3	2.3
8	Control room a/c condensing unit	1	90	0.09	35.4	3.186	-6	-0.54	4.25	0.3825
9	Converter azipod	2	1500	3	7.8	23.4	0	0	3.7	11.1
10	Converter bow thruster	2	500	1	55.8	55.8	0	0	2.3	2.3
11	Dispersant pump	1	93	0.093	31.2	2.902	6	0.558	4.15	0.386
12	Dry bulk air compressors	2	986	1.972	39	76.908	0	0	4.25	8.381
13	Dry bulk air dryer	2	185	0.37	37.2	13.764	-6	-2.22	4.15	1.5355
14	Emergency fire pump	1	165	0.165	48.6	8.019	-2.6	-0.429	3.6	0.594
15	Engine room a/c cooling pump	1	50	0.05	39.6	1.98	-5.5	-0.275	4.25	0.2125
16	Fifi pump	2	900	1.8	37.2	66.96	0	0	1.5	2.7
17	Fire & gral services pump	1	210	0.21	27.6	5.796	1.7	0.357	1.4	0.294

18	Fresh water cargo pump	1	190	0.19	39.6	7.524	5.3	1.007	1.6	0.304
19	Fresh water generator	1	300	0.3	48.3	14.49	2.2	0.66	4.5	1.35
20	Genset lo. Stand by pump	2	80	0.16	36.9	5.904	0	0	1.5	0.24
21	H.t. fw cooling pump	2	380	0.76	34.5	26.22	-2.1	-1.596	1.3	0.988
22	Hot water circulation pump	1	36	0.036	54.6	1.9656	-2.3	-0.0828	3.7	0.1332
23	Hydraulic oil transfer pump	1	47	0.047	33	1.551	-6	-0.282	4.25	0.19975
24	Hydraulic power unit cooling pump	1	84	0.084	31.2	2.6208	-6.2	-0.5208	1.3	0.1092
25	L.t. fw cooling pump	2	488	0.976	34.5	33.672	2.1	2.0496	1.3	1.2688
26	Lathe machine	1	750	0.75	42.6	31.95	-1.6	-1.2	1.7	1.275
27	Liquid mud pump	2	310	0.62	22.8	14.136	3.5	2.17	1.4	0.868
28	Lo heating	2	200	0.4	29.7	11.88	-2.6	-1.04	1.5	0.6
29	Lo purifier	2	425	0.85	31.2	26.52	2.5	2.125	1.2	1.02
30	Lo purifier pump	2	40	0.08	30.6	2.448	6.2	0.496	1.3	0.104
31	Lo transfer pumps	2	42	0.084	31.56	2.65104	2.4	0.2016	1.4	0.1176
32	Main console	1	1500	1.5	39.6	59.4	0	0	4.25	6.375
33	Main genset	3	23900	71.7	34.800	2495.16	0.00	0	2.25	161.325
34	Main genset central cooler	2	600	1.2	34.8	41.76	0	0	1.7	2.04
35	Main genset ht. Cooler	2	350	0.7	19.2	13.44	0	0	1.4	0.98
36	Main switchboard	1	1700	1.7	42	71.4	0	0	4.55	7.735
37	Mdo transfer pump	1	56	0.056	22.2	1.2432	1.3	0.0728	1.4	0.0784
38	Methanol pac	1	1500	1.5	24.6	36.9	3.5	5.25	4.55	6.825
39	Mud recirculation pumps	2	310	0.62	23.4	14.508	-3.5	-2.17	4.25	2.635
40	Oily water separator	1	600	0.6	25.5	15.3	-4	-2.4	1.7	1.02
41	Potable water hydropneumatic tank	1	213	0.213	52.8	11.2464	2.8	0.5964	2.2	0.4686
42	Potable water pump	1	51	0.051	52.2	2.6622	2	0.102	2.2	0.1122
43	Refeger plant condenser	2	480	0.96	51	48.96	2.6	2.496	4.3	4.128
44	Refeger plant cooling pump	1	42	0.042	51.6	2.1672	2.5	0.105	4.2	0.1764
45	Sanitart pump	1	42	0.042	52.8	2.2176	2	0.084	2.2	0.0924
46	Sanity water hydropneumatic tank	1	213	0.213	52.8	11.2464	2.8	0.5964	2.2	0.4686
47	Sea water strainer	2	175	0.35	26.4	9.24	0	0	1	0.35
48	Sewage treatment plant	1	1049	1.049	27	28.323	-3.5	-3.6715	4.55	4.77295
49	Sludge/dirty oil pump	1	50	0.05	22.2	1.11	-1.3	-0.065	1.4	0.07
50	Stand by sanitary/fresh water pump	1	42	0.042	52.9	2.2218	2.2	0.0924	4.3	0.1806
51	Starting air compressor	2	656	1.312	28.8	37.7856	0	0	4.45	5.8384
52	Starting air receiver	2	250	0.5	28.8	14.4	0	0	4.45	2.225
53	Sw cooling dry bulk system pump	2	55	0.11	40	4.4	-6	-0.66	1.3	0.143
54	Sw cooling pump	2	756	1.512	22.8	34.4736	-3.4	-5.1408	1.3	1.9656
55	Transformer	2	320	0.64	4.2	2.688	0	0	3.9	2.496
56	Ballast water manangment system	1	4000	4	28.8	115.2	1	4	1.7	6.8
	SubTotal			**220.3**	**19.0**	**4178.6**	**0.0**	**-0.1**	**2.4**	**532.6**
	Margin 5%			11.0						
	Total			**231.3**	**19.0**		**0.0**		**2.4**	

19.3 Outfit weight

The ship's outfit weight corresponds to the sum of all elements necessary for its proper operation, including both the main equipment and systems essential for its operability, as well as components related to habitability and comfort. This diversity makes its precise determination a complex and challenging process.

Some of these elements are easily identifiable and can be listed along with their weight and location within the ship, facilitating their inclusion in the total calculation. However, other components, especially those associated with outfitting and habitability areas, are more difficult to quantify accurately at this stage of the project.

The consulted literature indicates that to estimate the weights corresponding to the total outfit weight such as thermal outfit, furniture, bridge control and automation systems, and other components related to crew habitability and comfort a percentage typically ranging between 10% and 20% is used. Based on information gathered through discussions with our professors and shipowners of similar vessels in Argentina, as was done in the case of machinery weight, it was decided to adopt an intermediate value of 15% of the total outfit weight.

Table LXXIX - Outfit Weight Distribution and Location of Main Equipment.

Outfit Item	Qty.	Weight [kg]	Weight [MT]	LCG [m]	Horizontal Mom. [MTm]	TCG [m]	Transversal Mom. [MTm]	VCG [m]	Vertical Mom. [MTm]
Anchors	2	2850	5.7	59.500	339	0.00	0	9.34	53
Anchor chain	2	12100	24.2	53.400	1292	0.00	0	6.90	167
Hydraulic Anchor Windlass	1	10000	10	57.000	570	0.00	0	13.50	135
Chain stopper	2	640	1.28	58.2	74	0	0	12.3	16
Mooring capstans	2	1500	3	1.200	4	0.00	0	7.26	22
Hydraulic Anchor /Towing Winch	1	70500	70.5	34.200	2411	0.00	0	8.80	620
Hydraulic Capstans	2	600	1.2	55.200	66	0.00	0	8.30	10
Hydraulic Tugger Winch	2	1800	3.6	31.800	114	0.00	0	8.00	29
Hydraulic Shark Jaw & Towing Pins	1	6000	6	2.400	14	0.00	0	7.40	44
Double bitt	12	431	5.172	28.200	146	0.00	0	9.40	49
Towing bitt	1	600	0.6	61.200	37	0.00	0	12.30	7
Stern Roller	1	14000	14	-0.500	-7	0.00	0	6.30	88
Deck Crane	1	6300	6.3	36.000	227	-2.90	-18	12.00	76
Rescue Boat	1	2100	2.1	36.6	77	-5.4	-11	9.5	20
Rescue Boat Crane	1	3600	3.6	40.2	145	-6.7	-24	10.7	39
Monitors Control	2	136	0.272	45	12	0	0	21.4	6
Air conditioning plant	1	250	0.25	45	11	-6.3	-2	7.3	2
Kitchen	1	770	0.77	45	35	6.3	5	7.7	6
Laundry	1	305	0.305	45	14	-3	-1	7.5	2
Total			159	35.14	5581.56	-0.32	-51.37	8.75	1390.43
Margin 15%			24						
Total			**183**	**35.14**		**0.32**		**8.75**	

19.4 Margin

The determination of the lightship weight (LSW) is carried out through a successive and approximate process that involves the application of a safety margin. This margin generally decreases as the ship design progresses, since more accurate information becomes available and uncertainty about the final value is reduced. The highest level of uncertainty typically occurs during the initial stages.

The book “El proyecto básico del buque mercante” by Alvariño - Meizoso suggests using a safety margin of 4% to 6% during the second phase of weight assessment. This stage corresponds to an intermediate point in the project, where, although some degree of uncertainty still remains, enough information about the ship’s design and main components has already been gathered to allow for a more accurate estimate.

The design team decided to apply a 6% margin to be conservative, since, although preliminary information about the design and the main elements of the ship is available, certain uncertainties still remain. These include possible minor design changes in later stages, the addition of new equipment, or small modifications. Therefore, we believe that a larger margin helps cover these variations and ensures greater confidence in the project planning.

It is worth noting that the margin applied also accounts for the weight contribution of the Sandwich Plate System technology used in the methanol tank. Although this system is expected to be relatively lightweight, it still represents an additional load that must be considered in the overall assessment.

19.5 Lightship weight and center of gravity position

Below are the final results obtained in this section.

Table LXXX - Lightship Weight and Center of Gravity Position.

Weight Item	Weight [MT]	LCG [m]	Horizontal Mom. [MTm]	TCG [m]	Transversal Mom. [MTm]	VCG [m]	Vertical Mom. [MTm]
Steel Weight	920	31.36	28843.77	0.00	0.00	5.85	5385.14
Machinery Weight	231	19.0	4178.65	0.00	0.00	2.42	532.63
Outfit Weight	183	35.14	6418.80	-0.32	-59.07	8.75	1599.00
Margin 6%	80						
TOTAL (second stage)	**1414**	**27.9**	**39441**	**-0.042**	**-59**	**5.32**	**7517**

The design team analyzed the obtained values and, upon comparing them with those from the first stage, reached the following conclusions.

Table LXXXI - Weight and Center of Gravity Comparison Between Design Stages.

Stage	Weight [MT]	LCG [m]	TCG [m]	VCG [m]
Second stage	1414	27.9	-0.042	5.32
First stage	1713	32.14	0	5.37
Difference [%]	**17.47%**	**13.20%**		**0.99%**

- The method used in the first steel weight estimation is based on data from Danish ships built between the 1980s and 1990s. In contrast, the vessel under design was optimized and compared with modern units, yielding similar values. It is likely that these recent ships were designed using much more precise and advanced tools than those available at that time, which is why the value obtained in the second estimation is considered more reliable.
- The difference in the estimated weight is also due to the fact that the methods used in the first iteration are based on data and models that consider two-stroke diesel engines along with their associated equipment. In contrast, the vessel under design uses four-stroke engines powered by methanol and an electric system, which involves a different set of equipment and systems, generally lighter or with different configurations. This technological and equipment variation contributes to the actual weight differing from the estimate given by traditional methods, which do not account for these innovations.
- The longitudinal center of gravity (LCG) and the vertical center of gravity (VCG) differed from those in the first stage because the formulas used to estimate these positions are based on ships with conventional propulsion, that is, with a shaft line and propeller. In contrast, the vessel under design uses Azipod thrusters, which represent a significantly heavier load in the aft section. This greater concentration of weight at the stern causes the longitudinal center of gravity to shift aft, explaining the differences observed compared to the initial estimation.

20 TRIM AND INTACT STABILITY ANALYSIS

During this stage, the intact stability of the vessel was analyzed under different loading conditions. In particular, the vessel was assessed according to the loading conditions established by the **ABS** for this type of vessel, namely:

1. **Loading Condition 1**: 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.
2. **Loading Condition 2:** Vessel with 10% stores and fuel and fully loaded cargoes of i) above, arrival condition.
3. **Loading Condition 3:** 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.
4. **Loading Condition 4:** Vessel with 10% stores and fuel and fully loaded cargoes of iii) above, arrival condition.
5. **Loading Condition 5:** Vessel with full stores and fuel in ballast departure condition.
6. **Loading Condition 6:** Vessel with 10% stores and fuel in ballast arrival condition.
7. **Loading Condition 7:** Vessel in the worst anticipated operating condition (i.e., arrival condition with deck cargo only - 100% deck cargo with 10% stores and fuel).

The modeling and analysis of the tanks and compartments was carried out in Maxsurf Stability.

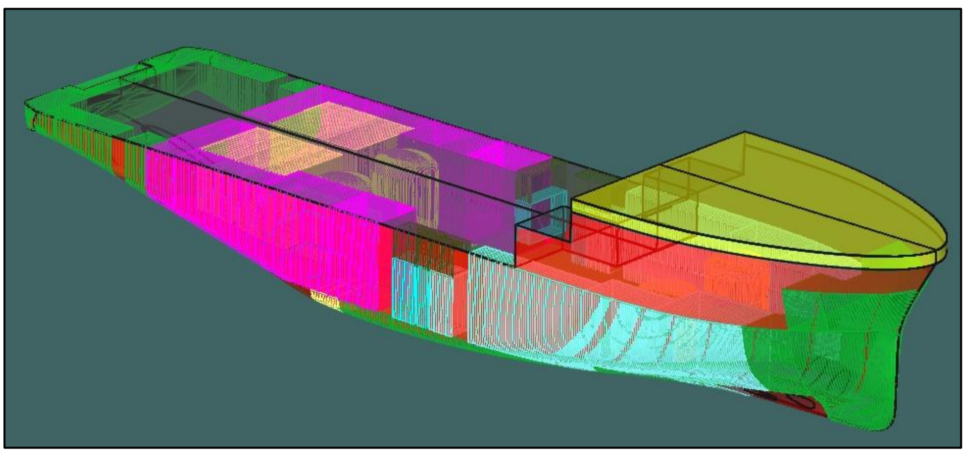


Figure 20-1 - Tanks.

The loading conditions mentioned above are included in APPENDIX J: LOADCASES.

20.1 Freeboard

In order to obtain the maximum Load Line draft, we proceed to determine the summer freeboard of our vessel. To do so, we used the 1966 International Convention on Load Lines (ICLL), obtaining the following values as a result:

Table LXXXII - Summer Freeboard, Draft and Displacement.

Name	Abbreviation	Value	Unit
Summer Freeboard	FB_S	1.096	m
Summer Draft	H_S	5.812	m
Summer Draft Displacement	Δ_S	4246	MT

It can be observed that the design draft is lower than the summer draft, which confirms that the condition is met. Furthermore, since the design draft is very close to the summer draft, it proves to be a well-defined condition that takes full advantage of the vessel's cargo-carrying capacity. We also determined the rest of the required freeboards as indicated in Table LXXXIII - Freeboards:

Table LXXXIII - Freeboards

Name	Abbreviation	Value	Unit
Winter Freeboard	FB_W	1.217	m
North Atlantic Winter Freeboard	FB_{WNA}	1.267	m
Tropical Freeboard	FB_T	0.975	m
Fresh Freeboard	FB_F	0.986	m
Tropical Fresh Freeboard	FB_{TF}	0.865	m

20.2 Trim, Hydrostatics and Curves of Form

The hydrostatic analysis of all the previously defined loading conditions was carried out, obtaining the following values for each of them.

Table LXXXIV - Hydrostatic Results by Loading Condition.

Item Name	LC1	LC2	LC3	LC4	LC5	LC6	LC7
Draft Amidships [m]	5.812	5.196	5.776	5.166	4.142	3.362	4.505
Displacement [MT]	4329	3707	4231	3636	2702	2050	3081
Heel [deg]	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Trim (+ve by stern) [m]	1.275	0.769	0.236	0.069	0.198	0.039	1.272
LCG [m]	27.576	28.434	28.735	29.346	29.897	30.374	28.210
TCG [m]	-0.003	0.002	-0.003	0.002	-0.004	0.004	0.003
VCG [m]	4.536	4.763	5.378	5.756	4.412	5.066	5.892
GMt corrected [m]	3.352	3.475	2.565	2.425	4.159	4.249	2.781

Following the hydrostatic analysis, the following curves were obtained:

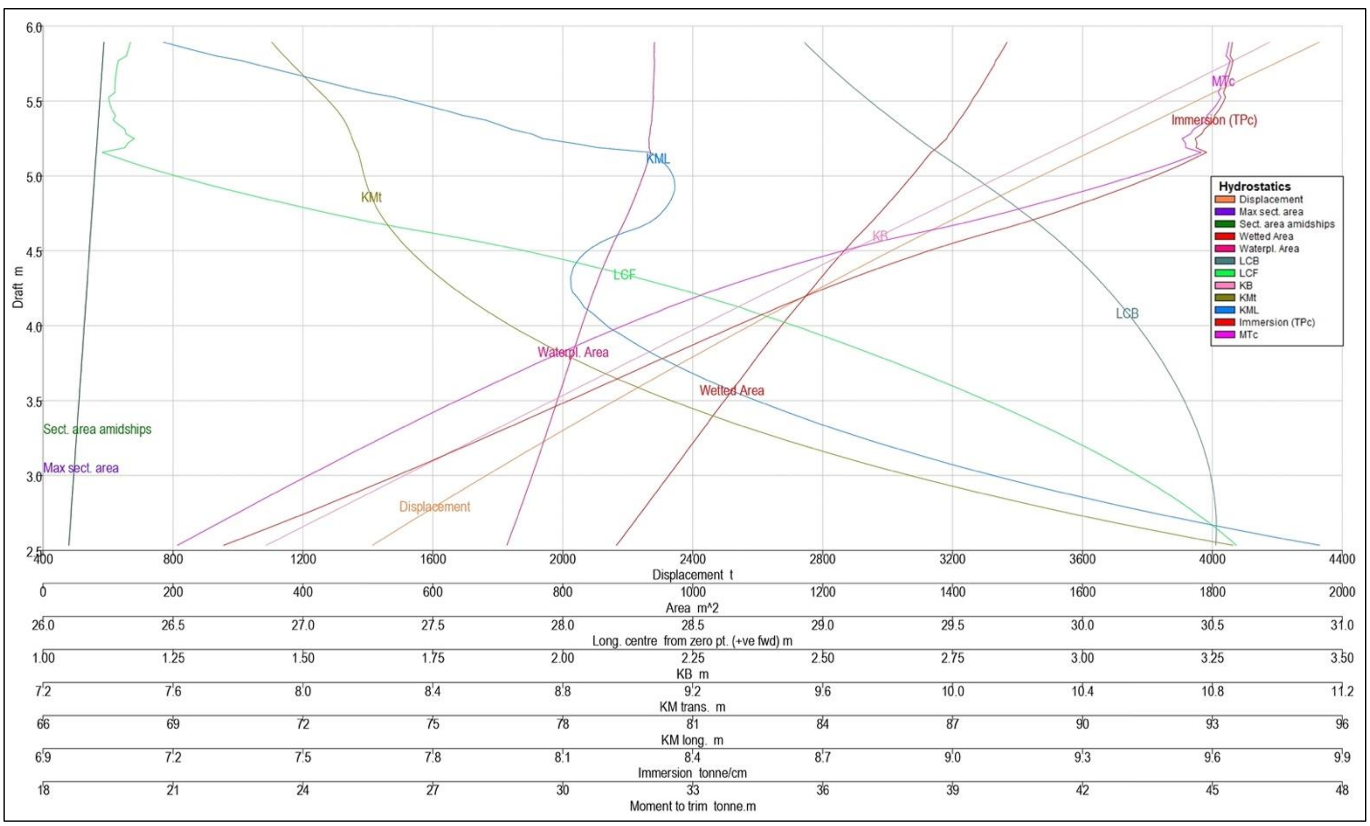


Figure 20.2-1 - Hydrostatics Curves.

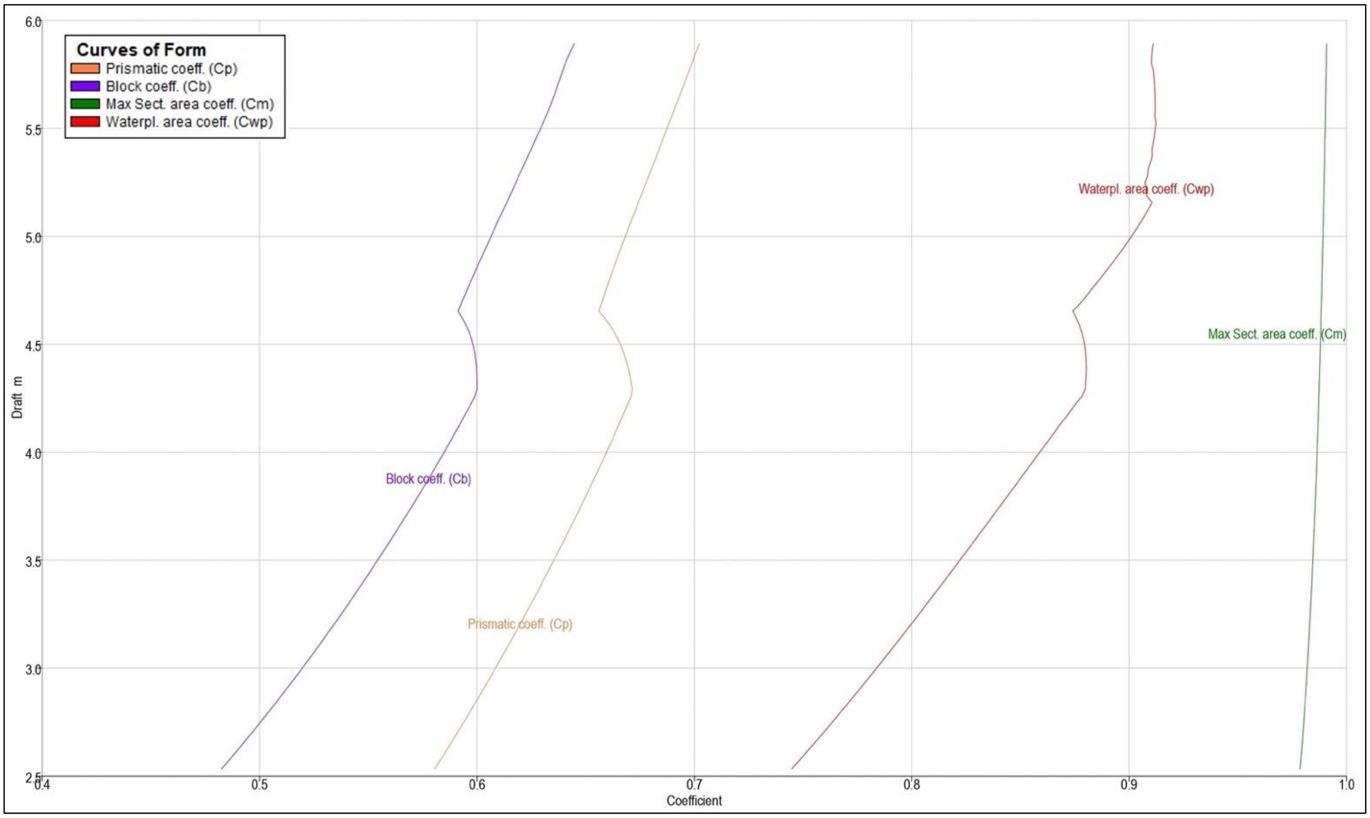


Figure 20.2-2 - Curves of Form.

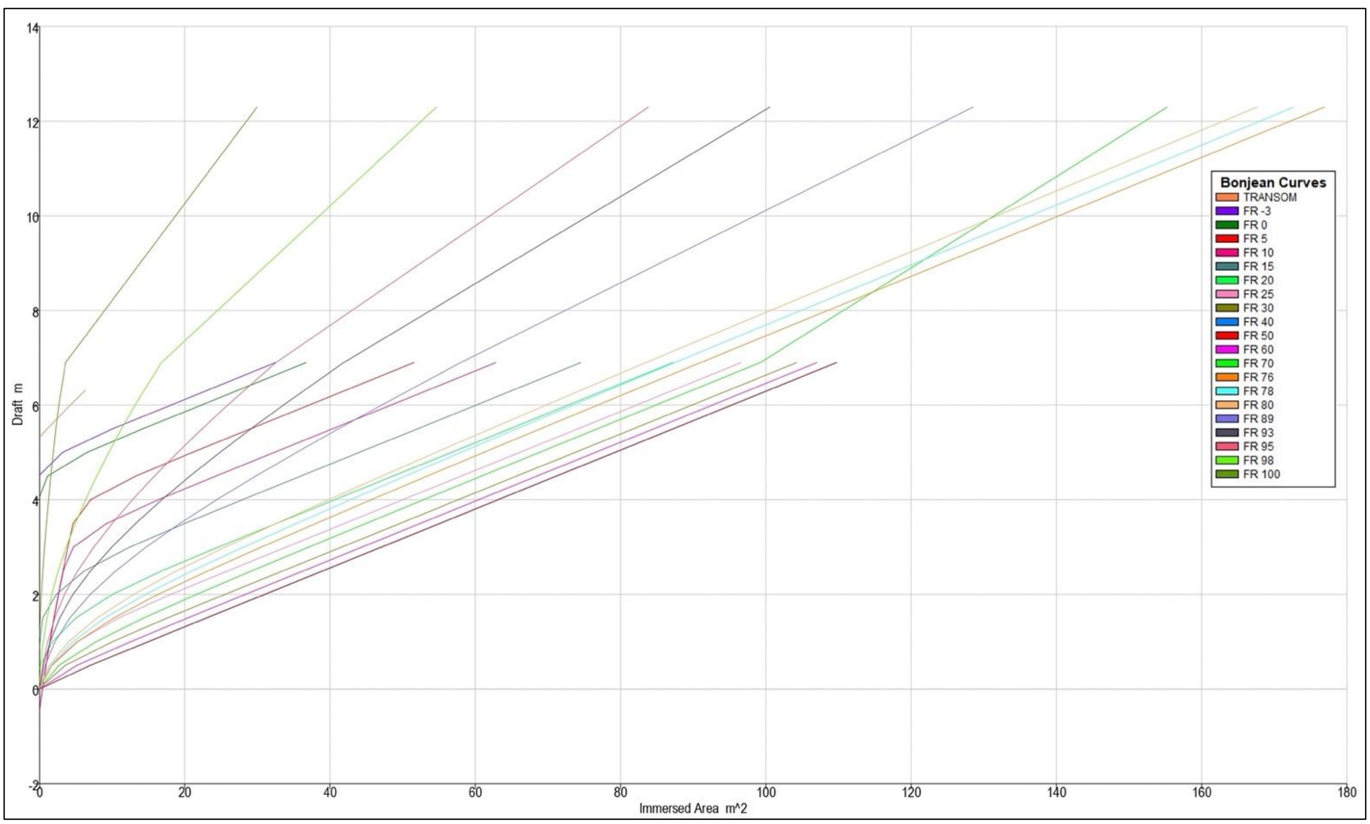


Figure 20.2-3 - Bonjean Curves.

20.3 *Large Angle Stability*

We then proceeded with the intact stability analysis, for which IMO MSC.267(85) (PART A - Ch.2 and PART B) criterion was applied, in order to assess whether the vessel can meet the stability requirements for its intended operations.

20.3.1 Criterion

20.3.1.1 IMO MSC 267(85) - PART A - Ch.2 - General Criteria

- *The area under the righting arm curve is not to be less than 0.055 meter-radians up to the angle of heel of 30 degrees.*
- *The area under the righting arm curve is not to be less than 0.090 meter-radians up to the angle of heel of 40 degrees or the angle of downflooding (θf) if the angle is less than 40 degrees.*
- *The area under the righting arm curve between the angles of heel of 30 degrees and 40 degrees or between 30 degrees and the angle of downflooding (θf), if downflooding occurs at less than 40 degrees, is no to be less than 0.030 meter-radians.*
- *The righting arm is to be at least 0.2 m at an angle greater than or equal to 30 degrees.*
- *The maximum righting arm is to occur at an angle of heel preferably exceeding 30 degrees but not less than 25 degrees.*
- *Initial GM is not to be less than 0.25 m.*

20.3.1.2 IMO MSC 267(85) - PART B - Recommendations for Certain Types of Ships - OSV

- *The area under the righting arm curve shall not be less than 0.070 meter-radians up to an angle of 15 degrees when the maximum righting arm occurs at 15 degrees, and 0.055 meter-radians up to an angle of 30 degrees when the maximum righting occurs at 30 degrees or more. When the maximum righting arm occurs at an angle between 15 degrees and 30 degrees, the required area under the righting arm curve shall be: 0.055 + 0.001 × (30 degrees - ϕ_{max}) meter-radians.*
- *The maximum righting arm is to occur at an angle of heel not less than 15 degrees.*

20.3.1.3 Severe Wind and Rolling Criterion (Weather Criterion)

The ability of the vessel to withstand the combined effects of beam wind and rolling shall be demonstrated for each operating condition.

- *The vessel is assumed to be subjected to a steady wind pressure acting perpendicular to the vessel's centerline which results in a steady wind heeling arm. The vessel heel to an angle of equilibrium is not to exceed 16 degrees or 80% of the angle of deck edge immersion, whichever is less.*
- *From the resultant angle of equilibrium, the vessel is assumed to roll due to wave action to an angle of roll to windward.*
- *The vessel is then subjected to a gust wind pressure which results in a gust wind heeling arm.*
- *Under these circumstances, area 2 is to be equal to or greater than area 1.*

For this criterion, the roll back angle was set to be calculated automatically by MAXSRUF using the IMO: roll back angle criterion.

20.3.1.4 ABS - 3.3.A2/15 - Additional Criteria for Towing Vessels

The area of the residual dynamic stability (area between righting and heeling arm curves beyond the angle of the first intercept) up to an angle of heel of 40 degrees beyond the angle of the first intercept (A1 + A2), or the angle of downflooding, where this angle is less than 40 degrees beyond the angle of the first intercept (A1), is not to be less than 0.090 meter-radians.

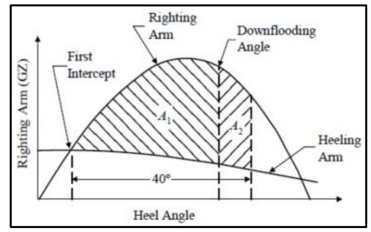


Figure 20.3-1 - Righting Arm and Heeling Arm Curves.

20.3.1.5 ABS - 5D.4.A1/3 - Intact Stability Requirements for Fire Fighting Operations

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 at amidships 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, is not to be less than 0.09 meter-radians.

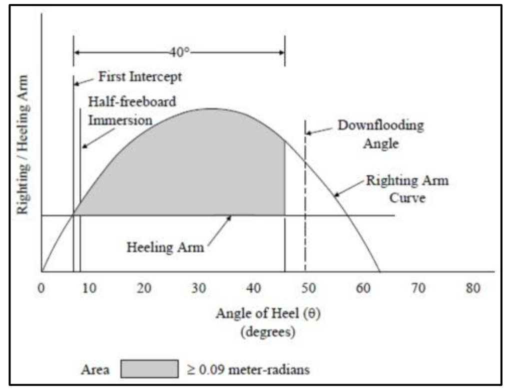


Figure 20.3-2 - Righting Arm and Heeling Arm Curves.

20.3.1.6 IMO MSC 415(97) Ch. 2.8 - Ships engaged in towing and escort operations

- *For ships engaged in harbour, coastal or ocean-going towing operations the area A contained between the righting lever curve and the **towing** heeling lever curve, measured from the heel angle, φ_e, to the angle of the second intersection, φ_c, or the angle of down-flooding, φ_f, whichever is less, should be greater than the area B contained between the heeling lever curve and the righting lever curve, measured from the heel angle $\varphi = 0$ to the heel angle, φ_c.*
- *For ships engaged in harbour, coastal or ocean-going towing operations the first intersection between the righting lever curve and the **tow-tripping** heeling lever curve should occur at an angle of heel less than the angle of down-flooding, φ_f.*

20.3.2 Downflooding Points

The following downflooding points were selected:

Table LXXXV - Downflooding Points Position.

#	Name	Long. Pos [m]	Offset [m]	Height [m]
1	ER Ventilation (S)	40.475	4.668	10.660
2	Funnel (S)	44.181	5.616	18.200

20.3.3 Results

After performing the large angle stability analysis for each ABS Loadcase, the following results were obtained:

Table LXXXVI - Large angle stability criterion results.

Code / Criteria	Value	Unit	Actual						
			1	2	3	4	5	6	7
267(85) - PART A - General criteria									
Area 0 to 30			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall not be less than (>=)	0.055	[m.rad]	0.2717	0.3793	0.2196	0.2644	0.5626	0.5568	0.3237
Area 0 to 40			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall not be less than (>=)	0.09	[m.rad]	0.4073	0.5827	0.3093	0.391	0.9207	0.9012	0.4825
Area 30 to 40			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall not be less than (>=)	0.03	[m.rad]	0.1356	0.2034	0.0898	0.1266	0.3581	0.3444	0.1588
Max GZ at 30 or greater			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall not be less than (>=)	0.2	[m]	0.808	1.183	0.528	0.749	2.093	1.989	0.96
Angle of maximum GZ			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall not be less than (>=)	25	[deg]	45.5	40	26.4	28.2	40.9	36.4	28.2
Initial GMt			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall not be less than (>=)	0.15	[m]	3.352	3.475	2.565	2.425	4.159	4.25	2.781
Severe wind and rolling			Pass	Pass	Pass	Pass	Pass	Pass	Pass
Angle of steady heel shall not be greater than (<=)	16	[deg]	0.5	0.7	0.6	1	0.8	1.3	1.2
Angle of steady heel / Deck edge immersion angle shall not be greater than (<=)	80	[%]	19.95	6.98	8.42	8.08	4.18	5.08	9.1
Area1/Area2 shall not be less than (>=)	100	[%]	210.8	278.38	163.42	212.83	365.78	280.22	273.19
267(85) - PART B - OSV									
GZ area between 0 and angle of maximum GZ			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall not be less than (>=)	0.055	[m.rad]	0.4839	0.5827	0.1859	0.2406	0.9539	0.7755	0.2932
Angle of maximum GZ			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall not be less than (>=)	15	[deg]	45.5	40	26.4	28.2	40.9	36.4	28.2
ABS - 5D.4.A1/3 - FIFI Operations									
Angle of equilibrium (with heel arm)			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall be less than (<)	1	[deg]	0.2	0.3	0.2	0.3	0.2	0.4	0.4
Area			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall be greater than (>)	0.09	[m.rad]	0.4007	0.5778	0.3027	0.3862	0.9145	0.8974	0.4777
ABS - 3.3.A2/15 - Towing Operations									
Area			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall be greater than (>)	0.09	[m.rad]	0.3825	0.5608	0.2793	0.3645	0.9062	0.881	0.4541
415(97) - Ch2.8 - Towing and Tow-tripping									
Area2 / Area1			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall not be less than (>=)	1	[-]	755.404	934.464	448.457	370.5	1403.175	756.842	394.252
First flooding angle of the DownfloodingPoints			Pass	Pass	Pass	Pass	Pass	Pass	Pass
shall be less than (<)	100	[%]	6.46	5.47	7.07	7.83	4.3	4.23	7.08

Then, the following righting arm (GZ) graphs were obtained:

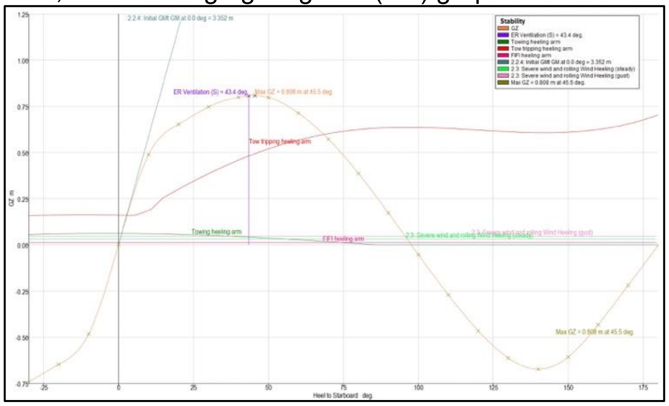


Figure 20.3-3 - GZ curves for LC1 (Details can be zoomed)

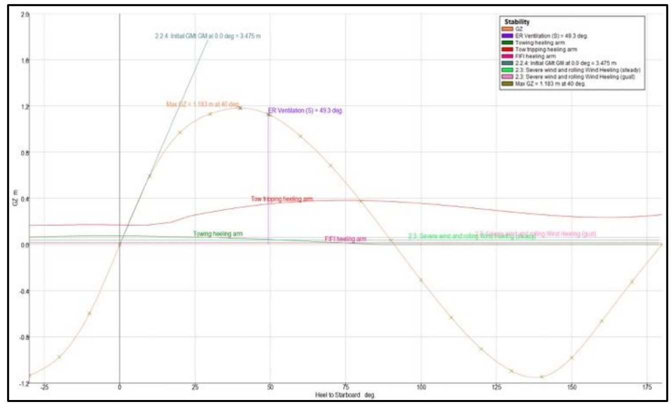


Figure 20.3-4 - GZ curves for LC2 (Details can be zoomed)

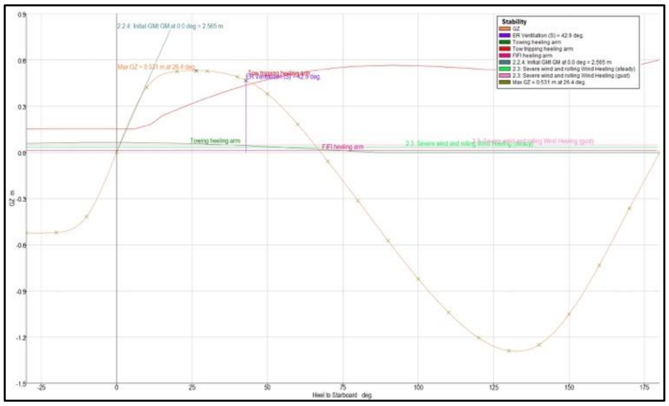


Figure 20.3-5 - GZ curves for LC3 (Details can be zoomed)

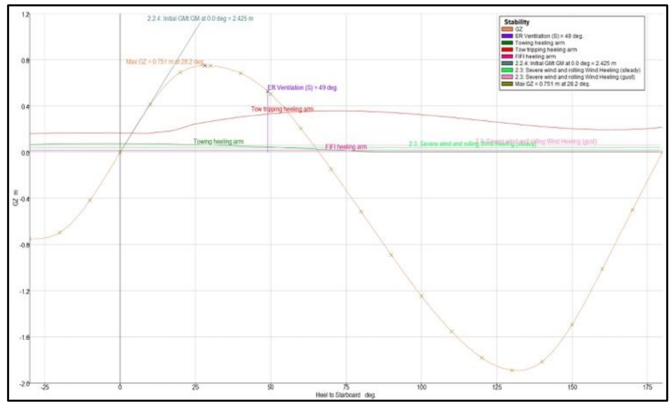


Figure 20.3-6 - GZ curves for LC4 (Details can be zoomed)

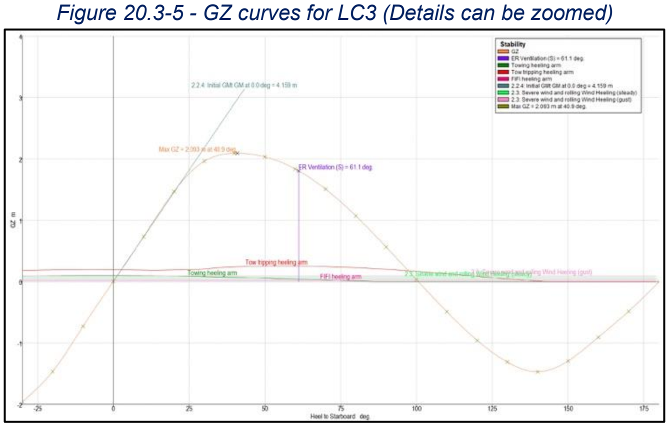


Figure 20.3-7 - GZ curves for LC5 (Details can be zoomed)

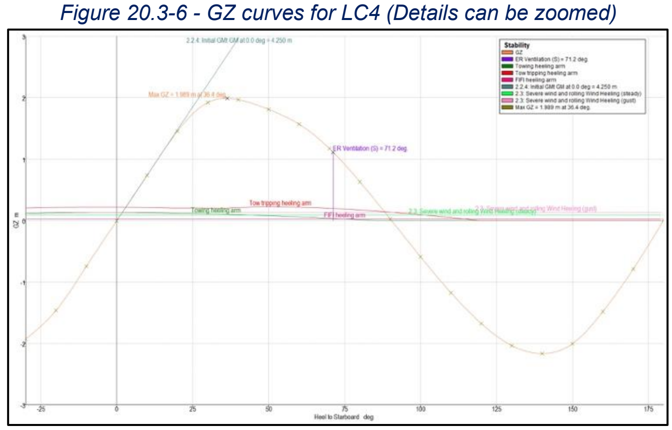


Figure 20.3-8 - GZ curves for LC6 (Details can be zoomed)

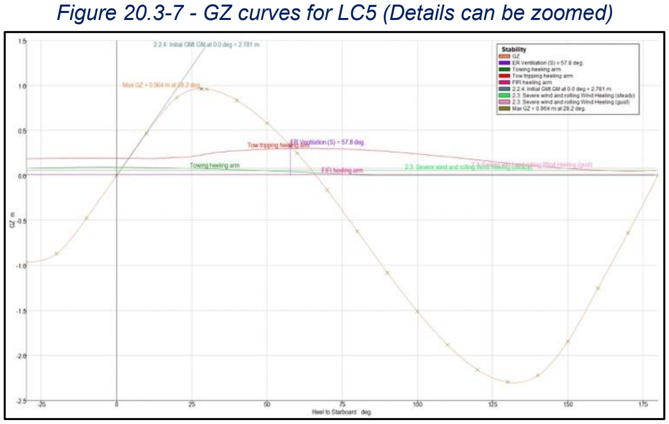


Figure 20.3-9 - GZ curves for LC7 (Details can be zoomed)

20.4 IMO MSC 415(97) Ch. 2.7 - Ships engaged in anchor handling operations

- *The residual area between the righting lever curve and the heeling lever curve should not be less than 0.070 meter-radians. The area is determined from the first intersection of the two curves, φ_e, to the angle of the second intersection, φ_c, or the angle of downflooding, φ_f, whichever is less.*
- *The maximum residual righting lever GZ between the righting lever curve and the heeling lever curve should be at least 0.2 m.*
- *The static angle at the first intersection, φ_e, between the righting lever curve and the heeling lever curve should not be greater than:*
  - *the angle at which the righting lever equals 50% of the maximum righting lever;*
  - *the deck edge immersion angle; or*
  - *15°,*

  whichever is less.
- *A minimum freeboard at stern, on centerline, of at least 0.005L should be maintained in all operating conditions, with a displacement given by Δ_2*

  The heeling lever $HL\varphi$ should be calculated as:

$$HL_{\varphi} = \left(\frac{M_{AH}}{\Delta_2}\right).\cos(\varphi) \tag{69}$$

Where:

- $M_{AH} = F_P * (h * sin(\alpha) * cos(\beta) + y * sin(\beta))$
- *Δ_2: The vessel displacement under the specified loading condition, including the effect of added vertical loads (Fv), applied at the ship's stern centerline.*
- *Vertical force component (kN): $F_V = F_P * sin(\beta)$*
- *α: the horizontal angle between the centreline and the vector at which the wire tension is applied to the ship in the upright position, positive outboard*
- *β: the vertical angle between the waterplane and the vector at which the wire tension is applied to the ship, positive downwards, should be taken at the maximum heeling moment angle as $tan^{-1}(y/(h \times sin(\alpha)))$, but not less than $cos^{-1}(1{,}5\ BP/\ (F_P\ cos\ \alpha))$, using consistent units;*
- *F_P: Permissible tension. The wire tension that may be applied to the ship in its loaded condition, while working through a specified tow pin set, at each angle α, for which all applicable stability criteria are met. F_P must never exceed F_d.*
- *Fd – Design maximum wire tension. The maximum winch wire pull or the maximum static winch brake holding force, whichever is greater.*
- *h: the vertical distance (m) from the centre the propulsive force acts on the ship to either*
  - *The uppermost part at the towing pin, or*
  - *A point along a line between the highest point of the winch pay-out and the top of the stern or any physical restriction that limits transverse wire movement.*
- *y: the transverse distance (m) from the centreline to the outboard point at which the wire tension is applied to the*
- *ship given by: $y_0 + x\,tan(\alpha)$; but not greater than B/2;*
- *B: the moulded breadth (m);*
- *y_0: the transverse distance (m) between the ship centreline to the inner part of the towing pin or any physical restriction of the transverse wire movement;*
- *x: the longitudinal distance (m) between the stern and the towing pin or any physical restriction of the transverse wire movement.*

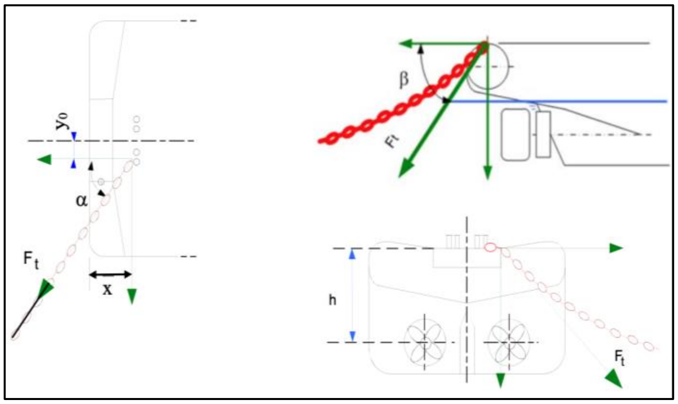


Figure 20.4-1 - Diagrams showing the parameters α, β, x, y and h. Ft shows the vector of the applied wire tension.

For anchor handling operations, a specific departure and arrival loading condition will be considered, as this type of operation represents one of the vessel's most critical scenarios. The stability criteria outlined in the IMO recommendations shall be verified exclusively for this operational condition.

The vessel displacement Δ_2, which includes the effect of vertical forces (F_V) associated with the operation, will vary depending on the loading condition under analysis. These values are automatically computed by Maxsurf Stability, by including an additional vertical force (only in anchor handling conditions) of a specified magnitude.

The admissible pulling force (F_p) will be determined iteratively using Maxsurf. The analysis begins with an initial value of F_p = 250 Metric tons, which is then gradually reduced until the applicable stability criterions are satisfied for each angle. This process is repeated for α values ranging from 0° to 90°, in increments of 5°, to determine the maximum allowable force that meets the required stability standards across the operational range.

The horizontal angle α = 90° is taken as the most critical case for analysis. While such extreme angles are unlikely under normal circumstances, they are entirely possible during anchor handling. This angle is not only supported by IMO recommendations but also by the Norwegian Maritime Directorate (NMD), which issued enhanced stability requirements following the tragic incident involving the AHTS Bourbon Dolphin in April 2007.

It is also recommended to adopt a standardized graphical representation of permissible tensions as a function of the pulling angle α. Such a format would improve the clarity and accessibility of this critical information, facilitating operational planning and enhancing crew familiarity with the vessel's performance limits during anchor handling operations.

The result is a curve showing recommended allowable tension versus pulling angle α, serving as a reference for safe anchor handling operations under different conditions.

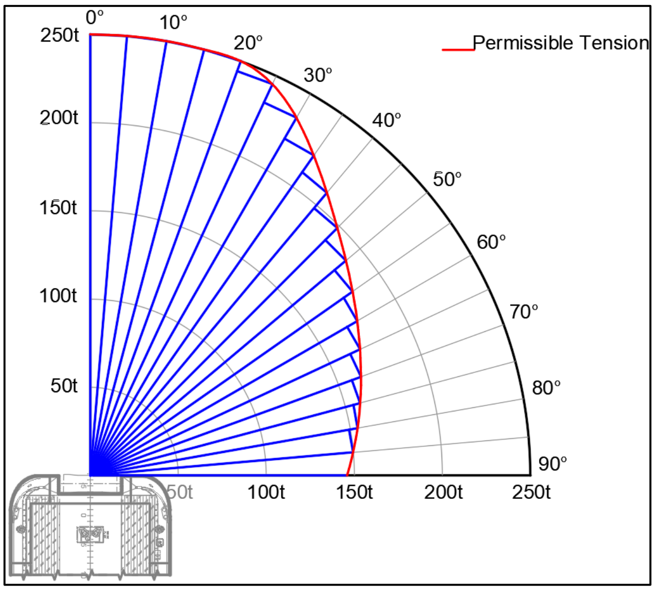


Figure 20.4-2 - Permissible tension sector diagram based on standard alpha values

21 DAMAGE STABILITY

For offshore supply vessels less than 100 meters in length, in accordance with the 2008 IMO Guidelines (as amended), Part 3, Chapter 3, Appendix 5, a damage stability analysis is required using the deterministic concept. This method is based on specific damage assumptions such as damage length, transverse extent, and vertical extent. In addition, compliance with the required compartment status must be demonstrated, taking into account the potential environmental risk depending on the type of cargo carried. The deterministic concept is specifically applied to offshore supply vessels, as established by ABS.

21.1 Damage Assumptions

The assumed extent of damage shall be as follows:

i) Damage is to be assumed to occur at any point along the length of the vessel between transverse watertight bulkheads. The longitudinal extent of the damage is:

For a vessel whose keel was laid, or which was at a similar stage of construction on or after 22 November 2012: with a length (Lf) greater than 43 m and less than 80 m: 3 m plus 3% of Lf;*

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

iii) The transverse extent of the damage is:

For a vessel whose keel was laid, or which was at a similar stage of construction on or after 22 November 2012: with a length (Lf) less than 80 m: 760 mm.*

21.2 Damage Size Calculation

According to applicable rules for vessels with keel laid after November 22, 2012, and Lf < 80 m:

Table LXXXVII - Damage Size Calculation.

Damage Extent	Description
Longitudinal	3 m + 3% of Lf = 4.92 m
Vertical	From the bottom of the cargo deck to the main deck (total hull depth)
Transverse	760 mm = 0.76 m

21.3 Free Surface Effect

Free surface effects must be calculated in accordance with 3-3-A2/9. The free surface effect of damaged non-consumable tanks may be omitted from the damage stability calculations.

21.4 Permeability

- *Tank permeability must be consistent with the amount of liquid carried, as shown in the loading conditions (3-3-A5/1)*
- *For empty tanks, permeability must be assumed not less than 0.95.*
- *Permeability is the ratio of the volume within a space assumed to be occupied by water to the total volume of that space, measured to the molded lines and without deductions for structural members (e.g., stiffeners).*
- *The permeability values of the remaining spaces shall be taken according to the following table MSC 82/24/Add.2 ANNEX 29 Page 7*

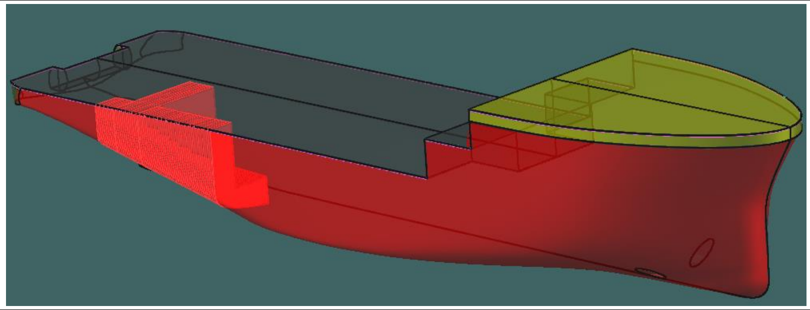
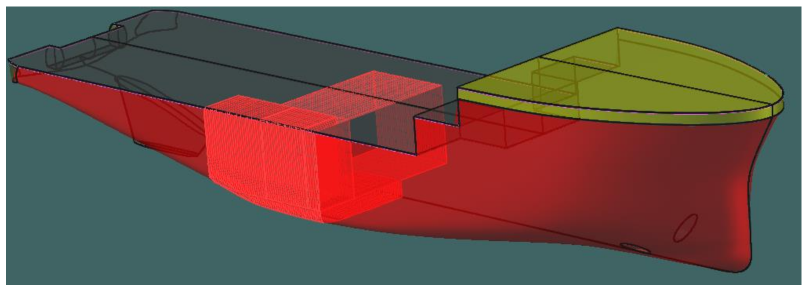
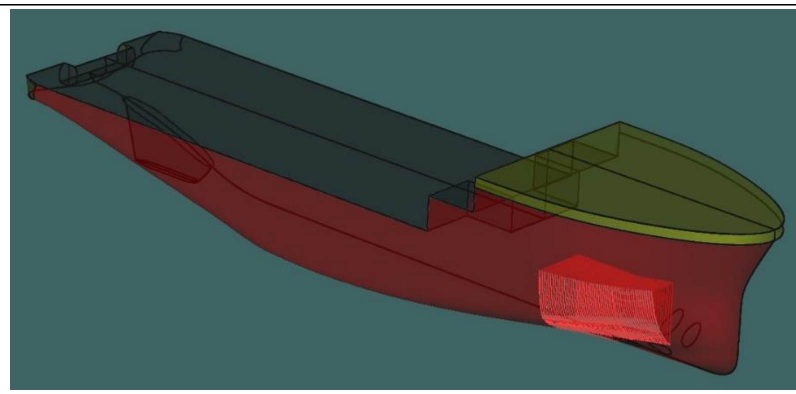
Table LXXXVIII - Permeability.

Spaces	Permeability (%)
Appropriated to stores	60
Occupied by accommodation	95
Occupied by machinery	85
Void spaces	95
Intended for dry cargo	95

21.5 Damage Cases

The following damage cases have been considered. The team decided to analyze one damage scenario at the bow, one at midship, and another further aft.

Table LXXXIX - Damage Cases.

Damage Case	Tanks Damaged	Maxsurf 3D View
1	NO.7 Ballast/Drill Water Tk (S) NO.2 Methanol Tk (S) NO.3 Methanol Tk (S) *Damage from the starboard in the stern vessel.*	
2	NO.5 Ballast/Drill Water Tk (S) NO.1 Methanol Tk (S) MDO Tk (S) Urea Tk (S) Pump Room Emergency Exit PR *Damage from the starboard in the bottom to the main deck for the vessel.*	
3	NO.1 Ballast/Drill Water Tk (S) NO.1 Fresh Water Tk (S) Potable Water Tk *Damage from starboard in the bow for the vessel.*	

21.6 Criteria

The following damage stability criteria shall be satisfied for offshore support vessels:

- *i) The final waterline, taking into account sinkage, heel, and trim, must remain below the lower edge of any opening through which progressive flooding may occur. These openings include ventilation pipes and those that can be closed by weathertight doors or hatches, and exclude openings fitted with weathertight covers, fixed watertight windows, small weathertight cargo tank hatches that ensure high deck integrity, remotely operated sliding watertight doors, and fixed-type side scuttles.*
- *ii) In the final stage of flooding, the angle of heel due to asymmetric flooding shall not exceed 15°. This angle may be increased to 17° provided there is no deck immersion.*
- *iii) Stability in the final flooding stage shall be investigated and may be considered sufficient if the righting arm curve shows a positive area of at least 20° beyond the equilibrium position, with a maximum residual righting arm of at least 100 mm (3.9 in.) within this range. Unprotected openings shall not become submerged at any angle of heel within the required range of residual stability, unless the space in question has been included as a floodable space in the damage stability*

calculations. Within this range, submersion of any of the above-mentioned openings, as well as any other opening that can be closed weathertight, may be permitted.

- *iv) The vessel shall retain adequate stability during intermediate stages of flooding.*

21.7 Results

A summary of the damage stability analysis is provided in the table below. All four damage scenarios meet or exceed the required criteria in every assessed condition.

Table XC - Damage Stability Results

Damage Case	Criteria	Value	Unit	Loadcase 1	2	3	4	5	6	7
1	**Maximum GZ (intermediate stages)**			Pass	Pass	Pass	Pass	Pass	Pass	Pass
	shall be greater than (>)	0.1	[m]	0.564	0.702	0.291	0.324	1.98	1.821	0.467
	Range of positive stability (intermediate stages)			Pass	Pass	Pass	Pass	Pass	Pass	Pass
	shall be greater than (>)	20	[deg]	92.7	84.7	56.8	50.1	99.7	89.7	49.6
	Heel angle at equilibrium for unsymmetrical flooding			Pass	Pass	Pass	Pass	Pass	Pass	Pass
	shall not be greater than (<=)	15	[deg]	2.9	4.9	2.2	5.7	1.3	0.1	6.6
2	**Maximum GZ (intermediate stages)**			Pass	Pass	Pass	Pass	Pass	Pass	Pass
	shall be greater than (>)	0.1	[m]	0.457	0.674	0.198	0.245	2.08	1.704	0.381
	Range of positive stability (intermediate stages)			Pass	Pass	Pass	Pass	Pass	Pass	Pass
	shall be greater than (>)	20	[deg]	95.9	92.9	53.7	46.8	102.9	88.5	51.5
	Heel angle at equilibrium for unsymmetrical flooding			Pass	Pass	Pass	Pass	Pass	Pass	Pass
	shall not be greater than (<=)	15	[deg]	4.4	6.5	3.5	8.7	0.4	5.9	8.0
3	**Maximum GZ (intermediate stages)**			Pass	Pass	Pass	Pass	Pass	Pass	Pass
	shall be greater than (>)	0.1	[m]	0.716	1.128	0.453	0.685	2.088	2.043	0.914
	Range of positive stability (intermediate stages)			Pass	Pass	Pass	Pass	Pass	Pass	Pass
	shall be greater than (>)	20	[deg]	94.8	90.4	63.3	63.4	99.8	91.4	67
	Heel angle at equilibrium for unsymmetrical flooding			Pass	Pass	Pass	Pass	Pass	Pass	Pass
	shall not be greater than (<=)	15	[deg]	0.9	1.2	0.8	1.5	0.4	0.1	0.6

22 SEAKEEPING ANALYSIS

The seakeeping analysis aims to evaluate the behavior of the vessel under open sea conditions, focusing on two fundamental aspects of the design: habitability, operability.

• Habitability is related to human comfort and crew performance on board, being especially relevant for vessels engaged in long-duration operations.

• Operability refers to the vessel's and crew's ability to carry out assigned tasks at sea, even under adverse weather conditions.

For this study, MAXSURF software was used, specifically the Motions module, to evaluate the MSI (Motion Sickness Incidence) and analyze crew comfort during navigation. The analysis was carried out using the strip method, modeling the hull with a fifth-degree polynomial and dividing it into 200 mapped sections, allowing for an accurate representation along the entire length of the vessel.

Likewise, an analysis of the vessel's dynamic behavior under an extreme condition was conducted to evaluate its response and performance in critical situations, ensuring the system's operational effectiveness.

22.1 Motion Sickness Incidence (MSI)

The analysis of Motion Sickness Incidence (MSI) is a key tool for evaluating the vessel's dynamic behavior from a human-centered perspective, as it estimates the percentage of people on board who may experience seasickness due to vessel motion at sea. This variable is particularly relevant when assessing two fundamental aspects of the design: habitability and operability.

From a habitability standpoint, a high MSI indicates sea conditions that may cause significant physical discomfort for crew members or passengers, affecting their comfort, morale, and overall well-being. This is especially critical on vessels engaged in long-duration voyages, where prolonged exposure to severe motion can have cumulative effects on health and performance.

Regarding operability, high MSI values also compromise the crew's ability to carry out assigned tasks effectively. Motion sickness can reduce concentration, reaction time, and precision, increasing the risk of operational errors, especially under demanding conditions or during complex maneuvers. In extreme cases, it may be necessary to alter the course or reduce speed to maintain acceptable MSI levels, which directly impacts the vessel's operational efficiency.

In this context, MSI analysis not only helps assess the impact of vessel motion on human performance but also serves as a design criterion to ensure that minimum standards of comfort and functionality are met, contributing to mission success and crew well-being.

To carry out this analysis, three strategic locations on the vessel were selected to evaluate the MSI: the bridge, the engine room, and the accommodation areas. These spaces were chosen because they represent the places where the crew will spend most of their time during navigation. Crew working on deck during navigation are not considered, as their stay there is minimal and, especially in rough sea conditions, they are rarely working on deck except for very short periods that do not significantly affect the MSI analysis.

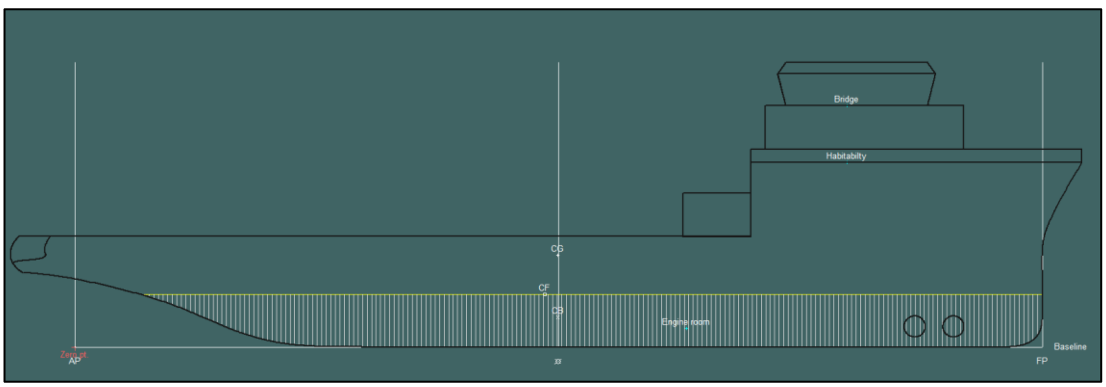


Figure 22.1-1 - Analysis Locations.

The Pierson-Moskowitz spectrum will be used for this analysis.

This spectrum was selected by the design team because it accurately represents a fully developed sea that is, a condition in which the wind has blown at a constant intensity over a prolonged period and across a sufficient fetch, allowing waves to reach their maximum development in terms of height and period. For this reason, it is considered a suitable and representative choice for performance analysis in the Argentine Sea, where similar wave conditions are typically observed in exposed areas.

In much of the northern sector of the Argentine Basin, particularly in offshore areas such as the outer continental shelf and slope, there are no obstacles that interfere with the predominant wind direction (usually from the southwest or south). This allows the fetch to extend for hundreds or even thousands of kilometers, favoring the full development of wave conditions. Under these circumstances, it is appropriate to apply spectra such as the Pierson-Moskowitz, which assume a fully developed sea and accurately represent the typical conditions of this region for ship behavior analysis.

The minimum load condition is considered because it will be the most critical in the seakeeping analysis, as the vessel is most susceptible to motions caused by the sea in this situation. This is due to the reduced load decreasing the stability and natural damping of the hull. This can result in higher accelerations and motions, affecting crew comfort.

The winds in the vessel's operational area were analyzed using data from the website Meteored (https://www.meteored.com.ar/mapas-meteorologicos/viento-ar.html). A representative range of typical regional winds was selected, and based on these conditions, the vessel's required speed to ensure comfortable navigation was evaluated, considering the most unfavorable wave train.

- For a wind speed of 15 knots navigation speed of 12.5 knots, the design team concludes that the vessel provides a high level of comfort for the crew. Consequently, this condition can be considered suitable for maintaining navigation at the service speed of 12.5 knots.
- For a wind speed of 20 knots, a good level of comfort for the crew is maintained at service speed. This reflects excellent vessel performance, as these are considerable wind conditions in which the design allows for maintaining stability and minimizing discomfort, thus ensuring safe and comfortable operation during navigation.
- For a wind speed of 25 knots, the design team concluded that it was necessary to reduce the sailing speed to 11.5 knots in order to keep the comfort level within acceptable limits. This decision prevents the discomfort index from exceeding the critical threshold of 8 hours. Although this is a demanding condition, the reduced speed ensures a safe and comfortable operation.
- At a wind speed of 30 knots, the vessel will be required to reduce its sailing speed to 10.5 knots in order to maintain acceptable comfort standards. The design team does not consider this to be a design issue, as such wind speeds are already quite severe, and this type of vessel is particularly sensitive to motion. Moreover, although this wind speed may occasionally occur during navigation in the operational area, it is not a typical everyday condition.

As a conclusion of this section, it is considered that the vessel demonstrates good performance in terms of crew comfort. The values obtained in the analysis support this statement, showing that reducing the sailing speed is only necessary under wind conditions that, although they may occur in the operational area, are not the most common. Generally, winds in the region vary between 15 and 22 knots.

For wind speeds above this range, although it has been shown that the vessel can continue sailing, consultations with various sources, including experienced crew members, concluded that such extreme conditions are infrequent. Furthermore, nowadays, voyage planning includes detailed meteorological studies, allowing operators to avoid sailing when conditions are unfavorable, unless it is strictly necessary. This ensures the safety and well-being of the crew.

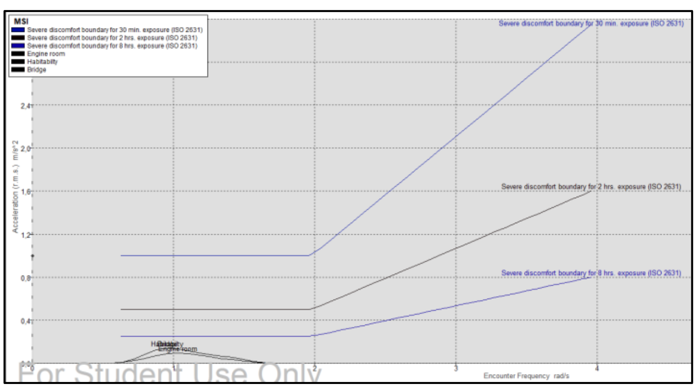


Figure 22.1-2 - MSI index for 15 knots of wind speed

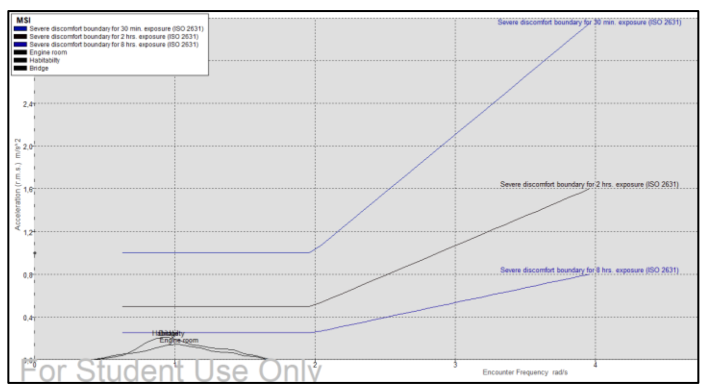


Figure 22.1-3 - MSI index for 20 knots of wind speed

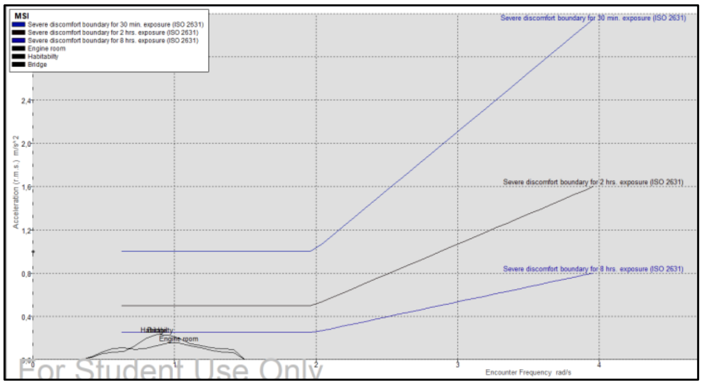


Figure 22.1-4 - MSI index for 25 knots of wind speed

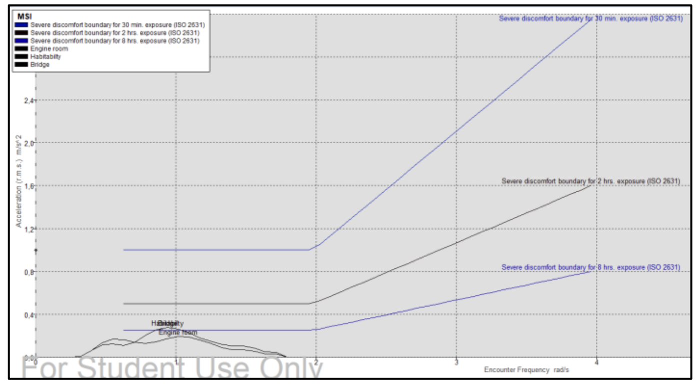


Figure 22.1-5 - MSI index for 30 knots of wind speed

22.2 Station Keeping Performance

To evaluate the performance of the vessel's dynamic positioning system, the ABS Guide for Dynamic Positioning Systems was adopted to ensure compliance with the applicable technical requirements. In this project, a system compliant with DPS-2 notation has been selected, which is capable of automatically maintaining the vessel's position and heading within a defined operational envelope, even under adverse environmental conditions and in the event of a single failure, provided it does not involve the loss of compartments.

During the design phase, both the vessel and its systems were conceived in accordance with the redundancy principles required by this notation. This ensures that, in the event of failure of any active component—such as generators, azipods, bow thrusters, switchboards, DP control computers, sensors, or remotely operated valves—the vessel maintains its positioning capability thanks to the continuous availability of control, electrical power, and thrust.

The azipod system must generate sufficient thrust in both longitudinal and transverse directions, as well as produce the yaw moment necessary for heading control. For vessels with DPS-2 notation, the vessel must also be equipped with an adequate number of bow thrusters whose capacity allows it to maintain both position and heading, even in the event of a single failure. This capability must be sustained under the maximum specified environmental conditions, ensuring safe vessel operation in extreme situations.

Since the vessel uses an electric propulsion system, the motors have been selected to ensure that a potential failure does not compromise the operation of the dynamic positioning system. The design incorporates the principle of redundancy, so that even in the event of a motor or thruster failure, the system can continue to operate effectively. For this reason, the propulsion system is considered a fundamental part in the calculation of the vessel's maneuvering capability, ensuring operational continuity within the established safety and performance margins, in compliance with the DPS-2 notation requirements.

The vessel is equipped with two bow thrusters, each providing 10 metric tons of thrust, intended to assist in the control of the dynamic positioning system and the stabilization of the heading.

The following situation is proposed:

Table XCI -Extreme situation

-	Value [knts]	Direction
Wind velocity	30	From Starboard
Current velocity	2	From Starboard

The forces exerted by the wind and current on the ship's hull depend on the angle of incidence relative to the longitudinal axis. These forces are maximum when acting laterally on the vessel, that is, at 90° and 270°, representing the most critical condition for the dynamic positioning system. The following formulas are presented to calculate these forces.

$$F_w = C_w \cdot \frac{1}{2} \cdot \rho_{air} \cdot V_{air}^2 \cdot A_w$$
$$F_{uw} = C_{uw} \cdot \frac{1}{2} \cdot \rho_{water} \cdot V_{water}^2 \cdot A_{uw} \quad (70)$$

- $C_{uw} = A\ value\ of\ 0.42\ is\ used, as\ it\ is\ only\ considered\ as\ an\ elliptical\ shape, with\ no\ wave - making\ effects\ due\ to\ the\ low\ Froude\ number.$
- $C_w = 0{,}59\ is\ supposed\ as\ Isherwood\ paper\ for\ Offshore\ Tug.$
- $A_w = Wind\ exposed\ area$
- $A_{uw} = Under\ water\ area$

Figure 22.2-1 - CAD Representation of Transverse and Longitudinal Sections

Values for the longitudinal and transversal area.

Table XCII - Longitudinal and transversal sections

	Longitudinal area	Transversal area	LCG	VCG
	[m^2]	[m^2]	[m]	[m]
Windage	355	201.5	43.1	12.1
Underwater	305.5	83.6	33.6	2.8

As previously mentioned, the vessel is equipped with azipods and two bow thrusters at the bow to maintain heading and position. These devices apply specific forces for this purpose, which are illustrated in the following image.

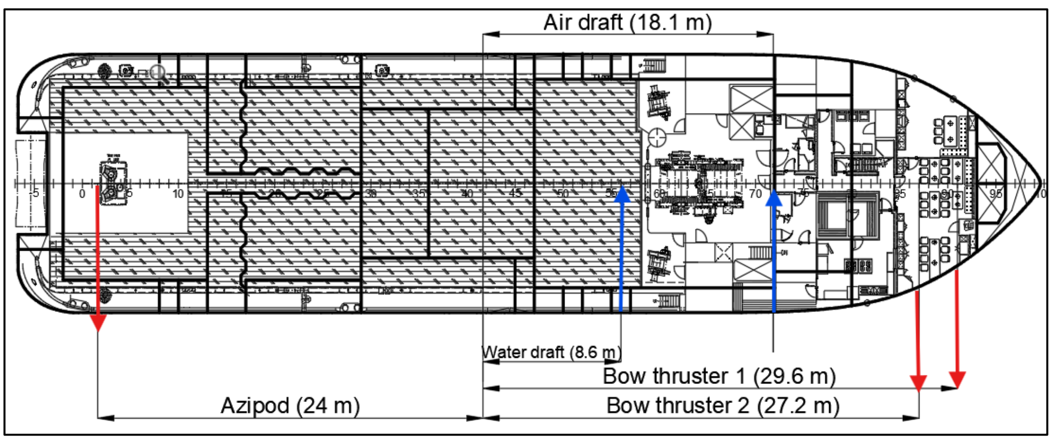


Figure 22.2-2 - Distribution of Acting Forces on the Vessel under Dynamic Positioning Conditions

The following table presents the force and moment values resulting from wind and tidal actions. The moments have been calculated with respect to the center of flotation under the full load condition.

Table XCIII - Forces and moments induced by wind and tide

	Longitudinal area	Force	Distance to the center of flotation.	Vertical Moment
	[m^2]	[MT]	[m]	[MT*m]
Windage	355	3.05	18.1	55.19
Underwater	305.5	7.1	8.6	60.98
Total		**10.1**	**-**	**116.17**

The following table shows the moments applied by the bow thrusters to counteract the effects of wind and tide.

Table XCIV - Moments generated by the bow thrusters

	Force	Long. position	Vertical Moment
	[MT]	[m]	[MT*m]
Bow thruster 1	10	29.6	296
Bow thruster 2	10	27.2	272

It is important to highlight that the bow thrusters were considered operating at their maximum available thrust, although they can operate at a lower load if necessary. The moment generated by the azipods was not taken into account; each azipod produces a thrust force of 37.5 MT. Although it is known that when fully rotated to a horizontal position they will not deliver the same thrust force, it is considered that they will provide more than enough force to maintain dynamic positioning if their use becomes necessary.

The operation of a single bow thruster is capable of generating the necessary moment to counteract the extreme wind and current conditions considered in the analyzed scenario. Therefore, it can be stated that, in the event of a technical failure preventing the operation of one of the bow thrusters, the other will be able to maintain heading and dynamic positioning without issues.

Additionally, the vessel is equipped with azipods which, thanks to their ability to rotate, provide additional thrust that aids in controlling dynamic positioning and heading. Although the exact moment generated by the azipods was not considered in this analysis, their contribution is deemed more than sufficient to complement the dynamic positioning system.

Together, these systems enable the vessel to achieve optimal performance in terms of dynamic positioning and heading maintenance, thus ensuring high reliability and operational safety under adverse environmental conditions.

23 ENDURANCE CALCULATION

The endurance calculation involves determining the required quantities of methanol, diesel (used as pilot fuel), and lubricating oil to meet the autonomy specified in the owner's requirements. This is based on the data obtained from the electrical balance and the operational profile. In this case, the navigation condition at service speed is evaluated. It is noted that the sea margin due to rough weather, fouling, and wind is already included in the power required for the service condition.

This process involves precisely determining the amount of lube oil, diesel and methanol required to meet the autonomy requirements set by the owner. An accurate calculation is based on data obtained from the electrical balance and the vessel's operational profile, ensuring a precise estimation of the resources needed for each journey.

A 10% margin is added as safety factor on the total consumption obtained. According to the generators selected, the fuel and oil requirements are the following:

Table XCV- Specific fuel and oil consumption

Item	Value	Unit
Ship speed	12.5	kts
Specific fuel consumption pilot fuel main engine	17	[g/kW·h]
Specific fuel consumption Methanol main engine	365	[g/kW·h]
Specific lube oil consumption per engine	0.35	[g/kW·h]

23.1 Methanol

For the service speed, an average between the day and night potence is used. From operational profile, service speed occupies 41.1%. That means that it is the most common condition for the vessel and is one of the most demanding conditions too. That's why the analysis is carried out considering the autonomy for service speed conditions.

The endurance calculation is based principally on the generators specific fuel consumption, set from the engine product guide, at the rated power

The required autonomy is 4,000 nautical miles.

$$W_{Methanol} = SFC_{Methanol} \cdot Total\ Power\ Required \cdot \frac{Autonomy}{Ship\ Speed} \cdot Margin$$

$$W_{Methanol} = 365 \frac{g}{kW \cdot h} \cdot 3791kW \cdot \frac{4{,}000nm}{12.5\ knots} \cdot 1.1 = 488MT \quad (71)$$

It is verified that the vessel with capacity on tanks for 563 MT of methanol meets the required capacity.

With this value, the vessel can reach the port-platform with a surplus to cover operations under "Harbor" and "Anchored" conditions.

23.2 Marine diesel oil

According to the generators specifications MDO is required as pilot fuel, that's why it is important to ensure that the ship tanks are capable to hold the required amount of Marine Diesel Oil.

Repeating the procedure in the previous point to obtain the amount of Marine Diesel Oil as follows:

$$W_{DO} = SFC_{DO} \cdot Service\ speed\ Power\ Required \cdot \frac{Autonomy}{Ship\ Speed} \cdot Margin$$
$$W_{DO} = 17\frac{g}{kW \cdot h} \cdot 3791kW \cdot \frac{4{,}000nm}{12.5\ knots} \cdot 1.1 = 23MT \quad (72)$$

It is noted that the vessel with a capacity tank of 36.57 MT is capable of carry the amount of MDO required.

23.3 Lube oil

Repeating the procedure for the lube oil required for the generators to work as follows:

$$W_{LO} = SFC_{LO} \cdot Total\ Power\ Required \cdot \frac{Autonomy}{Ship\ Speed} \cdot Margin = 0.35\frac{g}{kW \cdot h} \cdot 3791kW \cdot \frac{4{,}000nm}{12.5\ knots} \cdot 1.1 = 0.47MT$$

$$W_{LO} = SFC_{DO} \cdot Total\ Power\ Required \cdot \frac{Autonomy}{Ship\ Speed} \cdot Margin$$
$$W_{LO} = 0.35\frac{g}{kW \cdot h} \cdot 3791kW \cdot \frac{4{,}000nm}{12.5\ knots} \cdot 1.1 = 0.47MT \quad (73)$$

It is verified that the vessel has sufficient tank volumes to hold the required capacity of consumables to comply withs the owner's requirements

Table XCVI- Required capacity vs On Hold capacity

Item	Required	On Hold	Unit
Methanol	248	563	[MT]
MDO	23	37	[MT]
Lube Oil	0.47	15.5	[MT]

23.4 Maximum Endurance at Service Speed

For informational purposes, the vessel's maximum endurance at service speed is calculated using the following expression:

$$563MT = 365\frac{g}{kW \cdot h} \cdot 3791kW \cdot \frac{Máx\ Autonomy}{12.5Kts} \rightarrow Máx\ Autonomy = 4620NM \quad (74)$$

From this, a maximum endurance of 4620 nautical miles is obtained.

Subsequently, it is verified that there is sufficient pilot fuel and lubricating oil for this endurance:

$$W_{DO} = 17\frac{g}{kW \cdot h} \cdot 3791kW \cdot \frac{4{,}620nm}{12.5\ knots} \cdot 1.1 = 26{,}2\ MT$$
$$W_{LO} = 0.35\frac{g}{kW \cdot h} \cdot 3791kW \cdot \frac{4{,}620nm}{12.5\ knots} \cdot 1.1 = 0.54MT \quad (75)$$

Both values are below the maximum quantities available onboard, thus meeting the requirements.

23.5 FiFi Condition – Fuel Capacity Verification

According to ABS requirements, the vessel must be capable of carrying sufficient fuel to ensure continuous fire-fighting and propulsion operations with all fixed water monitors operating at maximum required capacity for a minimum of 24 hours.

Based on the power required in FiFi condition (1459 kW), as obtained from the electrical load balance, the minimum fuel required is calculated as:

$$W_{mín-FIFI} = SFC_{methanol} \cdot FIFI\ DPI\ condition\ Power\ Required \cdot 24hr = 16MT \tag{76}$$

The vessel has been verified to have adequate fuel storage capacity to comply with this requirement. The available methanol capacity ensures endurance beyond 24 hours of continuous FiFi operation, thereby meeting ABS criteria.

24 COST ANALYSIS

24.1 Construction

To obtain the cost estimation analysis, the team consulted the paper "Product-Oriented Design and Construction Cost Model" presented at the 1997 Ship Production Symposium. Additional information regarding SPS was obtained from professors with expertise in the subject.

The paper presents a calculation method for estimating construction costs based on regression equations. These equations relate the weight of each system included in the ship's lightweight to both the required man-hours and material costs (USD), along with a complexity factor associated with the type of vessel being analyzed.

The following table summarizes the regression equations used for estimating material costs and labor man-hours.

Table XCVII- Man Formulas for Hours and Material Cost.

Systems	Labor man hours	Material cost
	[hs]	USD
Hull	CFx 177 x Weight^0.862	800 x Weight
Machinery	CF x 365 x Weight^0.704	15000 + 20000 x Weight
Communications	682 x Weight^1.025	25000 x Weight
Electrical	1605 x Weight^0.795	40000 x Weight
Auxiliary	CF x 34.8 x Weight^1.24	10000 + 10000 x Weight
Outfitting y furniture	310 x Weight^0.949	5000 + 10000 x Weight

Based on the referenced paper, a complexity factor (CF) of 1.0 was determined for a Naval Tug Oceangoing. However, considering the higher construction complexity of this vessel, which features an almost full double hull, numerous small cofferdams and tanks, and most importantly, the integration of SPS (Sandwich Plate System) technology in the methanol tanks, the design team decided to increase the complexity factor to 1.7.

This adjustment reflects the anticipated challenges associated with these characteristics, particularly those arising from the implementation of Sandwich Plate System (SPS) technology. Although communication with the manufacturers confirmed that SPS is typically integrated by the shipyard together with standard steel works and does not significantly affect the construction schedule, available information regarding its cost and application time is limited. To address this uncertainty, an average of 3 man-hours per square meter and an estimated cost of 800 USD per square meter were assumed for SPS application.

In addition to a general 10 percent cost margin, a further 5 percent contingency was included to cover potential difficulties and additional components associated with methanol systems. Furthermore, a 10% yard's profit was considered.

The values obtained from the regression equations for different systems are summarized in the following table:

Table XCVIII- Man hours and material cost.

Systems	Labor man hours [h]	Material cost [MUSD]	Man hours cost [MUSD]
Hull	114.296	0.74	3.43
Machinery	28.141	4.17	0.84
Communications	8.709	0.30	0.26
Electrical	34.318	1.88	1.03
Auxiliary	6.835	0.45	0.21
Outfitting y furniture	43.494	1.84	1.30
SPS	1.979	0.45	0.059
Subtotal without margin [MUSD]		9.83	7.13
Margin		15%	
Yard's Profit		10%	
Total cost [MUSD]		21.20	

The following pie charts show the percentage distribution of each system.

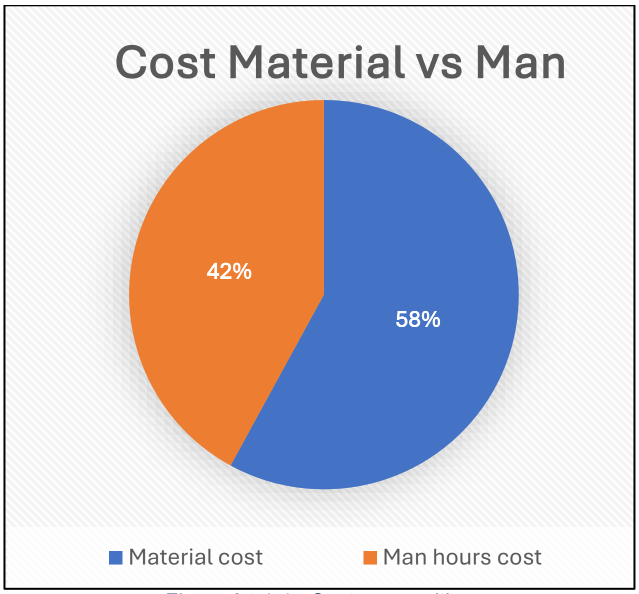


Figure 24.1-1– Cost composition.

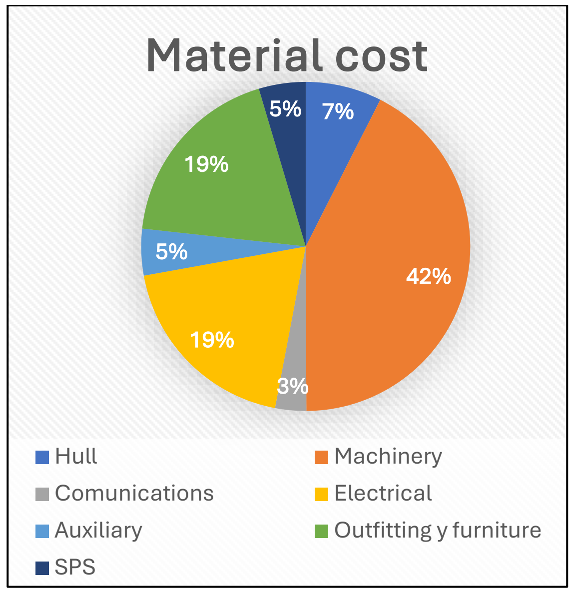


Figure 24.1-2-Material Cost.

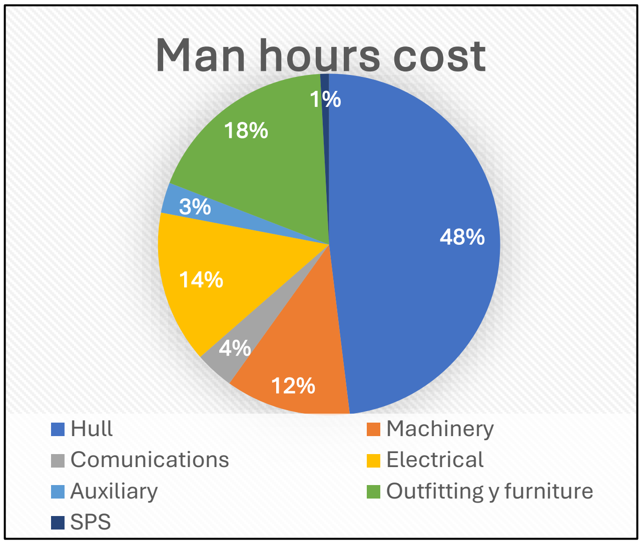


Figure 24.1-3-Man Hours Cost.

To estimate the construction time, it is necessary to consider the shipyard's capacity and limitations. In this case, a shipyard with a permanent staff of 380 people is assumed. The standard work schedule consists of 9-hour shifts from Monday to Friday. The following task distribution and work scheme will be applied.

Regarding the SPS technology, the manufacturers indicated that it is typically handled by the shipyard along with the rest of the steelworks and does not significantly affect the build timeline. Nevertheless, a higher time margin will be applied to account for any unforeseen complications, as well as the learning curve associated with the implementation of this relatively new technology.

Table XCIX-Distribution of task.

Systems	Labor man hours	Shipyard staff	Business days
	[h]	-	-
Hull	114.296	120	106
Machinery	28.141	50	63
Communications	8.709	25	39
Electrical	34.318	60	64
Auxiliary	6.835	20	38
Outfitting y furniture	43.494	90	54
SPS	1.979	15	15
Total		380	

A distribution of tasks and times was made in order to estimate the duration of the construction:

Table C-Task time

Task	Calendar day	Business days	Beggining	Finished
Hull	122	106	3/6/2025	3/10/2025
SPS	17	15	15/8/2025	1/9/2025
Machinery	73	63	23/8/2025	4/11/2025
Electrical	74	64	12/9/2025	25/11/2025
Communications	44	39	2/10/2025	15/11/2025
Auxiliary	32	28	1/11/2025	3/12/2025
Outfitting y furniture	51	45	26/11/2025	16/1/2026
Sea trials	10	9	16/1/2026	26/1/2026
Construction		237 days = 7 moths and 24 days		

To outline the timelines, a Gantt chart was created:

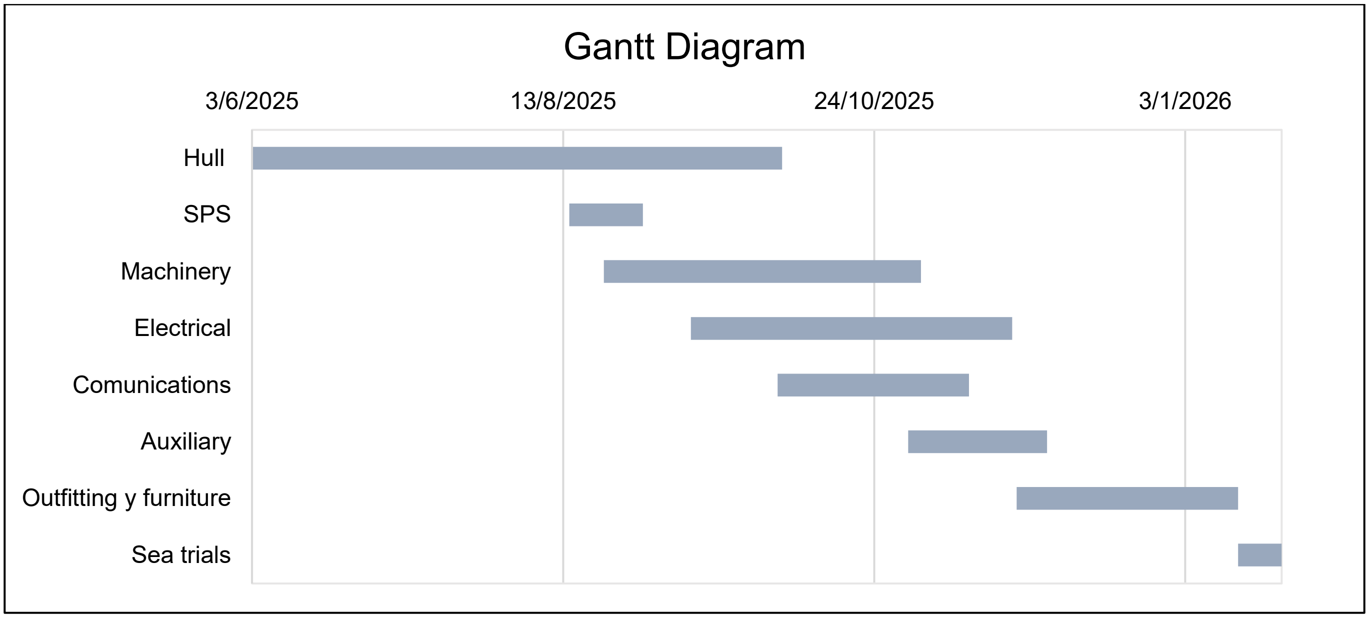


Figure 24.1-4-Gantt Chart.

24.2 Operating cost

The annual operating costs were estimated based on the methodology proposed in the book "Basic Project of Merchant Ships" by Alvariño. The operational expenses are categorized into crew costs, consumables, insurance, miscellaneous expenses, and maintenance and repair.

It is important to note that the operational costs of this vessel are expected to exceed the average for similar ships due to the incorporation of advanced technologies, such as the use of methanol as fuel. Consequently, the highest coefficients within the ranges recommended by the author have been applied to reflect this increased complexity.

$$AC = E_{crew} + E_{consumable} + E_{insourance} + E_{miscellaneous} + E_{maintenance} \tag{77}$$

- AC: Annual costs
- E_{Crew}: Crew expenses
- $E_{Consumables}$: Consumable expenses
- $E_{Insurance}$: Insurance expenses
- $E_{Miscellaneous}$: Miscellaneous expenses
- $E_{maintenance}$: Maintenance expenses

Crew expenses.

Crew expenses constitute one of the main operating costs of the ship, annual crew member cost has been estimated in MUSD 0,015 per year.

$$E_{crew} = \frac{MUSD}{person * year} 0.015 * 17\, person = MUSD\ 0.26\ \frac{USD}{year} \tag{78}$$

Consumable expenses

For this point, we will consider the estimated consumable expenses for the vessel.

$$E_{consumable} = cec * TP = \frac{MUSD\ 0.000150}{year * kW} * 5400\ kW\ = 0.81\ \frac{MUSD}{year} \tag{79}$$

- cec: Consumable expenses coefficient. This coefficient can vary between $\frac{usd\ 96}{year*kW}$ and $\frac{usd\ 120}{year*kW}$

However, considering the high cost of methanol, this coefficient has been increased to USD 150 per year·kW.

- TP: Total power installed

Insurance expenses

$$E_{insurance} = iec * TI = 0.015 * MUSD\ 21.204 = MUSD\ 0.32 \tag{80}$$

- iec: insurance expenses coefficient. 0.010 ≤ iec ≤ 0.015
- TI: total inversion

Miscellaneous expenses

$$E_{miscellaneous} = miec * TI = 0.015 * MUSD\ 21.204 = MUSD\ 0.32 \tag{81}$$

- miec: miscellaneous expenses coefficient. 0.010 ≤ iec ≤ 0.015
- TI: total inversion

Maintenance expenses

For this point, we will consider the estimated maintenance for the vessel.

$$E_{maintenance} = mec * TI = 0.02 * MUSD\ 21.204 = MUSD\ 0.42 \tag{82}$$

- mec: maintenance expenses coefficient. 0.010 ≤ iec ≤ 0.015

In order to account for the increased maintenance required by methanol systems and the additional equipment associated with their use, the coefficient will be increased to 0.02

- TI: total inversion

Below, the data obtained is summarized in the following table:

Table CI- Annual Costs

Expense	Value [MUSD]
Crew expenses	0.26
Consumable expenses	0.81
Insurance expenses	0.32
Miscellaneous expenses	0.32
Maintenance expenses	0.42
Total	**2.13**

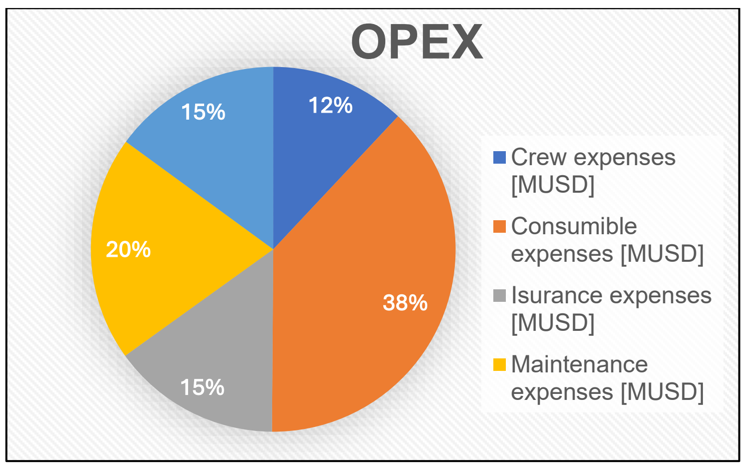


Figure 24.2-1-Annual Costs.

25 RISK ASSESMENT

This section aims to evaluate the development of the project based on the performance of the working team. Throughout the process, various tasks were carried out, in which both the knowledge acquired during academic training and previous experience in the professional field proved to be essential. As a result, several stages of the project were executed with a relatively low level of risk.

One of the major challenges of the project was the incorporation of green technologies. The selection and implementation of these sustainable solutions required extensive prior research by the team, due to the limited availability of concrete precedents in some cases. This effort is reflected throughout the report, where the decisions made are detailed based on the technical analysis carried out. However, as these are emerging technologies, they present a higher degree of uncertainty regarding their actual performance during implementation in real operating conditions.

The chosen procedure is through a risk matrix, as shown in the Table CII.

Table CII - Risk Approach.

Consequences of an error obtained in a design stage	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 station	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: It may affect and could require going back to the actual section and other 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

The following shows the possible value ranges and their respective descriptions.

Table CIII - Scales Took to Evaluate the Risk.

Action to implement	
From 1 to 8	It can be considered acceptable. might to be optimized in the future
From 8 to 12	A revision for improvements should be done
< 15	The risk of this stage is too high to move on with the design obtained

Table CIV - Risk results.

Step Description	Consequence [1]	Lock of confidence [2]	Risk score= [1]×[2]	CONTROL MEASURES
Initial Sizing	5	1	5	An adequate number of vessels was used as a sample, and the obtained results were also compared with those of existing vessels with similar characteristics, observing that the results showed similar dimensions among them.
Hull Modeling	3	2	6	The design team carried out an acceptable job in optimizing the hull form, aiming to achieve the best performance according to the tasks to be performed and to minimize resistance to forward motion.
Area/Volume Summary	3	1	3	The obtained values are considered acceptable, and no situation has been identified that would imply a high risk for the development of the project.
Structural Design	3	2	6	The values obtained were calculated in accordance with the ship classification rules and verified against the minimum required thicknesses. A finite element analysis should be carried out in a stage following the preliminary design, in order to validate the thicknesses in areas where the structure is subjected to concentrated loads.
Propulsion Plant	4	2	8	The selection of the generators for propulsion was carried out after prior consultation with a representative of the manufacturer in the South American region. The objective is to incorporate the most advanced technology currently available on the market, compatible with the use of methanol as fuel.
Equipment Selection	3	2	6	A thorough analysis was conducted for the selection of products, prioritizing those whose manufacturers have representatives in South America, in order to facilitate future spare parts purchases and ensure access to technical support.
Electrical Load	3	2	6	The operational profiles were developed with the aim of representing the actual load conditions as accurately as possible.
Weight Estimation	4	2	8	A thorough weight analysis was carried out, including a complete list of all components corresponding to steel, machinery, and outfitting, along with the corresponding percentages, including those more specific items whose exact weight is difficult to determine.
Intact/Damage Stability Analysis	4	2	8	This point was addressed with the second weight estimation. In case the weights are modified at a stage following the preliminary one, it must be rechecked.
Speed And Power & Endurance	4	2	8	A CFD analysis was carried out. Likewise, a scaled model could be built to test it in a towing tank.
Seakeeping Analysis	3	2	6	The results were obtained with MaxSurf applying the Pierson-Moskowitz method based on a parameter to model irregular waves.
Manning Estimate	2	1	2	No risks were identified at this point. The minimum crew was calculated according to the regulations of the naval authority in Argentina.
Cost Estimation	2	3	6	The costs were estimated using empirical formulas from 1997 which, although a good approximation for the initial stage, do not take into account latest-generation ships with new and environmentally friendly technologies. In a stage following the preliminary project, a more accurate cost estimation can be made.
Average		**6.0**		

The results obtained show that the risks at each design stage result in a final global risk value of 6, which is considered acceptable. However, it should always be optimized through further analysis after the preliminary project. Given that this is a preliminary stage, the result is satisfactory.

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27 APPENDIXES

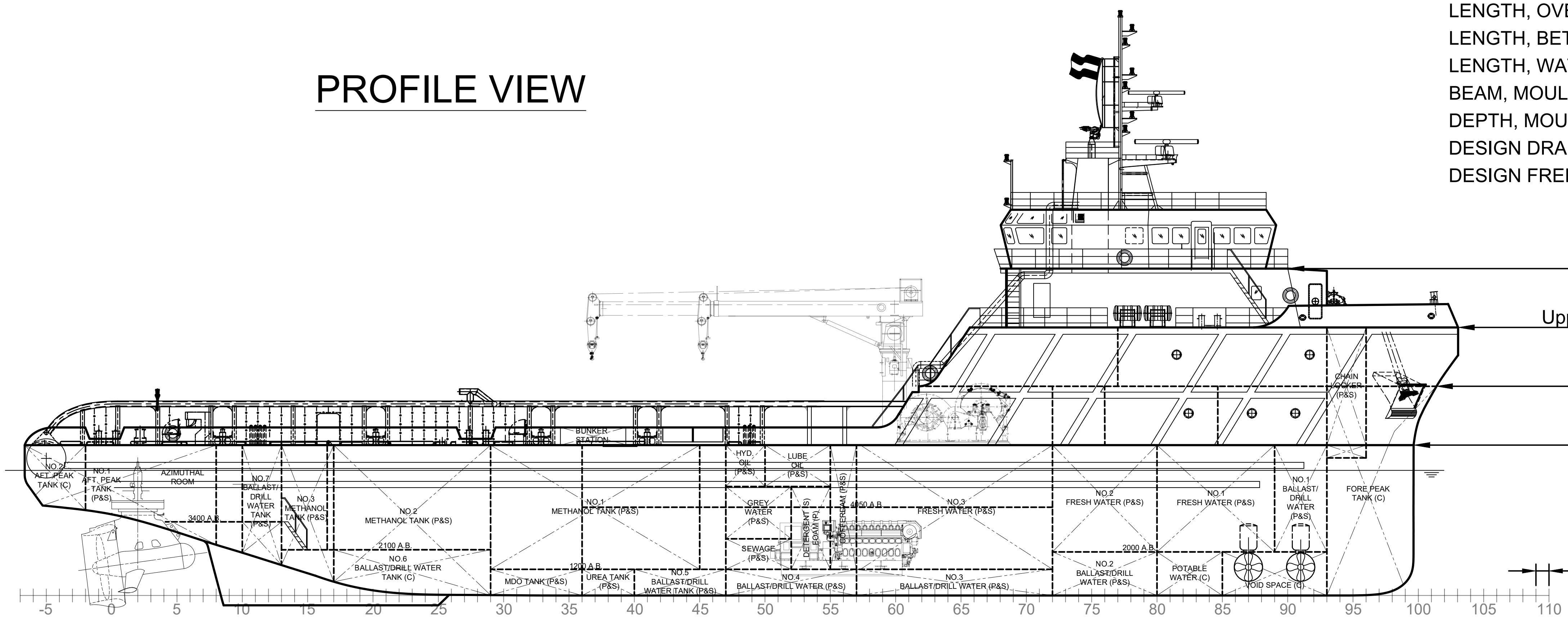
GENERAL ARRANGEMENT

(Profile & Main Deck plan view)

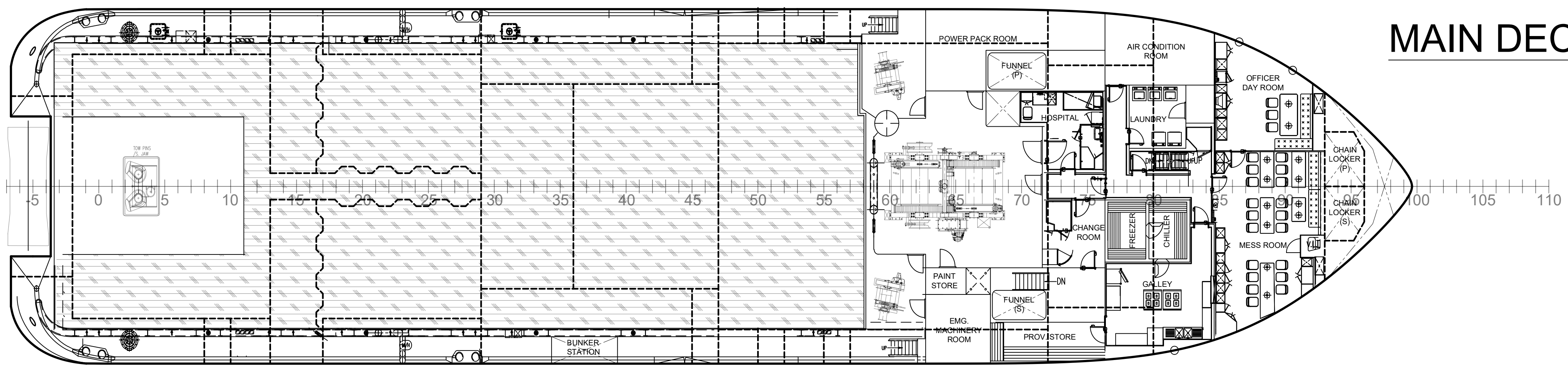
PRINCIPAL DIMENSIONS

LENGTH, OVERALL	66.30 m
LENGTH, BETWEEN PERPENDICULARS	57.80 m
LENGTH, WATERLINE	64.13 m
BEAM, MOULDED	16.10 m
DEPTH, MOULDED	6.90 m
DESIGN DRAFT	5.74 m
DESIGN FREEBOARD	1.16 m

PROFILE VIEW



MAIN DECK - 6900 A.B.



	Name:	Date:
Drawn by:	TM	01 Jun 2025
Checked by:	BH	02 Jun 2025
Approved by:	BH	02 Jun 2025

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FACULTAD REGIONAL BUENOS AIRES

Scale: 1:250

Drawing:
GENERAL ARRANGEMENT
Profile view & Main deck view

Vessel: 75-TON BP GREEN POWERED AHTS

Classification: ✠A1, Offshore Support Vessel (AH, Supply, Tow, FFV 1, OSP-S1), Methanol Fuel Ready, HYBRID [SCN], BWT, ✠DPS-2, ECG-SCR

Revision N°:	Size:	Sheet:
15	A3	01/03

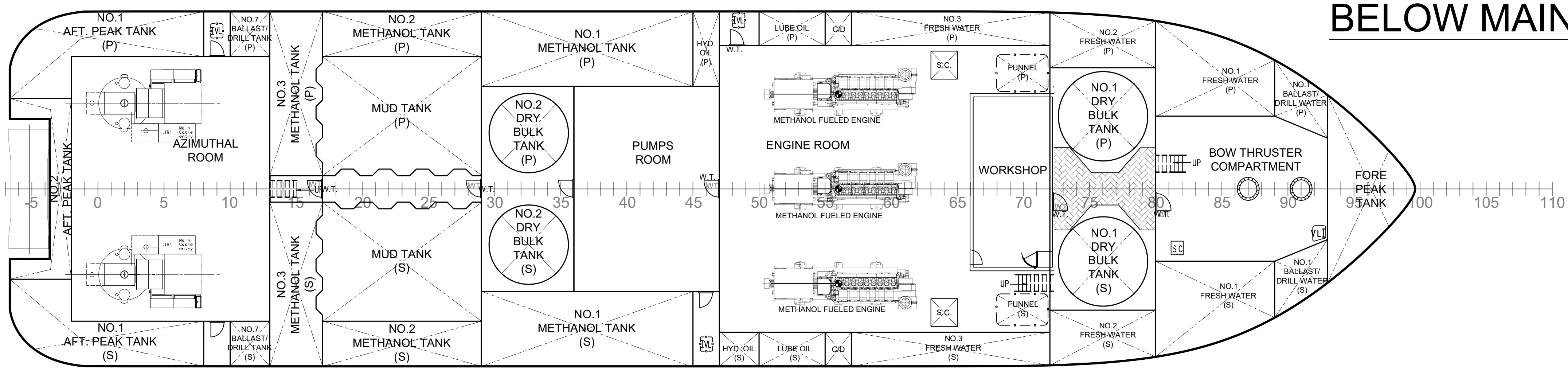
Dwg N° AHTS75 - GA - 15

Date Issued: 03 Jun 2025

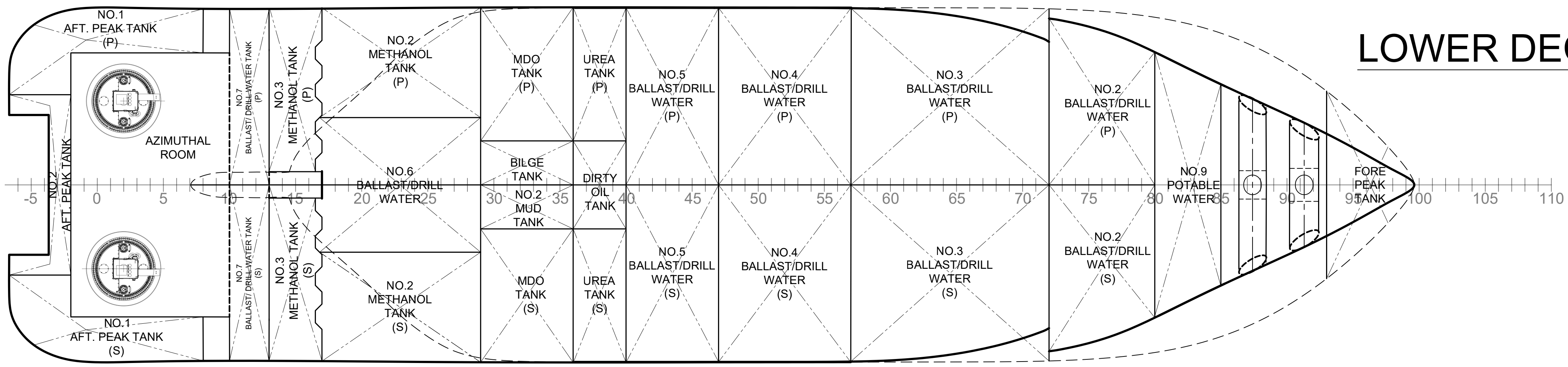
GENERAL ARRANGEMENT

(Lower decks plan view)

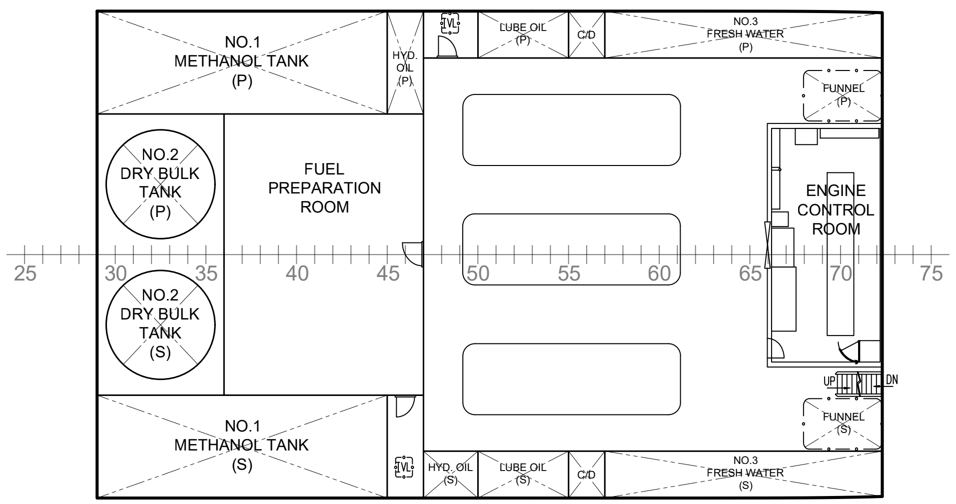
BELOW MAIN DECK - 6900 A.B.



LOWER DECK - 1200 A.B.



TWEEN DECK - 4050 A.B.



PRINCIPAL DIMENSIONS

LENGTH, OVERALL	66.30 m
LENGTH, BETWEEN PERPENDICULARS	57.80 m
LENGTH, WATERLINE	64.13 m
BEAM, MOULDED	16.10 m
DEPTH, MOULDED	6.90 m
DESIGN DRAFT	5.74 m
DESIGN FREEBOARD	1.16 m

	Name:	Date:
Drawn by:	TM	01 Jun 2025
Checked by:	BH	02 Jun 2025
Approved by:	BH	02 Jun 2025

UTN.BA
UNIVERSIDAD TECNOLÓGICA NACIONAL
FACULTAD REGIONAL BUENOS AIRES

Scale: 1:250

Drawing: GENERAL ARRANGEMENT
Lower decks plan view

Vessel: 75-TON BP GREEN POWERED AHTS

Classification: ✠A1, Offshore Support Vessel (AH, Supply, Tow, FFV 1, OSP-S1), Methanol Fuel Ready, HYBRID [SCN], BWT, ✠DPS-2, ECG-SCR

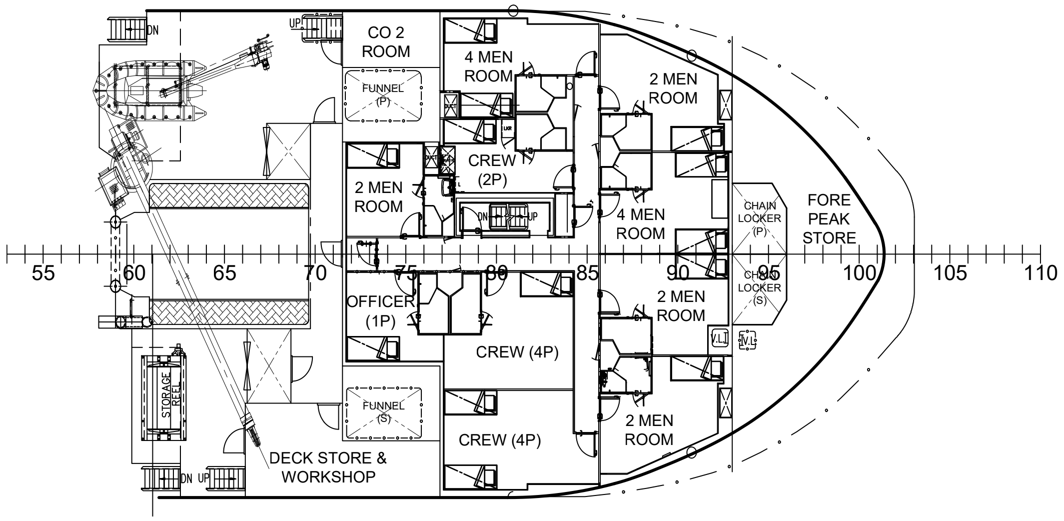
Revision N°:	Size:	Sheet:	Dwg N°
15	A3	02/03	AHTS75 - GA - 15

Date Issued: 03 Jun 2025

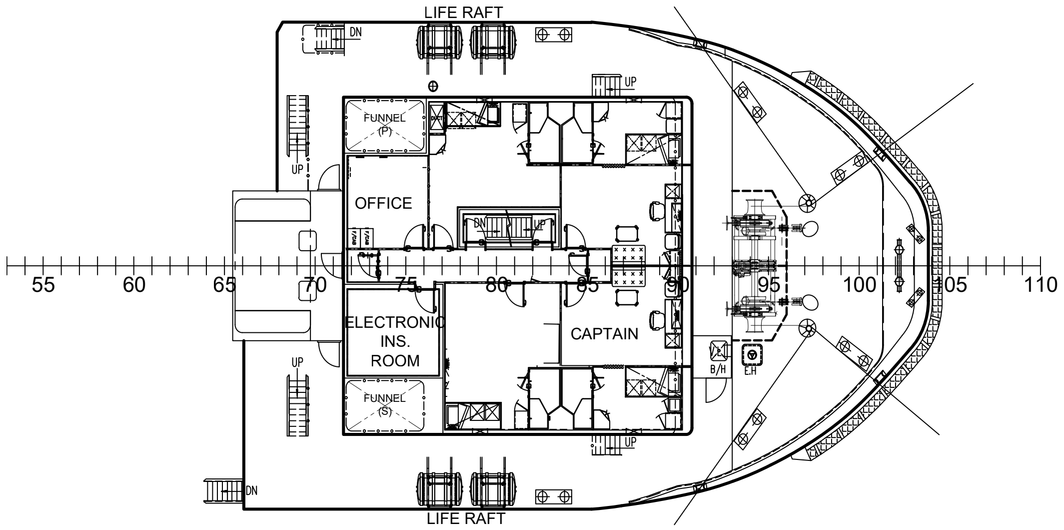
GENERAL ARRANGEMENT

(Upper decks plan view & trans. section view)

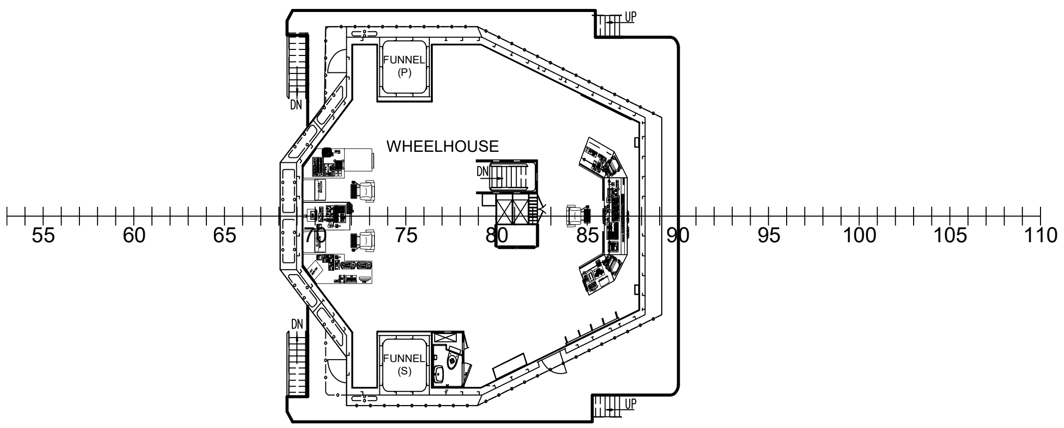
FORECASTLE DECK - 9600 A.B.

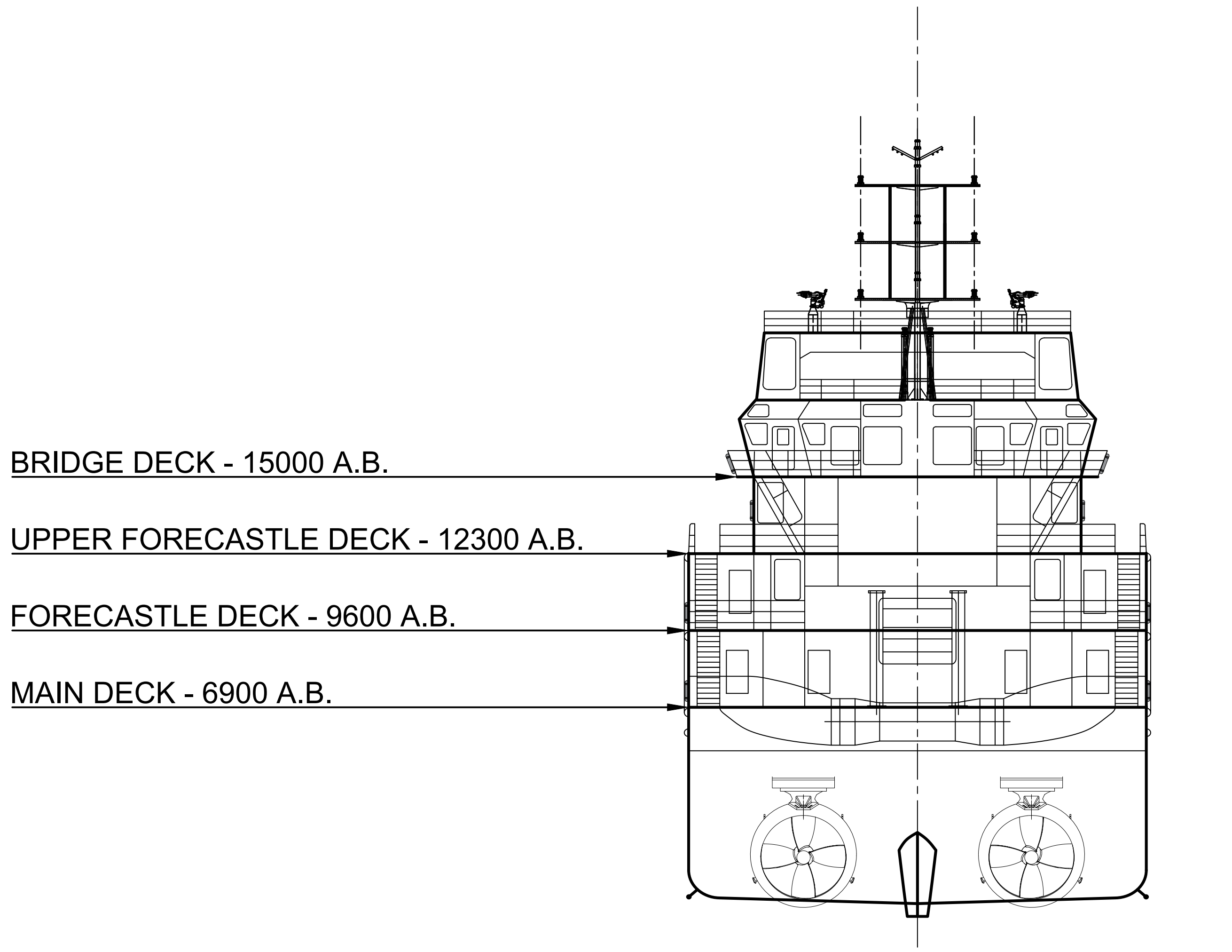


UPPER FORECASTLE DECK - 12300 A.B.



BRIDGE DECK - 15000 A.B.





PRINCIPAL DIMENSIONS

LENGTH, OVERALL	66.30 m
LENGTH, BETWEEN PERPENDICULARS	57.80 m
LENGTH, WATERLINE	64.13 m
BEAM, MOULDED	16.10 m
DEPTH, MOULDED	6.90 m
DESIGN DRAFT	5.74 m
DESIGN FREEBOARD	1.16 m

	Name:	Date:
Drawn by:	TM	01 Jun 2025
Checked by:	BH	02 Jun 2025
Approved by:	BH	02 Jun 2025

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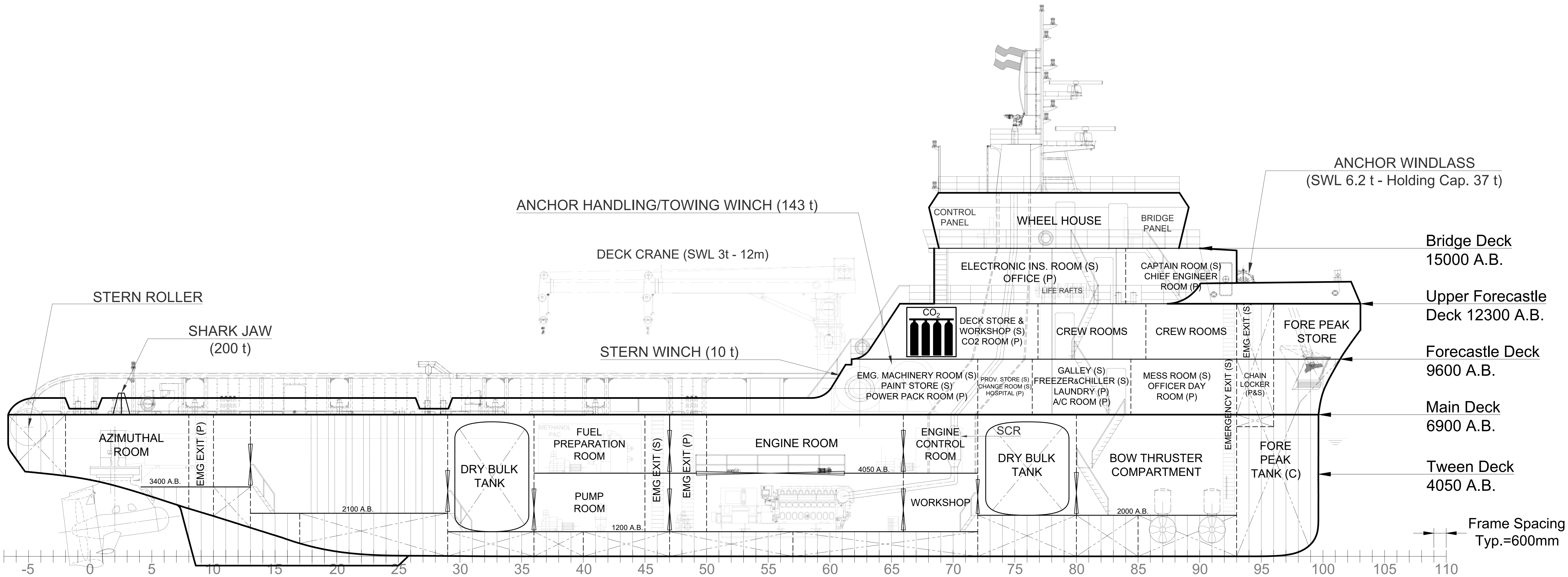
UNIVERSIDAD TECNOLÓGICA NACIONAL
FACULTAD REGIONAL BUENOS AIRES

Scale: 1:250	Drawing: GENERAL ARRANGEMENT — Upper decks plan view & Trans. section view		Vessel: 75-TON BP GREEN POWERED AHTS
			Classification: ✠A1, Offshore Support Vessel (AH, Supply, Tow, FFV 1, OSP-S1), Methanol Fuel Ready, HYBRID [SCN], BWT, ✠DPS-2, ECG-SCR
Revision N°: 15	Size: A3	Sheet: 03/03	Dwg N° AHTS75 - GA - 15
			Date Issued: 03 Jun 2025

INBOARD PROFILE



Notes:

- Unless otherwise specified, all dimensions are in millimeters.

PRINCIPAL DIMENSIONS

LENGTH, OVERALL .... 66.30 m
LENGTH, BETWEEN PERPENDICULARS .... 57.80 m
LENGTH, WATERLINE .... 64.13 m
BEAM, MOULDED .... 16.10 m
DEPTH, MOULDED .... 6.90 m
DESIGN DRAFT .... 5.74 m
DESIGN FREEBOARD .... 1.16 m

	Name:	Date:
Drawn by:	TM	01 Jun 2025
Checked by:	BH	02 Jun 2025
Approved by:	MS	02 Jun 2025

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UNIVERSIDAD TECNOLÓGICA NACIONAL
FACULTAD REGIONAL BUENOS AIRES

Scale: 1:250

Drawing:
ANNEX B:
INBOARD PROFILE

Vessel: 75-TON BP GREEN POWERED AHTS

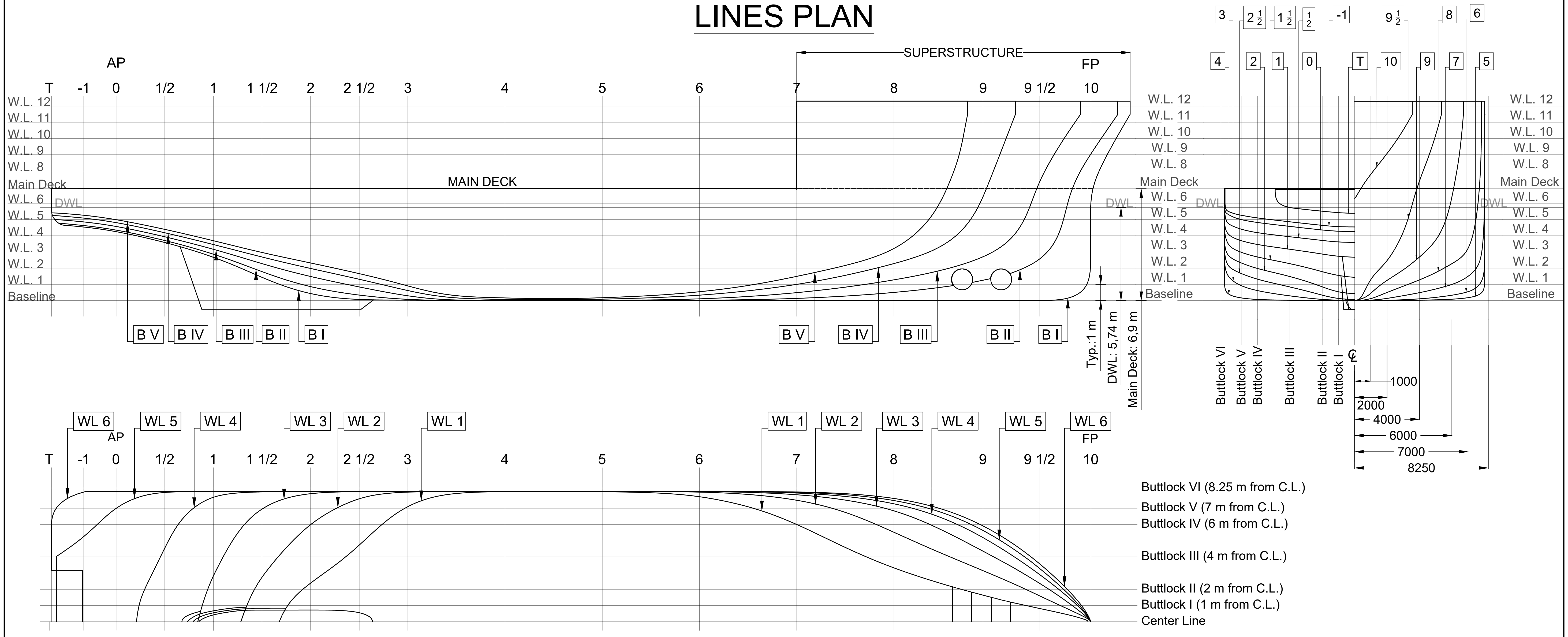
Classification: ✠A1, Offshore Support Vessel (AH, Supply, Tow, FFV 1, OSP-S1), Methanol Fuel Ready, HYBRID [SCN], BWT, ✠DPS-2, ECG-SCR

Revision N°:	Size:	Sheet:
13	A3	01/01

Dwg N° AHTS75 - IP - 13

Date Issued: 03 Jun 2025

LINES PLAN



POINTS TABLE																	
	TRANSVERSAL SECTIONS																
	Transom	#-1	#0	#1/2	#1	#1 1/2	#2	#2 1/2	#3	#4	#5	#6	#7	#8	#9	#9 1/2	#10
Dist. to #0	-3983	-2000	0	3000	6000	9000	12000	15000	18000	24000	30000	36000	42000	48000	53500	57000	60160
BL	-	-	-	-	429	718	723	571	0	0	0	0	0	0	0	-	-
WL 1	-	-	-	-	554	800	2426	4700	7213	8027	8020	7722	6021	3303	1641	810	-
WL 2	-	-	-	-	674	2816	6075	7682	8011	8033	8033	8004	7521	5520	3155	1597	-
WL 3	-	-	-	-	2854	7092	7943	8026	8032	8033	8033	8029	7846	6877	4355	2379	-
WL 4	-	-	-	4552	7720	8011	8031	8033	8033	8033	8033	8032	7942	7282	5194	2908	-
WL 5	-	5227	7052	7995	8031	8032	8033	8033	8033	8033	8033	8032	7986	7485	5643	3286	-
WL 6	6468	8002	8033	8032	8032	8033	8033	8033	8033	8033	8033	8033	8008	7612	5919	3574	-
Main Deck	-	7924	8030	8031	8032	8033	8033	8033	8033	8033	8033	8033	8017	7691	6103	3834	368

Dist. to BL	SUPERSTRUCTURE				
Section	#7	#8	#9	#9 1/2	#10
7000	8018	7699	6124	3869	434
8000	8023	7761	6307	4230	1158
9000	8026	7800	6463	4606	1946
10000	8027	7817	6578	4939	2667
11000	8027	7825	6671	5228	3289
12000	8027	7826	6713	5356	3553

PRINCIPAL DIMENSIONS

LENGTH, OVERALL .... 66.30 m
LENGTH, BETWEEN PERPENDICULARS .... 57.80 m
LENGTH, WATERLINE .... 64.13 m
BEAM, MOULDED .... 16.10 m
DEPTH, MOULDED .... 6.90 m
FRAME SPACING .... 600 mm
DESIGN DRAFT .... 5.74 m
SCANTLING DRAFT .... 6.20 m

Notes:

- Unless otherwise specified, all dimensions are in millimeters.

	Name:	Date:
Drawn by:	TM	25 May 2025
Checked by:	MS	01 Jun 2025
Approved by:	BH	02 Jun 2025

UNIVERSIDAD TECNOLÓGICA NACIONAL
FACULTAD REGIONAL BUENOS AIRES

Scale: 1:250

Drawing: ANNEX C: LINES PLAN

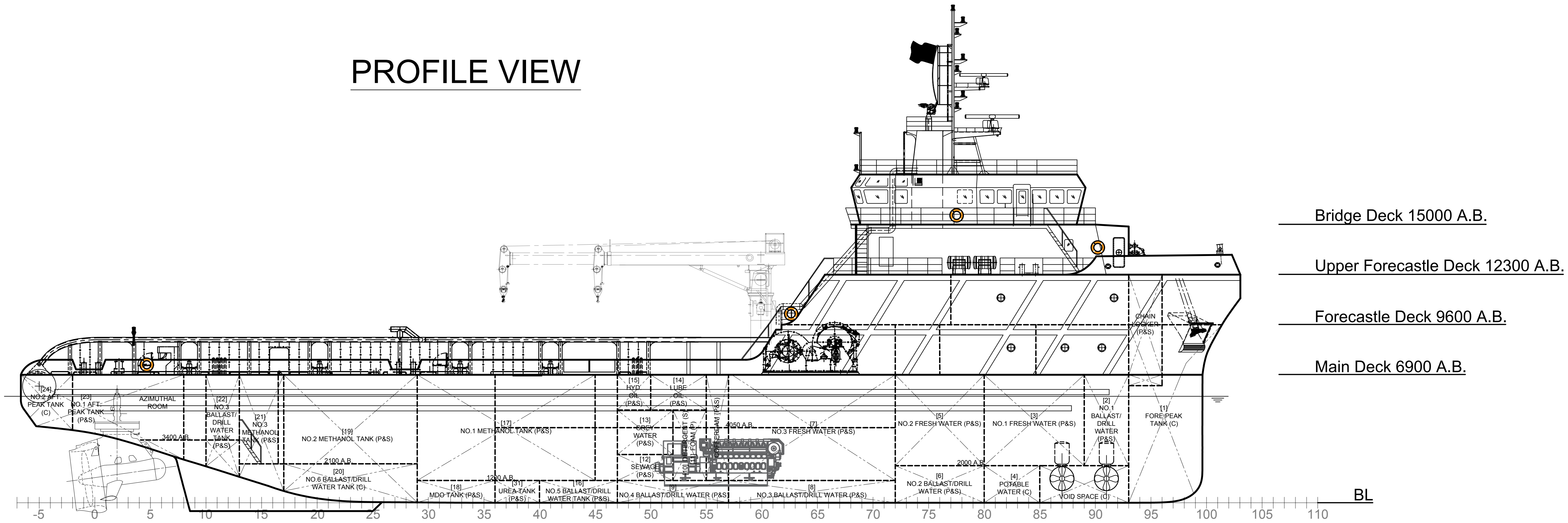
Vessel: 75-TON BP GREEN POWERED AHTS

Classification: ✠ A1, Offshore Support Vessel (AH, Supply, Tow, FFV 1, OSP-S1), Methanol Fuel Ready, HYBRID [SCN], BWT, ✠ DPS-2, ECG-SCR

Revision N°:	Size:	Sheet:	Dwg N°
12	A3	01/01	AHTS75 - LP - 12

Date Issued: 03 June 2025

PROFILE VIEW



Methanol Tank		SG*Fill Ratio= 0.79*98%				
N° Tank	Name	Volume (m^3)	LCG (m)	VCG (m)	XG (m)	Capacity (MT)
17	NO.1 Methanol Tk (P)	184.25	22.21	3.99	-6.34	142.65
	NO.1 Methanol Tk (S)	184.25	22.21	3.99	6.34	142.65
19	NO.2 Methanol Tk (P)	98.70	14.07	3.61	-6.27	76.42
	NO.2 Methanol Tk (S)	98.70	14.07	3.61	6.27	76.42
21	NO.3 Methanol Tk (P)	80.52	9.03	4.54	-4.06	62.34
	NO.3 Methanol Tk (S)	80.52	9.03	4.54	4.06	62.34
Total		726.96				563.00

Diesel Oil Tank		SG*Fill Ratio= 0.84*98%				
N° Tank	Name	Volume (m^3)	LCG (m)	VCG (m)	XG (m)	Capacity (MT)
18	MDO Tk (P)	22.21	19.70	0.69	-4.50	18.28
	MDO Tk (S)	22.21	19.70	0.69	4.50	18.28
Total		44.42				36.57

Lubricant Oil Tank		SG*Fill Ratio= 0.92*98%				
N° Tank	Name	Volume (m^3)	LCG (m)	VCG (m)	XG (m)	Capacity (MT)
14	Lube Oil (P)	8.60	31.50	5.92	-7.27	7.75
	Lube Oil (S)	8.60	31.50	5.92	7.27	7.75
15	Hydraulic Oil (P)	7.59	27.60	5.92	-6.34	6.84
	Hydraulic Oil (S)	5.16	29.10	5.92	7.27	4.65
Total		29.95				27.00

Miscellaneous Tank		SG*Fill Ratio= Variable				
N° Tank	Name	Volume (m^3)	LCG (m)	VCG (m)	XG (m)	Capacity (MT)
10	Detergent	10.47	32.10	3.10	-7.27	10.47
11	Foam	10.47	32.10	3.10	7.27	10.47
12	Sewage (P)	6.99	30.60	3.10	-7.27	6.29
	Sewage (S)	6.43	29.70	1.90	7.27	5.79
13	Grey Water (P)	15.43	27.60	3.10	-6.34	15.43
	Grey Water (S)	11.04	29.70	3.80	7.27	11.04
28	Dirty Oil Tk	11.28	22.80	0.59	0.00	11.28
29	Bilge Water Tk	9.95	19.51	0.61	-1.00	8.36
30	Sludge Tk	9.95	19.51	0.61	1.00	24.89
31	Urea Tk (P)	15.83	22.81	0.62	-4.83	17.42
	Urea Tk (S)	15.83	22.81	0.62	4.83	17.42
Total		123.69				138.85

Cement		SG*Fill Ratio= 1.38*100%				
N° Tank	Name	Volume (m^3)	LCG (m)	VCG (m)	XG (m)	Capacity (MT)
24	NO.1 Dry Bulk Tk (P)	51.54	45.59	4.27	-3.30	71.12
	NO.1 Dry Bulk Tk (S)	51.54	45.59	4.27	3.30	71.12
25	NO.2 Dry Bulk Tk (P)	62.92	19.53	3.87	-2.78	86.83
	NO.2 Dry Bulk Tk (S)	62.92	19.53	3.87	2.78	86.83
Total		228.91				315.89

Mud Tank		SG*Fill Ratio= 2.5*100%				
N° Tank	Name	Volume (m^3)	LCG (m)	VCG (m)	XG (m)	Capacity (MT)
26	Mud Tk (P)	173.24	13.86	4.64	-3.26	433.11
	Mud Tk (S)	173.24	13.86	4.64	3.26	433.11
Total		346.49				866.21

NOTES:
- SG: Specific density (MT/m^3)
- LCG at #0 (+) FORWARD, (-) AFTER
- XG: (+) TO STB (-) TO PORT

	Name:	Date:
Drawn by:	PG	07 May 2025
Checked by:	MS	01 Jun 2025
Approved by:	BH	02 Jun 2025

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UNIVERSIDAD TECNOLÓGICA NACIONAL
FACULTAD REGIONAL BUENOS AIRES

Scale: 1:250

Drawing:

ANNEX D: CAPACITY PLAN

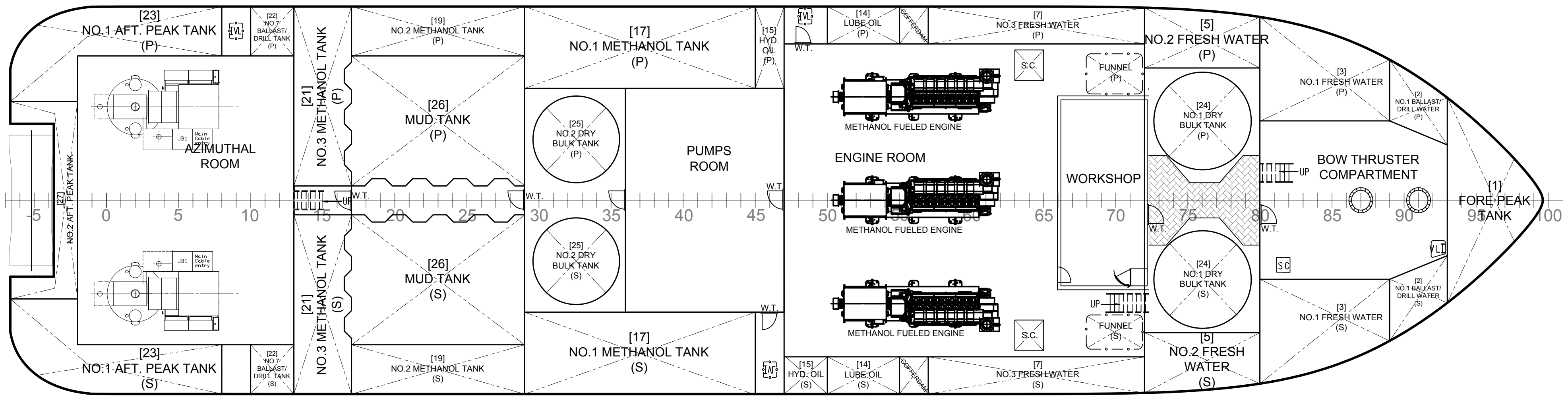
Vessel: 75-TON BP GREEN POWERED AHTS

Classification: ✠A1, Offshore Support Vessel (AH, Supply, Tow, FFV 1, OSP-S1), Methanol Fuel Ready, HYBRID [SCN], BWT, ✠DPS-2, ECG-SCR

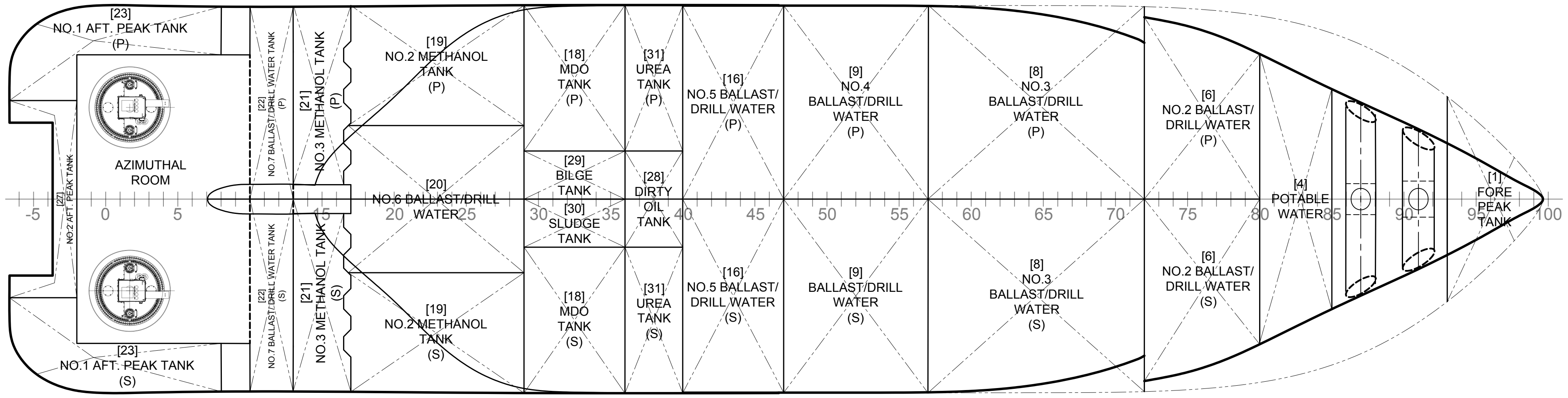
Revision N°:	Size:	Sheet:	Dwg N°
08	A3	01/03	AHTS75 - CP - 08

Date Issued: 03 Jun 2025

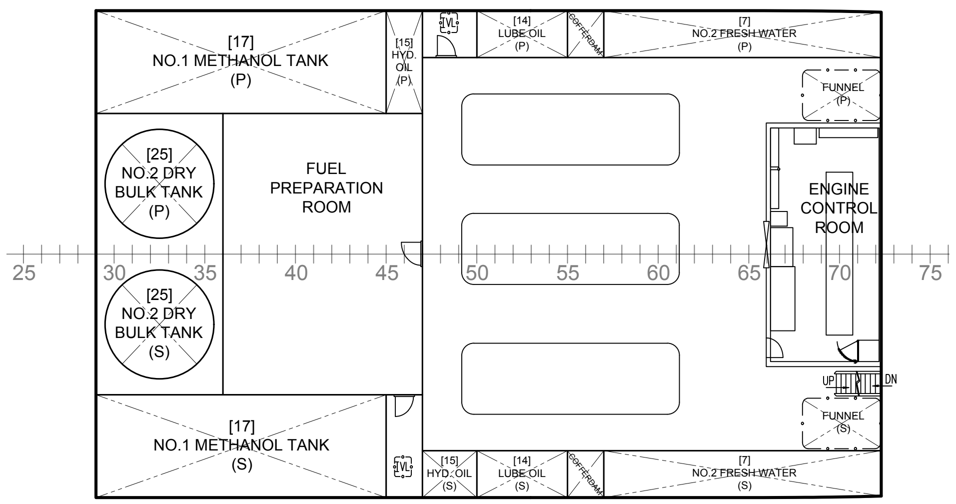
BELOW DECK - 6900 A.B.



LOWER DECK - 1200 A.B.



TWEEN DECK - 4050 A.B.



Ballast/Drill Water Tank		SG*Fill Ratio= 1.025*100%				
N° Tank	Name	Volume (m^3)	LCG (m)	VCG (m)	XG (m)	Capacity (MT)
1	Fore Peak Tk	168.63	57.63	5.95	0.00	172.84
2	NO.1 Ballast/Drill Water Tk (P)	20.16	54.55	5.05	-3.86	20.66
	NO.1 Ballast/Drill Water Tk (S)	20.16	54.55	5.05	3.86	20.66
6	NO.2 Ballast/Drill Water Tk (P)	39.26	45.43	1.24	-2.43	40.24
	NO.2 Ballast/Drill Water Tk (S)	39.26	45.43	1.24	2.43	40.24
8	NO.3 Ballast/Drill Water Tk (P)	58.68	38.25	0.69	-3.03	60.14
	NO.3 Ballast/Drill Water Tk (S)	58.68	38.25	0.69	3.03	60.14
9	NO.4 Ballast/Drill Water Tk (P)	53.23	31.16	0.64	-3.77	54.56
	NO.4 Ballast/Drill Water Tk (S)	53.23	31.16	0.64	3.77	54.56
16	NO.5 Ballast/Dirll Water Tk (P)	54.40	25.14	0.63	-4.15	55.76
	NO.5 Ballast/Dirll Water Tk (S)	54.40	25.14	0.63	4.15	55.76
20	NO.6 Ballast/Drill Water	70.93	14.21	1.25	0.00	72.70
22	NO.7 Ballast/Drill Water (P)	18.00	6.92	4.45	-5.58	18.45
	NO.7 Ballast/Drill Water (S)	18.00	6.92	4.45	5.58	18.45
23	NO.1 After Peak Tk (P)	43.64	0.36	5.85	-6.53	44.73
	NO.1 After Peak Tk (S)	43.64	0.36	5.85	6.53	44.73
27	NO.2 After Peak Tk	32.66	-2.16	5.65	0.00	33.47
Total		846.93				868.10

Fresh Water Tanks		SG*Fill Ratio= 1*100%				
N° Tank	Name	Volume (m^3)	LCG (m)	VCG (m)	XG (m)	Capacity (MT)
3	NO.1 Fresh Water Tk (P)	79.50	50.40	4.75	-4.96	79.50
	NO.1 Fresh Water Tk (S)	79.50	50.40	4.75	4.96	79.50
5	NO.2 Fresh Water Tk (P)	48.73	45.48	4.62	-6.58	48.73
	NO.2 Fresh Water Tk (S)	48.73	45.48	4.62	6.58	48.73
7	NO.3 Fresh Water Tk (P)	73.21	38.54	4.16	-7.23	73.21
	NO.3 Fresh Water Tk (S)	73.21	38.54	4.16	7.23	73.21
4	Potable Water Tk	23.42	48.97	1.26	0.00	23.42
Total		426.30				426.30

NOTES:
- SG: Specific density (MT/m^3)
- LCG at #0 (+) FORWARD, (-) AFTER
- XG: (+) TO STB (-) TO PORT

	Name:	Date:
Drawn by:	PG	07 May 2025
Checked by:	MS	01 Jun 2025
Approved by:	BH	02 Jun 2025

UTN.BA
UNIVERSIDAD TECNOLÓGICA NACIONAL
FACULTAD REGIONAL BUENOS AIRES

Scale: 1:250

Drawing: ANNEX D: CAPACITY PLAN

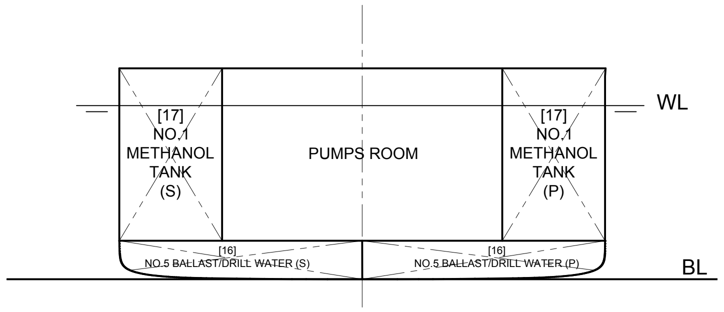
Vessel: 75-TON BP GREEN POWERED AHTS

Classification: ✠A1, Offshore Support Vessel (AH, Supply, Tow, FFV 1, OSP-S1), Methanol Fuel Ready, HYBRID [SCN], BWT, ✠DPS-2, ECG-SCR

Revision N°: 08 | Size: A3 | Sheet: 02/03

Dwg N° AHTS75 - CP - 08

Date Issued: 03 Jun 2025



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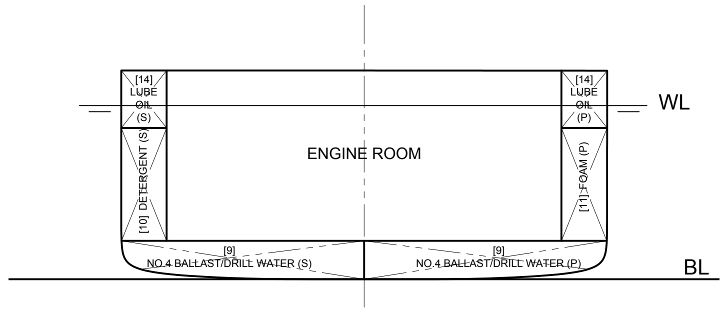

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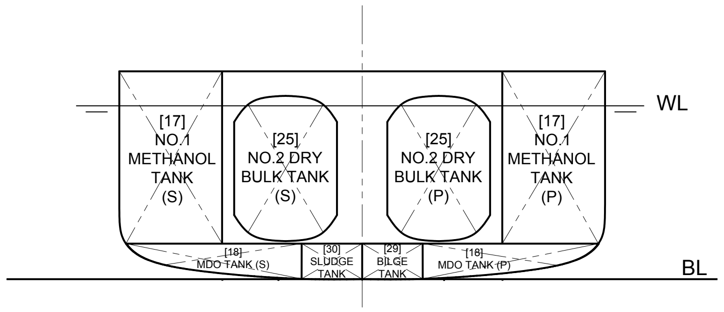

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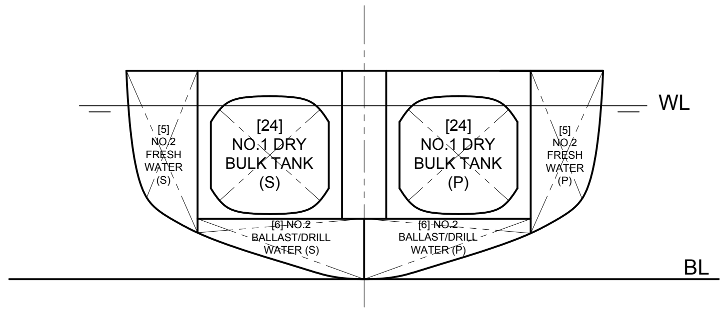

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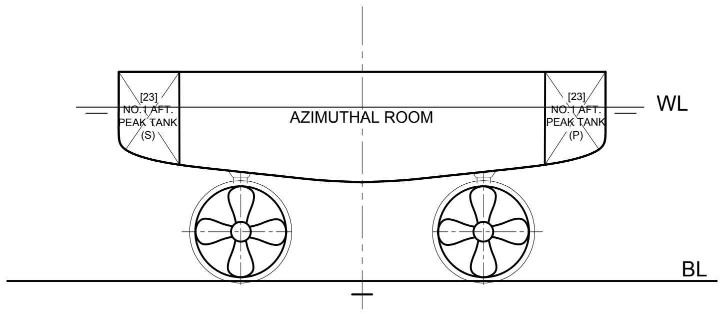

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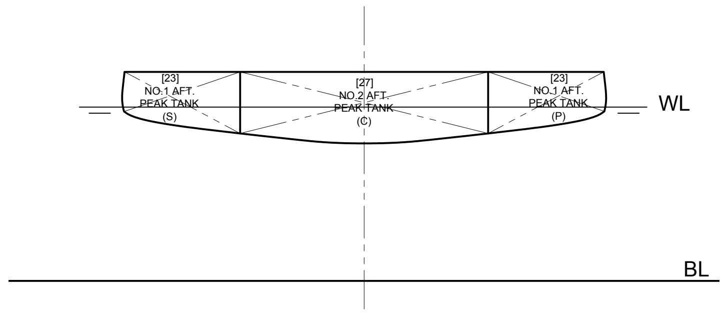


FR.-3

	Name:	Date:
Drawn by:	PG	07 May 2025
Checked by:	MS	01 Jun 2025
Approved by:	BH	02 Jun 2025

UNIVERSIDAD TECNOLÓGICA NACIONAL
FACULTAD REGIONAL BUENOS AIRES

Scale: 1:250

Drawing: ANNEX D: CAPACITY PLAN

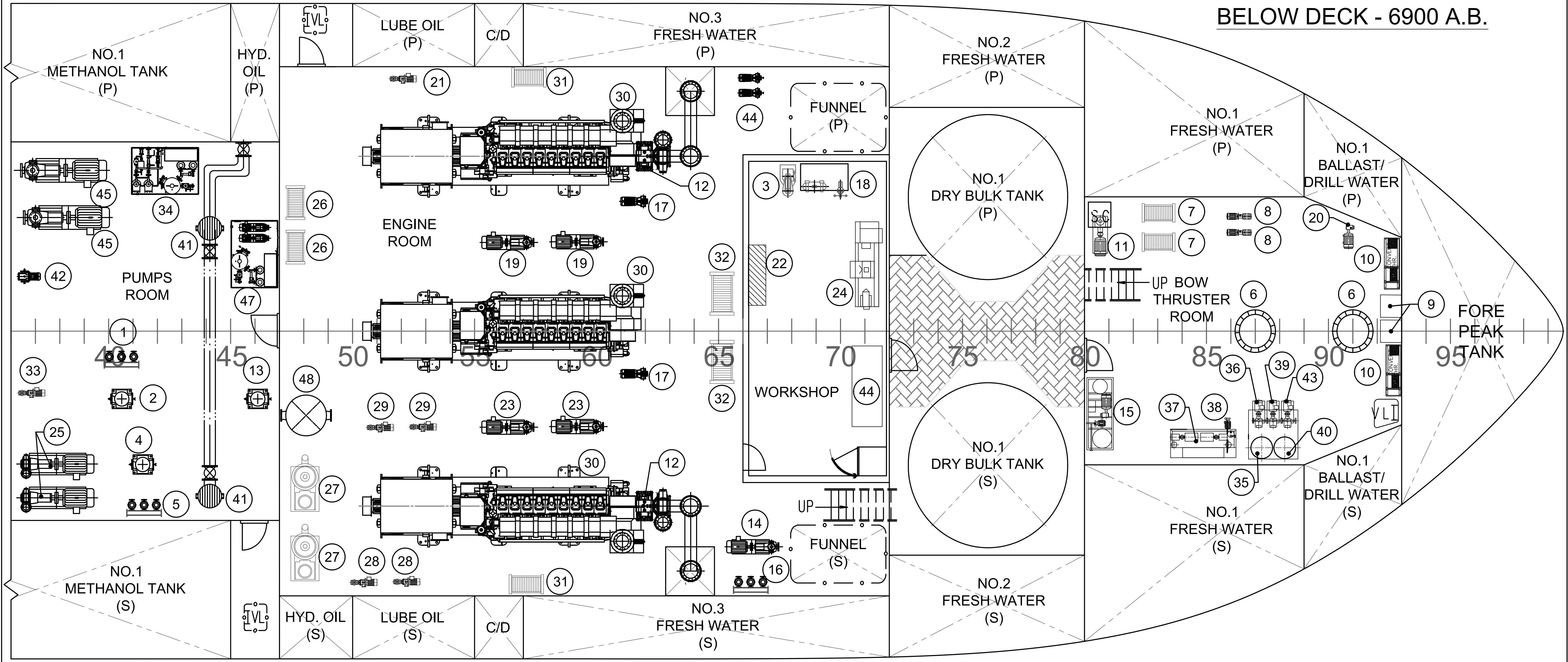
Vessel: 75-TON BP GREEN POWERED AHTS

Classification: ✠ A1, Offshore Support Vessel (AH, Supply, Tow, FFV 1, OSP-S1), Methanol Fuel Ready, HYBRID [SCN], BWT, ✠DPS-2, ECG-SCR

Revision N°:	Size:	Sheet:
08	A3	03/03

Dwg N° AHTS75 - CP - 08

Date Issued: 03 Jun 2025



N°	DESCRIPTION	QTY.	SUPPLIER	TYPE	CAPACITY
1	BALLAST/DRILL WATER MANIFOLD	1			-
2	BALLAST/DRILL WATER PUMP	1	AZCUE		75 M^3/HR @ 5 BAR
3	BENCH DRILL PRESS	1			-
4	BILGE & FIRE PUMP	1	AZCUE		75 M^3/HR @ 5 BAR
5	BILGE MANIFOLD	1			-
6	BOW THRUSTER	2	WÄRTSILÄ	CT/FT125H	600 KW Ø1250 mm
7	BOW THRUSTER COOLER	2	WÄRTSILÄ		
8	BOW THRUSTER COOLING PUMP	2	ACUE	MO11/20	1.1 M^3/HR 2.5 BAR
9	BOW THRUSTER HYDRAULIC POWER UNIT	2	WÄRTSILÄ		
10	CONVERTER BOW THRUSTER	2			-
11	EMERGENCY FIRE PUMP	1	AZCUE	CA-80/20-A	35 M^3/HR 5 BAR
12	FIFI PUMP	2	FFS	SFP 250x350xXP	1850 M^3/HR @166 M
13	FIRE & GRAL SERVICES PUMP	1	AZCUE		75 M^3/HR @ 5 BAR
14	FRESH WATER CARGO PUMP	1	AZCUE	CM-EP 80/20R	75 M^3/HR @ 40 MHD
15	FRESH WATER GENERATOR	1	TECNICOMAR	SW 1.5T	5500 LTS/DAY
16	FRESH WATER MANIFOLD	1			-
17	GENSET LO. STAND BY PUMP	2	AZCUE	BT-LV 90T	50 M^3/HR @ 8 BAR
18	GRINDER AND BENCH VISE	1			-
19	H.T. FW COOLING PUMP	2	SHINKO IND LTD	SVA150	120 M^3/HR @ 4 BAR
20	HOT WATER CIRCULATION PUMP	1	JIANGSU TAIXING		1.8 M^3/HR - 4 BAR
21	HYDRAULIC POWER UNIT COOLING PUMP	1	AZCUE		60 M^3/HR @ 2.2 BAR
22	INJECTOR TEST BENCH	1			-
23	L.T. FW COOLING PUMP	2	SHINKO IND LTD	SVA150	200 M^3/HR @ 4 BAR
24	LATHE MACHINE	1			-
25	LIQUID MUD PUMP	2	ALLWEILER	MAGNUM 4x3x13	75 M^3/HR @ 18 BAR
26	LO HEATING	2	MIT	BYS14.5	20 kW/HR
27	LO PURIFIER	2	ALFA LAVAL	P605	800 LTS/HR
28	LO PURIFIER PUMP	2	GORIO	GLC3	2.5 M^3/HR @ 6 BAR
29	LO TRANSFER PUMPS	2	GORIO	GLG5	4 M^3/HR @ 6 BAR
30	MAIN GENSET	3	WÄRTSILÄ	9L20 METHANOL	1900 kW
31	MAIN GENSET CENTRAL COOLER	2	ALFA LAVAL	M15-BFM	200 M^3/HR

N°	DESCRIPTION	QTY.	SUPPLIER	TYPE	CAPACITY
32	MAIN GENSET HT. COOLER	2	ALFA LAVAL		
33	MDO TRANSFER PUMP	1	AZCUE	IL52DS	10 M^3/HR @ 2 BAR
34	OILY WATER SEPARATOR	1	VICTOR MARINE	CS3000	3 M^3/HR
35	POTABLE WATER HYDROPNEUMATIC TANK	1	ARRONA		300 LTS @ 3.5 BAR
36	POTABLE WATER PUMP	1	AZCUE	MO1920	2 M^3/HR @ 3.5 BAR
37	REFEGER PLANT CONDENSER	2	TAIXING SHIP GEARS WORK	CZL-3	4 kW
38	REFEGER PLANT COOLING PUMP	1	AZCUE	CA-50-2A	3 M^3/HR @ 2.2 BAR
39	SANITART PUMP	1	AZCUE	MO1920	2 M^3/HR @ 3.5 BAR
40	SANITY WATER HYDROPNEUMATIC TANK	1	ARRONA		300 Lts @ 3.5 BAR
41	SEA WATER STRAINER	2	JINBO MARINE	CB/T497-94A	
42	SLUDGE/DIRTY OIL PUMP	1	ALFA LAVAL	3S-0042	2.9 M^3/HR @ 4 BAR
43	STAND BY SANITARY/FRESH WATER PUMP	1	AZCUE	MO1920	2 M^3/HR @ 3.5 BAR
44	SW COOLING DRY BULK SYSTEM PUMP	2	AZCUE	CA-50-3	8 M^3/HR - 3 BAR
45	SW COOLING PUMP	2	SHINKO IND LTD	SVA200	400 M^3/HR @ 4 BAR
46	WORKBENCH	1			-
47	BALLAST WATER MANAGEMENT SYSTEM	1	COMPACTCLEAN OPTIMO		
48	UREA DAILY TANK	1			25 LTS

PRINCIPAL DIMENSIONS

LENGTH, OVERALL . . . . 66.30 m
LENGTH, BETWEEN PERPENDICULARS . . . . 57.80 m
LENGTH, WATERLINE . . . . 64.13 m
BEAM, MOULDED . . . . 16.10 m
DEPTH, MOULDED . . . . 6.90 m
DESIGN DRAFT . . . . 5.74 m
DESIGN FREEBOARD . . . . 1.16 m

	Name:	Date:
Drawn by:	BH	01 Jun 2025
Checked by:	MS	02 Jun 2025
Approved by:	PG	02 Jun 2025

UNIVERSIDAD TECNOLÓGICA NACIONAL
FACULTAD REGIONAL BUENOS AIRES

Scale: 1:100

Drawing:
ANNEX E: ENGINE ROOM ARRANGEMENT

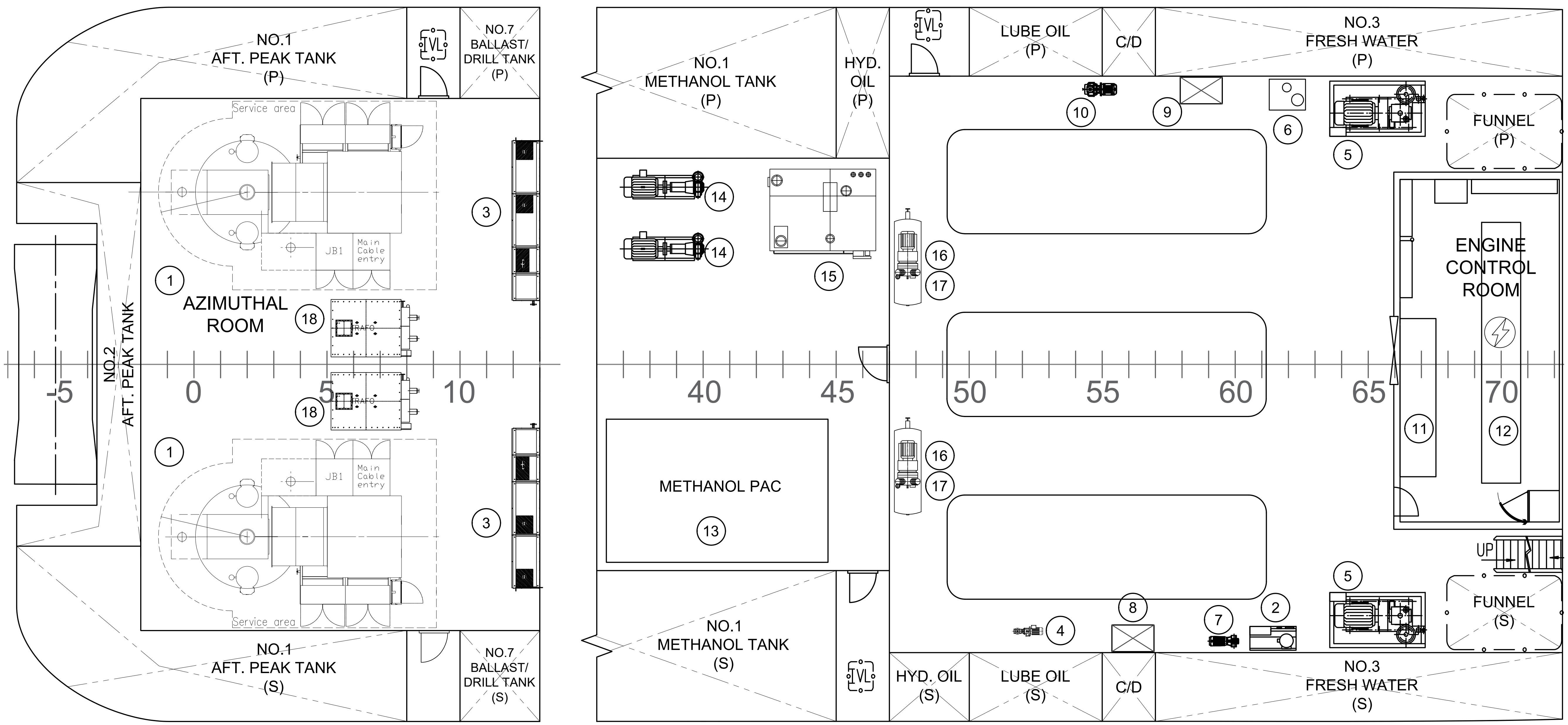
Vessel: 75-TON BP GREEN POWERED AHTS

Classification: ✠ A1, Offshore Support Vessel (AH, Supply, Tow, FFV 1, OSP-S1), Methanol Fuel Ready, HYBRID [SCN], BWT, ✠ DPS-2, ECG-SCR

Revision N°: 04
Size: A3
Sheet: 01/02
Dwg N° AHTS75 - ERA - 04
Date Issued: 03 Jun 2025

AZIMUTHAL ROOM - 6900 A.B.

TWEEN DECK - 4050 A.B.



PRINCIPAL DIMENSIONS

LENGTH, OVERALL . . . . 66.30 m
LENGTH, BETWEEN PERPENDICULARS . . . . 57.80 m
LENGTH, WATERLINE . . . . 64.13 m
BEAM, MOULDED . . . . 16.10 m
DEPTH, MOULDED . . . . 6.90 m
DESIGN DRAFT . . . . 5.74 m
DESIGN FREEBOARD . . . . 1.16 m

N°	DESCRIPTION	QTY.	SUPPLIER	TYPE	CAPACITY
1	AZIPODS	2	ABB	DZ1100A	Ø3000 mm - 2500 kW
2	CONTROL ROOM A/C CONDENSING UNIT	1	VIKING	FFS 1200LB	19 kW
3	CONVERTER AZIPOD	2			-
4	DISPERSANT PUMP	1	ALLWEILER	SOHB113 G11T W	$2M^3$/HR @6.5 BAR
5	DRY BULK AIR COMPRESSORS	2	ATLAS COPCO	GA200-75	5.5 BAR
6	DRY BULK AIR DRYER	2	ATLAS COPCO	ND 300A	300 LTS/S
7	ENGINE ROOM AC COOLING PUMP	1	VIKING	FFS1200LB	
8	EXPANSION TANK HT. MAIN GENSET	1			-
9	EXPANSION TANK LT. MAIN GENSET	1			-
10	HYDRAULIC OIL TRANSFER PUMP	1	ALLWEILER	SPF 10 R38 G8.3	$1M^3$/HR @ 2BAR
11	MAIN CONSOLE	1			-
12	MAIN SWITCHBOARD	1			-
13	METHANOL PAC	1	WÄRTSILÄ		
14	MUD RECIRCULATION PUMPS	2	ALLWEILER	MAGNUM 3x2x13	$50M^3$/HR @ 3BAR
15	SEWAGE TREATMENT PLANT	1	JIANGSU TAIXING		WCB-50(S)
16	STARTING AIR COMPRESSOR	2	SPERRE	HL2/90	
17	STARTING AIR RECEIVER	2			2X200LTS @ 30 BAR
18	TRANSFORMER	2			-

	Name:	Date:
Drawn by:	BH	01 Jun 2025
Checked by:	MS	01 Jun 2025
Approved by:	PG	02 Jun 2025

UTN.BA
UNIVERSIDAD TECNOLÓGICA NACIONAL
FACULTAD REGIONAL BUENOS AIRES

Scale: 1:100

Drawing: ANNEX E: ENGINE ROOM ARRANGEMENT

Vessel: 75-TON BP GREEN POWERED AHTS

Classification: ✠ A1, Offshore Support Vessel (AH, Supply, Tow, FFV 1, OSP-S1), Methanol Fuel Ready, HYBRID [SCN], BWT, ✠ DPS-2, ECG-SCR

Revision N°:	Size:	Sheet:
04	A3	02/02

Dwg N° AHTS75 - ERA - 04

Date Issued: 03 June 2025

ANNEX F: ELECTRIC LOAD BALANCE

N°	List of Loads / Groups	Units Installed	Unitary Power	Total Installed Power	Unit Service	Total Power in Service	NAVITAGION AT SERVICE SPEED									
							DAY					NIGHT				
			kW	kW		kW	FL	FSI	FSE	F	Kw	FL	FSI	FSE	F	Kw
	Electric Propulsion															
1	Main electric Propellers	2.00	2500.00	5000.00	2.00	5000.00	0.62	1.00	1.00	0.62	3100	0.62	1.00	1.00	0.62	3100.00
2	Bow Thrusters	2.00	600.00	1200.00	1.00	600.00	0.70	0.50	0.00	0.00	0.00	0.70	0.50	0.00	0.00	0.00
	Subtotal			6200.00		5600.00					3100.00					3100.00
	Propulsion service															
3	H.T. FW Cooling pump	2.00	22.00	44.00	1.00	22.00	0.95	0.50	0.70	0.33	7.32	0.95	0.50	0.70	0.33	7.32
4	L.T. FW Cooling pump	2.00	45.00	90.00	1.00	45.00	0.95	0.50	0.70	0.33	14.96	0.95	0.50	0.70	0.33	14.96
5	GENSET LO. Stand by pump	2.00	12.00	24.00	1.00	12.00	0.95	0.50	0.90	0.43	5.13	0.95	0.50	0.90	0.43	5.13
6	Lub oil purifiers	2.00	10.00	20.00	1.00	10.00	0.95	0.50	0.90	0.43	4.28	0.95	0.50	0.90	0.43	4.28
7	Transfer pumps	2.00	3.00	6.00	2.00	6.00	0.95	1.00	0.90	0.86	5.13	0.95	1.00	0.90	0.86	5.13
8	LO transfer pumps	2.00	5.50	11.00	1.00	5.50	0.95	0.50	0.10	0.05	0.26	0.95	0.50	0.10	0.05	0.26
9	Bow Thruster cooling pump	2.00	5.00	10.00	2.00	10.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00
10	Bow Thruster hydraulic power unit	2.00	10.00	20.00	2.00	20.00	0.80	1.00	0.00	0.00	0.00	0.80	1.00	0.00	0.00	0.00
11	SW Cooling pump	2.00	80.00	160.00	1.00	80.00	0.95	0.50	0.70	0.33	26.60	0.95	0.50	0.70	0.33	26.60
12	MethanolPac	1.00	300.00	300.00	1.00	300.00	0.75	1.00	0.90	0.68	202.50	0.75	1.00	0.90	0.68	202.50
	Subtotal			178		89					266.17					266.17
	FIFI AND OIL RECOVERY SYSTEM:															
13	FIFI Pumps	2.00	60.00	120.00	2.00	120.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
14	Oil dispersant system	1.00	5.00	5.00	1.00	5.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
15	FIFI monitors	2.00	50.00	100.00	2.00	100.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
	Subtotal			225.00		225.00					0.00					0.00
	Pumps & Equipment (As per class)															
16	Bilge & fire pump	2.00	30.00	60.00	1.00	30.00	0.95	0.50	0.30	0.14	4.28	0.95	0.50	0.30	0.14	4.28
17	Hot Water Circulating Pump	1.00	2.00	2.00	1.00	2.00	0.95	1.00	0.80	0.76	1.52	0.95	1.00	0.80	0.76	1.52
18	Fresh Water Cargo Pumps	1.00	30.00	30.00	1.00	30.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
19	Drill Water / Ballast Pump	1.00	30.00	30.00	1.00	30.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
20	Liquid Mud Pump	2.00	50.00	100.00	1.00	50.00	0.50	0.50	0.50	0.13	6.25	0.50	0.50	0.50	0.13	6.25
21	Dry bulk air compressors	2.00	220.00	440.00	1.00	220.00	0.90	0.50	0.10	0.05	9.90	0.90	0.50	0.10	0.05	9.90
22	Dry bulk air dryer	2.00	60.00	120.00	1.00	60.00	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.00	0.00	0.00
23	Fresh Water Pressure Set	2.00	5.00	10.00	1.00	5.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00
24	Sea Water Pressure Set	2.00	5.00	10.00	1.00	5.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00
25	Dirty Oil Pump	2.00	5.00	10.00	1.00	5.00	0.95	0.50	0.30	0.14	0.71	0.95	0.50	0.30	0.14	0.71
26	Oily water separator	1.00	1.20	1.20	1.00	1.20	0.95	1.00	0.80	0.76	0.91	0.95	1.00	0.80	0.76	0.91
27	Mud recirculation pumps	2.00	20.00	40.00	1.00	20.00	0.90	0.50	0.40	0.18	3.60	0.90	0.50	0.40	0.18	3.60
28	Hydraulic oil transfer pump	1.00	1.50	1.50	1.00	1.50	0.90	1.00	0.10	0.09	0.14	0.90	1.00	0.10	0.09	0.14
29	Dispersant pump	1.00	5.50	5.50	1.00	5.50	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
30	Fire & general services pump	1.00	2.00	2.00	1.00	2.00	0.95	1.00	0.20	0.19	0.38	0.95	1.00	0.20	0.19	0.38
31	Engine room ac cooling pump	1.00	2.00	2.00	1.00	2.00	0.95	1.00	0.30	0.29	0.57	0.95	1.00	0.30	0.29	0.57
32	LO heating	2.00	20.00	40.00	1.00	20.00	0.85	0.50	0.20	0.09	1.70	0.85	0.50	0.20	0.09	1.70
33	LO purifier	2.00	5.00	10.00	1.00	5.00	0.85	0.50	0.20	0.09	0.43	0.85	0.50	0.20	0.09	0.43
34	Hydraulic power unit cooling pump	1.00	7.50	7.50	1.00	7.50	0.90	1.00	0.50	0.45	3.38	0.90	1.00	0.50	0.45	3.38
35	SW cooling dry bulk system pump	2.00	5.00	10.00	1.00	5.00	0.95	0.50	0.20	0.10	0.48	0.95	0.50	0.20	0.10	0.48
	Subtotal			812.00		437.00					30.38					30.38
	Deck, Towing / Anchor-handling & Mooring Equipment															
36	Anchor Windlass	2.00	38.00	76.00	2.00	76.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
37	Anchor / Towing Winch	1.00	215.00	215.00	1.00	215.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
38	Capstans	2.00	20.00	40.00	2.00	40.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
39	Tugger Winch	2.00	30.00	60.00	2.00	60.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
40	Shark Jaw	1.00	20.00	20.00	1.00	20.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
41	Towing Pins	2.00	10.00	20.00	1.00	10.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00
42	Lifeboat davit	2.00	65.00	130.00	1.00	65.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00
43	Deck crane	1.00	25.00	25.00	1.00	25.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
	Subtotal			586.00		511.00					0.00					0.00
	Gallery / Provision Rooms:															
44	Gallery general	1.00	70.00	70.00	1.00	70.00	0.90	1.00	0.65	0.59	40.95	0.90	1.00	0.65	0.59	40.95
45	Compressors of refrigerated provisions	3.00	13.00	39.00	2.00	26.00	0.90	0.67	0.70	0.42	10.92	0.90	0.67	0.70	0.42	10.92
46	Refeger plant cooling pump	1.00	1.50	1.50	2.00	3.00	0.95	2.00	0.40	0.76	2.28	0.95	2.00	0.40	0.76	2.28
47	Kitchen	1.00	50.00	50.00	1.00	50.00	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.60	0.54	27.00
48	General Bars	1.00	35.00	35.00	1.00	35.00	0.90	1.00	0.50	0.45	15.75	0.90	1.00	0.50	0.45	15.75
49	General Laundry	1.00	25.00	25.00	1.00	25.00	0.90	1.00	0.40	0.36	9.00	0.90	1.00	0.40	0.36	9.00
	Subtotal			220.50		209.00					105.90					105.90
	Lighting															
50	Navigation lights	1.00	8.00	8.00	1.00	8.00	0.95	1.00	1.00	0.95	7.60	0.95	1.00	1.00	0.95	7.60
51	Interior lighting	1.00	6.00	6.00	1.00	6.00	0.95	1.00	0.65	0.62	3.71	0.95	1.00	0.80	0.76	4.56
52	Outside lighting	1.00	20.00	20.00	1.00	20.00	0.95	1.00	0.10	0.10	1.90	0.95	1.00	1.00	0.95	19.00
	Subtotal			34.00		34.00					13.21					31.16
	Emergency Load															
53	Engine room ventilation fan	3.00	5.50	16.50	3.00	16.50	0.85	1.00	0.90	0.77	12.62	0.85	1.00	0.90	0.77	12.62
54	Emergency genset supply fan	2.00	2.00	4.00	2.00	4.00	0.85	1.00	0.70	0.60	2.38	0.85	1.00	0.70	0.60	2.38
55	Emergency lightning	1.00	2.40	2.40	1.00	2.40	0.90	1.00	0.70	0.63	1.51	0.90	1.00	0.70	0.63	1.51
56	Radio system	1.00	3.00	3.00	1.00	3.00	0.90	1.00	1.00	0.90	2.70	0.90	1.00	1.00	0.90	2.70
57	Navigation aids equipment	1.00	3.40	3.40	1.00	3.40	0.90	1.00	1.00	0.90	3.06	0.90	1.00	1.00	0.90	3.06
58	Communication equipment	1.00	4.50	4.50	1.00	4.50	0.90	1.00	1.00	0.90	4.05	0.90	1.00	1.00	0.90	4.05
59	Emergency genset services	1.00	16.00	16.00	1.00	16.00	0.85	1.00	0.10	0.09	1.36	0.85	1.00	0.10	0.09	1.36
60	Supply power for control equipment	1.00	8.00	8.00	1.00	8.00	0.75	1.00	1.00	0.75	6.00	0.75	1.00	1.00	0.75	6.00
61	emergency fire pump	1.00	15.00	15.00	1.00	15.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00
62	Fire pump	2.00	18.50	37.00	2.00	37.00	0.95	1.00	0.80	0.76	28.12	0.95	1.00	0.80	0.76	28.12
63	Starting air compressor	2.00	25.00	50.00	1.00	25.00	0.95	0.50	0.20	0.10	2.38	0.95	0.50	0.20	0.10	2.38
64	Stand by sanitary/fresh water pump	1.00	2.20	2.20	1.00	2.20	0.90	1.00	0.20	0.18	0.40	0.90	1.00	0.20	0.18	0.40
	Subtotal			159.80		137.00					61.80					61.80
	Sanitary Services and Septic Services															
65	Fresh water generator	1.00	6.00	6.00	1.00	6.00	0.90	1.00	0.60	0.54	3.24	0.90	1.00	0.60	0.54	3.24
66	Fresh water heater	2.00	25.00	50.00	2.00	50.00	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.60	0.54	27.00
67	Hydrophore freshwater pump	3.00	7.00	21.00	2.00	14.00	0.90	0.67	0.70	0.42	5.88	0.90	0.67	0.70	0.42	5.88
68	Sewage treatment plant	1.00	5.20	5.20	1.00	5.20	0.80	1.00	0.80	0.64	3.33	0.80	1.00	0.80	0.64	3.33
69	Garbage system crushers	1.00	15.00	15.00	1.00	15.00	0.85	1.00	0.80	0.68	10.20	0.85	1.00	0.80	0.68	10.20
70	Ballast Water Management System	1.00	108.00	108.00	1.00	108.00	0.85	1.00	0.20	0.17	18.36	0.85	1.00	0.20	0.17	18.36
71	Solid waste incinerator	1.00	6.70	6.70	1.00	6.70	0.85	1.00	0.80	0.68	4.56	0.85	1.00	0.80	0.68	4.56
72	Sludge/dirty oil pump	1.00	6.70	6.70	1.00	6.70	0.90	1.00	0.60	0.54	3.62	0.90	1.00	0.60	0.54	3.62
73	Sanitary pump	1.00	2.20	2.20	1.00	2.20	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84
74	Potable water pump	1.00	2.20	2.20	1.00	2.20	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84
	Subtotal			223.00		211.60					76.18					76.18
	Other services															
75	Navigation instruments	1.00	12.00	12.00	1.00	12.00	0.85	1.00	0.90	0.77	9.18	0.85	1.00	0.90	0.77	9.18
76	Communications instruments	1.00	11.00	11.00	1.00	11.00	0.85	1.00	0.90	0.77	8.42	0.85	1.00	0.90	0.77	8.42
77	Cargo equipment	1.00	60.00	60.00	1.00	60.00	0.85	1.00	0.70	0.60	35.70	0.85	1.00	0.70	0.60	35.70
78	Workshop	1.00	65.00	65.00	1.00	65.00	0.50	1.00	0.40	0.20	13.00	0.50	1.00	0.40	0.20	13.00
	Subtotal			148.00		148.00					66.30					66.30
	Air-conditioning / Heating															
79	Air conditioning plant	1.00	80.00	80.00	1.00	80.00	0.95	1.00	0.50	0.48	38.00	0.95	1.00	0.50	0.48	38.00
80	Electric heating	1.00	50.00	50.00	1.00	50.00	0.95	1.00	0.50	0.48	23.75	0.95	1.00	0.50	0.48	23.75
	Subtotal			130.00		130.00					61.75					61.75
	Total			8916.30		7731.60					3781.69					3799.64

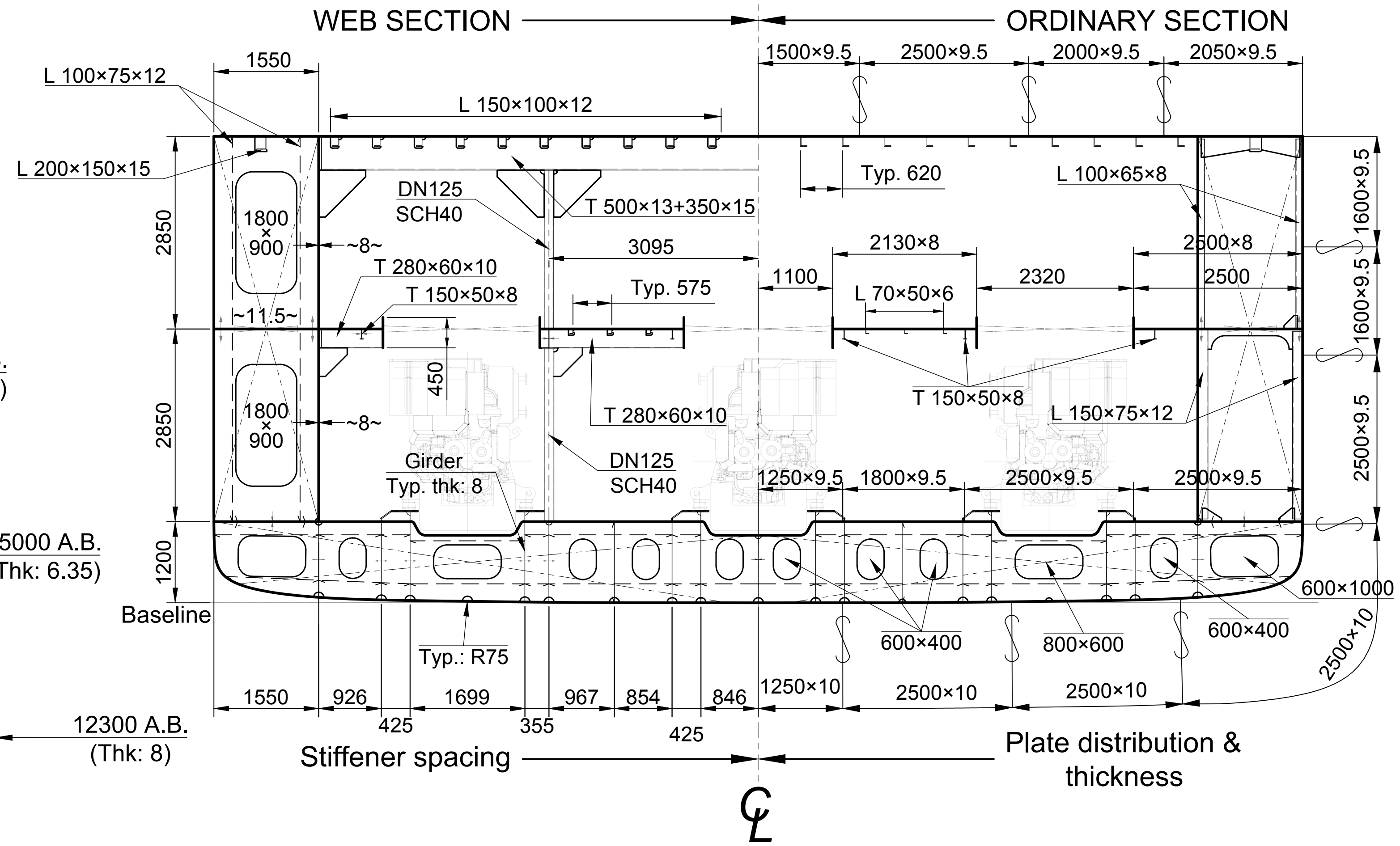
N°	List of Loads / Groups	HARBOR / ANCHORED										TOWING									
		DAY					NIGHT					DAY					NIGHT				
		FL	FSI	FSE	F	Kw	FL	FSI	FSE	F	Kw	FL	FSI	FSE	F	Kw	FL	FSI	FSE	F	Kw
	Electric Propulsion																				
1	Main electric Propellers	0.75	1.00	0.00	0.00	0.00	0.75	1.00	0.00	0.00	0.00	0.77	1.00	1.00	0.77	3850.00	0.77	1.00	1.00	0.77	3850.00
2	Bow Thrusters	0.70	0.50	0.00	0.00	0.00	0.70	0.50	0.00	0.00	0.00	0.85	0.50	0.40	0.17	102.00	0.85	0.50	0.40	0.17	102.00
	Subtotal					0.00					0.00					3952.00					3952.00
	Propulsion service																				
3	H.T. FW Cooling pump	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.50	0.24	5.23	0.95	0.50	0.50	0.24	5.23
4	L.T. FW Cooling pump	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.50	0.24	10.69	0.95	0.50	0.50	0.24	10.69
5	GENSET LO. Stand by pump	0.95	0.50	0.80	0.38	4.56	0.95	0.50	0.80	0.38	4.56	0.95	0.50	0.95	0.45	5.42	0.95	0.50	0.95	0.45	5.42
6	Lub oil purifiers	0.95	0.50	0.60	0.29	2.85	0.95	0.50	0.60	0.29	2.85	0.95	0.50	0.95	0.45	4.51	0.95	0.50	0.95	0.45	4.51
7	Transfer pumps	0.95	1.00	0.60	0.57	3.42	0.95	1.00	0.60	0.57	3.42	0.95	1.00	0.95	0.90	5.42	0.95	1.00	0.95	0.90	5.42
8	LO transfer pumps	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00
9	Bow Thruster cooling pump	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00
10	Bow Thruster hydraulic power unit	0.80	1.00	0.00	0.00	0.00	0.80	1.00	0.00	0.00	0.00	0.80	1.00	0.00	0.00	0.00	0.80	1.00	0.00	0.00	0.00
11	SW Cooling pump	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.50	0.24	19.00	0.95	0.50	0.50	0.24	19.00
12	MethanolPac	0.75	1.00	0.80	0.60	180.00	0.75	1.00	0.80	0.60	180.00	0.75	1.00	0.95	0.71	213.75	0.75	1.00	0.95	0.71	213.75
	Subtotal					190.83					190.83					264.01					264.01
	FIFI AND OIL RECOVERY SYSTEM:																				
13	FIFI Pumps	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
14	Oil dispersant system	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
15	FIFI monitors	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
	Subtotal					0.00					0.00					0.00					0.00
	Pumps & Equipment (As per class)																				
16	Bilge & fire pump	0.95	0.50	0.70	0.33	9.98	0.95	0.50	0.70	0.33	9.98	0.95	0.50	0.30	0.14	4.28	0.95	0.50	0.30	0.14	4.28
17	Hot Water Circulating Pump	0.95	1.00	0.80	0.76	1.52	0.95	1.00	0.80	0.76	1.52	0.95	1.00	0.80	0.76	1.52	0.95	1.00	0.80	0.76	1.52
18	Fresh Water Cargo Pumps	0.90	1.00	0.30	0.27	8.10	0.90	1.00	0.30	0.27	8.10	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
19	Drill Water / Ballast Pump	0.90	1.00	0.30	0.27	8.10	0.90	1.00	0.30	0.27	8.10	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
20	Liquid Mud Pump	0.50	0.50	0.40	0.10	5.00	0.50	0.50	0.40	0.10	5.00	0.50	0.50	0.50	0.13	6.25	0.50	0.50	0.50	0.13	6.25
21	Dry bulk air compressors	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00
22	Dry bulk air dryer	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.00	0.00	0.00
23	Fresh Water Pressure Set	0.90	0.50	0.20	0.09	0.45	0.90	0.50	0.20	0.09	0.45	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00
24	Sea Water Pressure Set	0.90	0.50	0.20	0.09	0.45	0.90	0.50	0.20	0.09	0.45	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00
25	Dirty Oil Pump	0.95	0.50	0.30	0.14	0.71	0.95	0.50	0.30	0.14	0.71	0.95	0.50	0.30	0.14	0.71	0.95	0.50	0.30	0.14	0.71
26	Oily water separator	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.30	0.29	0.34	0.95	1.00	0.30	0.29	0.34
27	Mud recirculation pumps	0.90	0.50	0.40	0.18	3.60	0.90	0.50	0.40	0.18	3.60	0.90	0.50	0.40	0.18	3.60	0.90	0.50	0.40	0.18	3.60
28	Hydraulic oil transfer pump	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.30	0.27	0.41	0.90	1.00	0.30	0.27	0.41
29	Dispersant pump	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
30	Fire & general services pump	0.95	1.00	0.20	0.19	0.38	0.95	1.00	0.20	0.19	0.38	0.95	1.00	0.20	0.19	0.38	0.95	1.00	0.20	0.19	0.38
31	Engine room ac cooling pump	0.95	1.00	0.30	0.29	0.57	0.95	1.00	0.30	0.29	0.57	0.95	1.00	0.40	0.38	0.76	0.95	1.00	0.40	0.38	0.76
32	LO heating	0.85	0.50	0.10	0.04	0.85	0.85	0.50	0.10	0.04	0.85	0.85	0.50	0.20	0.09	1.70	0.85	0.50	0.20	0.09	1.70
33	LO purifier	0.85	0.50	0.10	0.04	0.21	0.85	0.50	0.10	0.04	0.21	0.85	0.50	0.20	0.09	0.43	0.85	0.50	0.20	0.09	0.43
34	Hydraulic power unit cooling pump	0.90	1.00	0.20	0.18	1.35	0.90	1.00	0.20	0.18	1.35	0.90	1.00	0.30	0.27	2.03	0.90	1.00	0.30	0.27	2.03
35	SW cooling dry bulk system pump	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00
	Subtotal					39.92					39.92					20.37					20.37
	Deck, Towing / Anchor-handling & Mooring Equipment																				
36	Anchor Windlass	0.90	1.00	0.40	0.36	27.36	0.90	1.00	0.40	0.36	27.36	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
37	Anchor / Towing Winch	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
38	Capstans	0.90	1.00	0.20	0.18	7.20	0.90	1.00	0.20	0.18	7.20	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
39	Tugger Winch	0.90	1.00	0.30	0.27	16.20	0.90	1.00	0.30	0.27	16.20	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
40	Shark Jaw	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.50	0.45	9.00	0.90	1.00	0.50	0.45	9.00
41	Towing Pins	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.90	0.41	4.05	0.90	0.50	0.90	0.41	4.05
42	Lifeboat davit	0.90	0.50	0.10	0.05	2.93	0.90	0.50	0.10	0.05	2.93	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00
43	Deck crane	0.90	1.00	0.50	0.45	11.25	0.90	1.00	0.50	0.45	11.25	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
	Subtotal					64.94					64.94					13.05					13.05
	Gallery / Provision Rooms:																				
44	Gallery general	0.90	1.00	0.90	0.81	56.70	0.90	1.00	0.90	0.81	56.70	0.90	1.00	0.65	0.59	40.95	0.90	1.00	0.65	0.59	40.95
45	Compressors of refrigerated provisions	0.90	0.67	0.70	0.42	10.92	0.90	0.67	0.70	0.42	10.92	0.90	0.67	0.70	0.42	10.92	0.90	0.67	0.70	0.42	10.92
46	Refeger plant cooling pump	0.95	2.00	0.40	0.76	2.28	0.95	2.00	0.40	0.76	2.28	0.95	2.00	0.40	0.76	2.28	0.95	2.00	0.40	0.76	2.28
47	Kitchen	0.90	1.00	0.90	0.81	40.50	0.90	1.00	0.90	0.81	40.50	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.60	0.54	27.00
48	General Bars	0.90	1.00	0.90	0.81	28.35	0.90	1.00	0.90	0.81	28.35	0.90	1.00	0.50	0.45	15.75	0.90	1.00	0.50	0.45	15.75
49	General Laundry	0.90	1.00	0.80	0.72	18.00	0.90	1.00	0.80	0.72	18.00	0.90	1.00	0.40	0.36	9.00	0.90	1.00	0.40	0.36	9.00
	Subtotal					156.75					156.75					105.90					105.90
	Lighting																				
50	Navigation lights	0.95	1.00	1.00	0.95	7.60	0.95	1.00	1.00	0.95	7.60	0.95	1.00	1.00	0.95	7.60	0.95	1.00	1.00	0.95	7.60
51	Interior lighting	0.95	1.00	0.80	0.76	4.56	0.95	1.00	0.80	0.76	4.56	0.95	1.00	0.65	0.62	3.71	0.95	1.00	0.80	0.76	4.56
52	Outside lighting	0.95	1.00	0.10	0.10	1.90	0.95	1.00	1.00	0.95	19.00	0.95	1.00	0.10	0.10	1.90	0.95	1.00	1.00	0.95	19.00
	Subtotal					14.06					31.16					13.21					31.16
	Emergency Load																				
53	Engine room ventilation fan	0.85	1.00	0.80	0.68	11.22	0.85	1.00	0.80	0.68	11.22	0.85	1.00	0.90	0.77	12.62	0.85	1.00	0.90	0.77	12.62
54	Emergency genset supply fan	0.85	1.00	0.30	0.26	1.02	0.85	1.00	0.30	0.26	1.02	0.85	1.00	0.70	0.60	2.38	0.85	1.00	0.70	0.60	2.38
55	Emergency lightning	0.90	1.00	1.00	0.90	2.16	0.90	1.00	1.00	0.90	2.16	0.90	1.00	0.70	0.63	1.51	0.90	1.00	0.70	0.63	1.51
56	Radio system	0.90	1.00	0.80	0.72	2.16	0.90	1.00	0.80	0.72	2.16	0.90	1.00	1.00	0.90	2.70	0.90	1.00	1.00	0.90	2.70
57	Navigation aids equipment	0.90	1.00	0.80	0.72	2.45	0.90	1.00	0.80	0.72	2.45	0.90	1.00	1.00	0.90	3.06	0.90	1.00	1.00	0.90	3.06
58	Communication equipment	0.90	1.00	0.80	0.72	3.24	0.90	1.00	0.80	0.72	3.24	0.90	1.00	1.00	0.90	4.05	0.90	1.00	1.00	0.90	4.05
59	Emergency genset services	0.85	1.00	0.60	0.51	8.16	0.85	1.00	0.60	0.51	8.16	0.85	1.00	0.10	0.09	1.36	0.85	1.00	0.10	0.09	1.36
60	Supply power for control equipment	0.75	1.00	0.80	0.60	4.80	0.75	1.00	0.80	0.60	4.80	0.75	1.00	1.00	0.75	6.00	0.75	1.00	1.00	0.75	6.00
61	emergency fire pump	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00
62	Fire pump	0.95	1.00	0.80	0.76	28.12	0.95	1.00	0.80	0.76	28.12	0.95	1.00	0.50	0.48	17.58	0.95	1.00	0.50	0.48	17.58
63	Starting air compressor	0.95	0.50	0.20	0.10	2.38	0.95	0.50	0.20	0.10	2.38	0.95	0.50	0.20	0.10	2.38	0.95	0.50	0.20	0.10	2.38
64	Stand by sanitary/fresh water pump	0.90	1.00	0.20	0.18	0.40	0.90	1.00	0.20	0.18	0.40	0.90	1.00	0.20	0.18	0.40	0.90	1.00	0.20	0.18	0.40
	Subtotal					63.33					63.33					51.26					51.26
	Sanitary Services and Septic Services																				
65	Fresh water generator	0.90	1.00	0.60	0.54	3.24	0.90	1.00	0.60	0.54	3.24	0.90	1.00	0.60	0.54	3.24	0.90	1.00	0.60	0.54	3.24
66	Fresh water heater	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.60	0.54	27.00
67	Hydrophore freshwater pump	0.90	0.67	0.60	0.36	5.04	0.90	0.67	0.60	0.36	5.04	0.90	0.67	0.70	0.42	5.88	0.90	0.67	0.70	0.42	5.88
68	Sewage treatment plant	0.80	1.00	0.10	0.08	0.42	0.80	1.00	0.10	0.08	0.42	0.80	1.00	0.60	0.48	2.50	0.80	1.00	0.60	0.48	2.50
69	Garbage system crushers	0.85	1.00	0.10	0.09	1.28	0.85	1.00	0.10	0.09	1.28	0.85	1.00	0.30	0.26	3.83	0.85	1.00	0.30	0.26	3.83
70	Ballast Water Management System	0.85	1.00	1.00	0.85	91.80	0.85	1.00	1.00	0.85	91.80	0.85	1.00	0.00	0.00	0.00	0.85	1.00	0.00	0.00	0.00
71	Solid waste incinerator	0.85	1.00	0.20	0.17	1.14	0.85	1.00	0.20	0.17	1.14	0.85	1.00	0.30	0.26	1.71	0.85	1.00	0.30	0.26	1.71
72	Sludge/dirty oil pump	0.90	1.00	0.80	0.72	4.82	0.90	1.00	0.80	0.72	4.82	0.90	1.00	0.60	0.54	3.62	0.90	1.00	0.60	0.54	3.62
73	Sanitary pump	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84
74	Potable water pump	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84
	Subtotal					134.73					134.73					47.77					47.77
	Other services																				
75	Navigation instruments	0.85	1.00	0.20	0.17	2.04	0.85	1.00	0.20	0.17	2.04	0.85	1.00	0.90	0.77	9.18	0.85	1.00	0.90	0.77	9.18
76	Communications instruments	0.85	1.00	0.30	0.26	2.81	0.85	1.00	0.30	0.26	2.81	0.85	1.00	0.90	0.77	8.42	0.85	1.00	0.90	0.77	8.42
77	Cargo equipment	0.85	1.00	0.20	0.17	10.20	0.85	1.00	0.20	0.17	10.20	0.85	1.00	0.70	0.60	35.70	0.85	1.00	0.70	0.60	35.70
78	Workshop	0.50	1.00	0.80	0.40	26.00	0.50	1.00	0.80	0.40	26.00	0.50	1.00	0.40	0.20	13.00	0.50	1.00	0.40	0.20	13.00
	Subtotal					41.05					41.05					66.30					66.30
	Air-conditioning / Heating																				
79	Air conditioning plant	0.95	1.00	0.70	0.67	53.20	0.95	1.00	0.70	0.67	53.20	0.95	1.00	0.50	0.48	38.00	0.95	1.00	0.50	0.48	38.00
80	Electric heating	0.95	1.00	0.80	0.76	38.00	0.95	1.00	0.80	0.76	38.00	0.95	1.00	0.50	0.48	23.75	0.95	1.00	0.50	0.48	23.75
	Subtotal					91.20					91.20					61.75					61.75
	Total					796.80					813.90					4595.60					4613.56

N°	List of Loads / Groups	BOLLARD PULL										CHARGE& DISCHARGE DPII									
		DAY					NIGHT					DAY					NIGHT				
		FL	FSI	FSE	F	Kw	FL	FSI	FSE	F	Kw	FL	FSI	FSE	F	Kw	FL	FSI	FSE	F	Kw
	Electric Propulsion																				
1	Main electric Propellers	0.88	1.00	1.00	0.88	4400.00	0.88	1.00	1.00	0.88	4400.00	0.10	1.00	0.85	0.08	412.25	0.10	1.00	0.85	0.08	412.25
2	Bow Thrusters	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.00	0.00	0.00	0.90	0.50	0.80	0.36	216.00	0.90	0.50	0.80	0.36	216.00
	Subtotal					4400.00					4400.00					628.25					628.25
	Propulsion service																				
3	H.T. FW Cooling pump	0.95	0.50	0.50	0.24	5.23	0.95	0.50	0.50	0.24	5.23	0.95	0.50	0.50	0.24	5.23	0.95	0.50	0.50	0.24	5.23
4	L.T. FW Cooling pump	0.95	0.50	0.50	0.24	10.69	0.95	0.50	0.50	0.24	10.69	0.95	0.50	0.50	0.24	10.69	0.95	0.50	0.50	0.24	10.69
5	GENSET LO. Stand by pump	0.95	0.50	0.95	0.45	5.42	0.95	0.50	0.95	0.45	5.42	0.95	0.50	0.30	0.14	1.71	0.95	0.50	0.30	0.14	1.71
6	Lub oil purifiers	0.95	0.50	0.95	0.45	4.51	0.95	0.50	0.95	0.45	4.51	0.95	0.50	0.35	0.17	1.66	0.95	0.50	0.35	0.17	1.66
7	Transfer pumps	0.95	1.00	0.95	0.90	5.42	0.95	1.00	0.95	0.90	5.42	0.95	1.00	0.40	0.38	2.28	0.95	1.00	0.40	0.38	2.28
8	LO transfer pumps	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.20	0.10	0.52	0.95	0.50	0.20	0.10	0.52
9	Bow Thruster cooling pump	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.30	0.29	2.85	0.95	1.00	0.30	0.29	2.85
10	Bow Thruster hydraulic power unit	0.80	1.00	0.00	0.00	0.00	0.80	1.00	0.00	0.00	0.00	0.80	1.00	0.30	0.24	4.80	0.80	1.00	0.30	0.24	4.80
11	SW Cooling pump	0.95	0.50	0.50	0.24	19.00	0.95	0.50	0.50	0.24	19.00	0.95	0.50	0.50	0.24	19.00	0.95	0.50	0.50	0.24	19.00
12	MethanolPac	0.75	1.00	0.95	0.71	213.75	0.75	1.00	0.95	0.71	213.75	0.75	1.00	0.80	0.60	180.00	0.75	1.00	0.80	0.60	180.00
	Subtotal					264.01					264.01					228.74					228.74
	FIFI AND OIL RECOVERY SYSTEM:																				
13	FIFI Pumps	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
14	Oil dispersant system	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
15	FIFI monitors	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
	Subtotal					0.00					0.00					0.00					0.00
	Pumps & Equipment (As per class)																				
16	Bilge & fire pump	0.95	0.50	0.30	0.14	4.28	0.95	0.50	0.30	0.14	4.28	0.95	0.50	0.20	0.10	2.85	0.95	0.50	0.20	0.10	2.85
17	Hot Water Circulating Pump	0.95	1.00	0.80	0.76	1.52	0.95	1.00	0.80	0.76	1.52	0.95	1.00	0.30	0.29	0.57	0.95	1.00	0.30	0.29	0.57
18	Fresh Water Cargo Pumps	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.50	0.45	13.50	0.90	1.00	0.50	0.45	13.50
19	Drill Water / Ballast Pump	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.40	0.36	10.80	0.90	1.00	0.40	0.36	10.80
20	Liquid Mud Pump	0.50	0.50	0.50	0.13	6.25	0.50	0.50	0.50	0.13	6.25	0.50	0.50	0.20	0.05	2.50	0.50	0.50	0.20	0.05	2.50
21	Dry bulk air compressors	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.10	0.05	9.90	0.90	0.50	0.10	0.05	9.90
22	Dry bulk air dryer	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.80	0.34	20.40	0.85	0.50	0.80	0.34	20.40
23	Fresh Water Pressure Set	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.30	0.14	0.68	0.90	0.50	0.30	0.14	0.68
24	Sea Water Pressure Set	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.30	0.14	0.68	0.90	0.50	0.30	0.14	0.68
25	Dirty Oil Pump	0.95	0.50	0.30	0.14	0.71	0.95	0.50	0.30	0.14	0.71	0.95	0.50	0.40	0.19	0.95	0.95	0.50	0.40	0.19	0.95
26	Oily water separator	0.95	1.00	0.30	0.29	0.34	0.95	1.00	0.30	0.29	0.34	0.95	1.00	0.30	0.29	0.34	0.95	1.00	0.30	0.29	0.34
27	Mud recirculation pumps	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.40	0.18	3.60	0.90	0.50	0.40	0.18	3.60
28	Hydraulic oil transfer pump	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.30	0.27	0.41	0.90	1.00	0.30	0.27	0.41
29	Dispersant pump	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
30	Fire & general services pump	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.30	0.29	0.57	0.95	1.00	0.30	0.29	0.57
31	Engine room ac cooling pump	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.40	0.38	0.76	0.95	1.00	0.40	0.38	0.76
32	LO heating	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.20	0.09	1.70	0.85	0.50	0.20	0.09	1.70
33	LO purifier	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.20	0.09	0.43	0.85	0.50	0.20	0.09	0.43
34	Hydraulic power unit cooling pump	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.40	0.36	2.70	0.90	1.00	0.40	0.36	2.70
35	SW cooling dry bulk system pump	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.70	0.33	1.66	0.95	0.50	0.70	0.33	1.66
	Subtotal					13.10					13.10					70.62					70.62
	Deck, Towing / Anchor-handling & Mooring Equipment																				
36	Anchor Windlass	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.50	0.45	34.20	0.90	1.00	0.50	0.45	34.20
37	Anchor / Towing Winch	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.20	0.18	38.70	0.90	1.00	0.20	0.18	38.70
38	Capstans	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.40	0.36	14.40	0.90	1.00	0.40	0.36	14.40
39	Tugger Winch	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.40	0.36	21.60	0.90	1.00	0.40	0.36	21.60
40	Shark Jaw	0.90	1.00	0.50	0.45	9.00	0.90	1.00	0.50	0.45	9.00	0.90	1.00	0.20	0.18	3.60	0.90	1.00	0.20	0.18	3.60
41	Towing Pins	0.90	0.50	0.90	0.41	4.05	0.90	0.50	0.90	0.41	4.05	0.90	0.50	0.40	0.18	1.80	0.90	0.50	0.40	0.18	1.80
42	Lifeboat davit	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00
43	Deck crane	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
	Subtotal					13.05					13.05					114.30					114.30
	Gallery / Provision Rooms:																				
44	Gallery general	0.90	1.00	0.65	0.59	40.95	0.90	1.00	0.65	0.59	40.95	0.90	1.00	0.70	0.63	44.10	0.90	1.00	0.70	0.63	44.10
45	Compressors of refrigerated provisions	0.90	0.67	0.70	0.42	10.92	0.90	0.67	0.70	0.42	10.92	0.90	0.67	0.60	0.36	9.36	0.90	0.67	0.60	0.36	9.36
46	Refeger plant cooling pump	0.95	2.00	0.40	0.76	2.28	0.95	2.00	0.40	0.76	2.28	0.95	2.00	0.40	0.76	2.28	0.95	2.00	0.40	0.76	2.28
47	Kitchen	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.50	0.45	22.50	0.90	1.00	0.50	0.45	22.50
48	General Bars	0.90	1.00	0.50	0.45	15.75	0.90	1.00	0.50	0.45	15.75	0.90	1.00	0.50	0.45	15.75	0.90	1.00	0.50	0.45	15.75
49	General Laundry	0.90	1.00	0.40	0.36	9.00	0.90	1.00	0.40	0.36	9.00	0.90	1.00	0.50	0.45	11.25	0.90	1.00	0.50	0.45	11.25
	Subtotal					105.90					105.90					105.24					105.24
	Lighting																				
50	Navigation lights	0.95	1.00	1.00	0.95	7.60	0.95	1.00	1.00	0.95	7.60	0.95	1.00	1.00	0.95	7.60	0.95	1.00	1.00	0.95	7.60
51	Interior lighting	0.95	1.00	0.65	0.62	3.71	0.95	1.00	0.80	0.76	4.56	0.95	1.00	0.65	0.62	3.71	0.95	1.00	0.80	0.76	4.56
52	Outside lighting	0.95	1.00	0.10	0.10	1.90	0.95	1.00	1.00	0.95	19.00	0.95	1.00	0.10	0.10	1.90	0.95	1.00	1.00	0.95	19.00
	Subtotal					13.21					31.16					13.21					31.16
	Emergency Load																				
53	Engine room ventilation fan	0.85	1.00	0.90	0.77	12.62	0.85	1.00	0.90	0.77	12.62	0.85	1.00	1.00	0.85	14.03	0.85	1.00	1.00	0.85	14.03
54	Emergency genset supply fan	0.85	1.00	0.70	0.60	2.38	0.85	1.00	0.70	0.60	2.38	0.85	1.00	0.50	0.43	1.70	0.85	1.00	0.50	0.43	1.70
55	Emergency lightning	0.90	1.00	0.70	0.63	1.51	0.90	1.00	0.70	0.63	1.51	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
56	Radio system	0.90	1.00	1.00	0.90	2.70	0.90	1.00	1.00	0.90	2.70	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
57	Navigation aids equipment	0.90	1.00	1.00	0.90	3.06	0.90	1.00	1.00	0.90	3.06	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
58	Communication equipment	0.90	1.00	1.00	0.90	4.05	0.90	1.00	1.00	0.90	4.05	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00
59	Emergency genset services	0.85	1.00	0.10	0.09	1.36	0.85	1.00	0.10	0.09	1.36	0.85	1.00	0.00	0.00	0.00	0.85	1.00	0.00	0.00	0.00
60	Supply power for control equipment	0.75	1.00	1.00	0.75	6.00	0.75	1.00	1.00	0.75	6.00	0.75	1.00	0.00	0.00	0.00	0.75	1.00	0.00	0.00	0.00
61	emergency fire pump	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00
62	Fire pump	0.95	1.00	0.50	0.48	17.58	0.95	1.00	0.50	0.48	17.58	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00
63	Starting air compressor	0.95	0.50	0.20	0.10	2.38	0.95	0.50	0.20	0.10	2.38	0.95	0.50	0.20	0.10	2.38	0.95	0.50	0.20	0.10	2.38
64	Stand by sanitary/fresh water pump	0.90	1.00	0.20	0.18	0.40	0.90	1.00	0.20	0.18	0.40	0.90	1.00	0.20	0.18	0.40	0.90	1.00	0.20	0.18	0.40
	Subtotal					51.26					51.26					15.73					15.73
	Sanitary Services and Septic Services																				
65	Fresh water generator	0.90	1.00	0.60	0.54	3.24	0.90	1.00	0.60	0.54	3.24	0.90	1.00	0.60	0.54	3.24	0.90	1.00	0.60	0.54	3.24
66	Fresh water heater	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.60	0.54	27.00
67	Hydrophore freshwater pump	0.90	0.67	0.70	0.42	5.88	0.90	0.67	0.70	0.42	5.88	0.90	0.67	0.70	0.42	5.88	0.90	0.67	0.70	0.42	5.88
68	Sewage treatment plant	0.80	1.00	0.60	0.48	2.50	0.80	1.00	0.60	0.48	2.50	0.80	1.00	0.60	0.48	2.50	0.80	1.00	0.60	0.48	2.50
69	Garbage system crushers	0.85	1.00	0.30	0.26	3.83	0.85	1.00	0.30	0.26	3.83	0.85	1.00	0.30	0.26	3.83	0.85	1.00	0.30	0.26	3.83
70	Ballast Water Management System	0.85	1.00	0.00	0.00	0.00	0.85	1.00	0.00	0.00	0.00	0.85	1.00	0.00	0.00	0.00	0.85	1.00	0.00	0.00	0.00
71	Solid waste incinerator	0.85	1.00	0.30	0.26	1.71	0.85	1.00	0.30	0.26	1.71	0.85	1.00	0.30	0.26	1.71	0.85	1.00	0.30	0.26	1.71
72	Sludge/dirty oil pump	0.90	1.00	0.60	0.54	3.62	0.90	1.00	0.60	0.54	3.62	0.90	1.00	0.60	0.54	3.62	0.90	1.00	0.60	0.54	3.62
73	Sanitary pump	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84
74	Potable water pump	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84
	Subtotal					47.77					47.77					47.77					47.77
	Other services																				
75	Navigation instruments	0.85	1.00	0.90	0.77	9.18	0.85	1.00	0.90	0.77	9.18	0.85	1.00	1.00	0.85	10.20	0.85	1.00	1.00	0.85	10.20
76	Communications instruments	0.85	1.00	0.90	0.77	8.42	0.85	1.00	0.90	0.77	8.42	0.85	1.00	1.00	0.85	9.35	0.85	1.00	1.00	0.85	9.35
77	Cargo equipment	0.85	1.00	0.70	0.60	35.70	0.85	1.00	0.70	0.60	35.70	0.85	1.00	1.00	0.85	51.00	0.85	1.00	1.00	0.85	51.00
78	Workshop	0.50	1.00	0.40	0.20	13.00	0.50	1.00	0.40	0.20	13.00	0.50	1.00	1.00	0.50	32.50	0.50	1.00	1.00	0.50	32.50
	Subtotal					66.30					66.30					103.05					103.05
	Air-conditioning / Heating																				
79	Air conditioning plant	0.95	1.00	0.50	0.48	38.00	0.95	1.00	0.50	0.48	38.00	0.95	1.00	0.50	0.48	38.00	0.95	1.00	0.50	0.48	38.00
80	Electric heating	0.95	1.00	0.50	0.48	23.75	0.95	1.00	0.50	0.48	23.75	0.95	1.00	0.50	0.48	23.75	0.95	1.00	0.50	0.48	23.75
	Subtotal					61.75					61.75					61.75					61.75
	Total					5036.33					5054.29					1388.65					1406.60

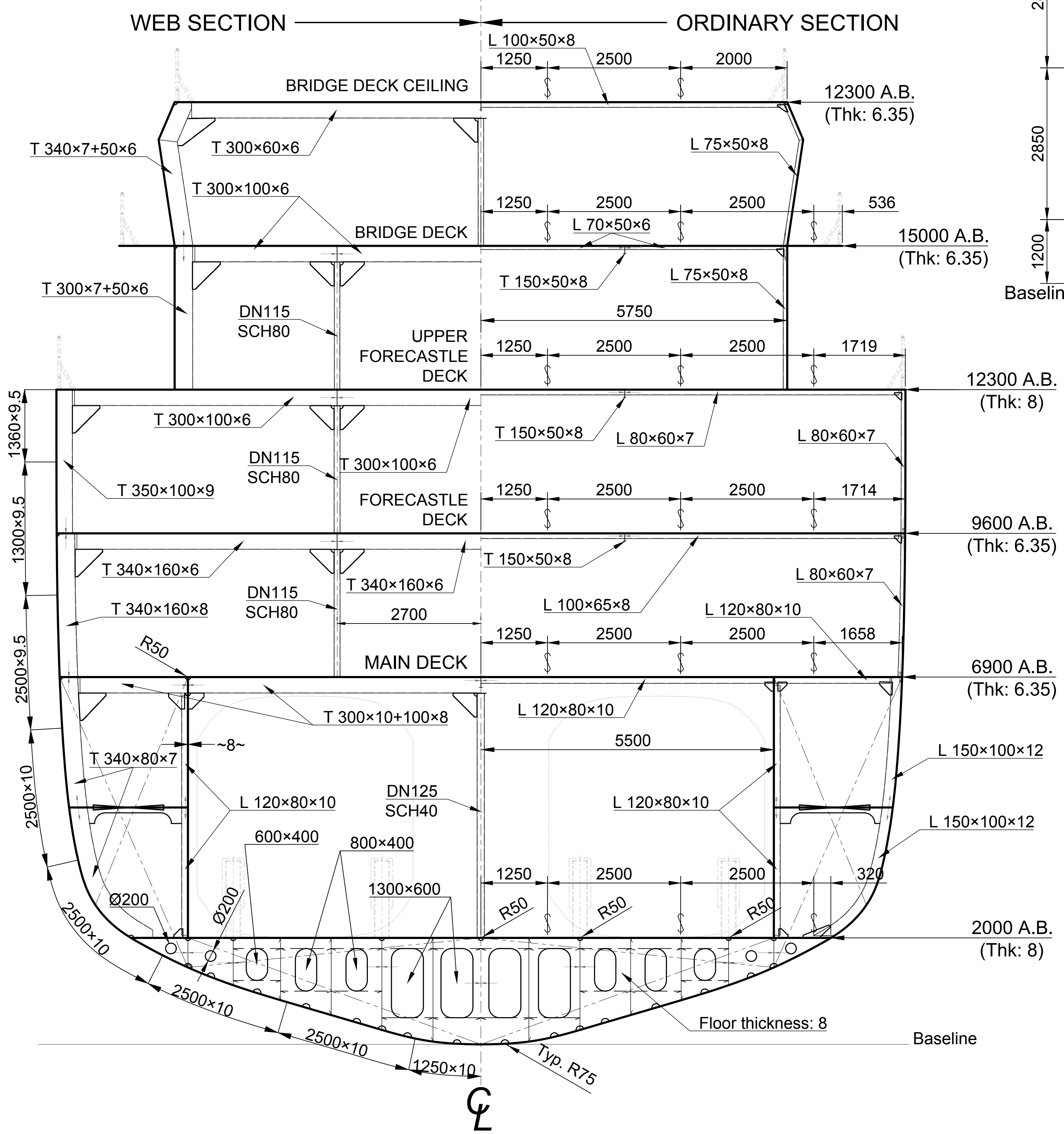
N°	List of Loads / Groups	ANCHOR HANDLING OPERATION										FIFI DPII										EMERGENCY	
		DAY					NIGHT					DAY					NIGHT						
		FL	FSI	FSE	F	Kw	FL	FSI	FSE	F	Kw	FL	FSI	FSE	F	Kw	FL	FSI	FSE	F	Kw	F	Kw
	Electric Propulsion																						
1	Main electric Propellers	0.10	1.00	0.85	0.08	412.25	0.10	1.00	0.85	0.08	412.25	0.10	1.00	0.85	0.08	412.25	0.10	1.00	0.85	0.08	412.25	0.00	0.00
2	Bow Thrusters	0.90	0.50	0.80	0.36	216.00	0.90	0.50	0.80	0.36	216.00	0.90	0.50	0.80	0.36	216.00	0.90	0.50	0.80	0.36	216.00	0.00	0.00
	Subtotal					628.25					628.25					628.25					628.25		0.00
	Propulsion service																						
3	H.T. FW Cooling pump	0.95	0.50	0.30	0.14	3.14	0.95	0.50	0.30	0.14	3.14	0.95	0.50	0.50	0.24	5.23	0.95	0.50	0.50	0.24	5.23		0.00
4	L.T. FW Cooling pump	0.95	0.50	0.30	0.14	6.41	0.95	0.50	0.30	0.14	6.41	0.95	0.50	0.50	0.24	10.69	0.95	0.50	0.50	0.24	10.69		0.00
5	GENSET LO. Stand by pump	0.95	0.50	0.80	0.38	4.56	0.95	0.50	0.80	0.38	4.56	0.95	0.50	0.40	0.19	2.28	0.95	0.50	0.40	0.19	2.28	0.00	0.00
6	Lub oil purifiers	0.95	0.50	0.80	0.38	3.80	0.95	0.50	0.80	0.38	3.80	0.95	0.50	0.40	0.19	1.90	0.95	0.50	0.40	0.19	1.90	0.00	0.00
7	Transfer pumps	0.95	1.00	0.50	0.48	2.85	0.95	1.00	0.50	0.48	2.85	0.95	1.00	0.40	0.38	2.28	0.95	1.00	0.40	0.38	2.28	0.00	0.00
8	LO transfer pumps	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.10	0.05	0.26	0.95	0.50	0.10	0.05	0.26		0.00
9	Bow Thruster cooling pump	0.95	1.00	0.20	0.19	1.90	0.95	1.00	0.20	0.19	1.90	0.95	1.00	0.20	0.19	1.90	0.95	1.00	0.20	0.19	1.90		0.00
10	Bow Thruster hydraulic power unit	0.80	1.00	0.20	0.16	3.20	0.80	1.00	0.20	0.16	3.20	0.80	1.00	0.20	0.16	3.20	0.80	1.00	0.20	0.16	3.20		0.00
11	SW Cooling pump	0.95	0.50	0.30	0.14	11.40	0.95	0.50	0.30	0.14	11.40	0.95	0.50	0.30	0.14	11.40	0.95	0.50	0.30	0.14	11.40		0.00
12	MethanolPac	0.75	1.00	0.75	0.56	168.75	0.75	1.00	0.75	0.56	168.75	0.75	1.00	0.80	0.60	180.00	0.75	1.00	0.80	0.60	180.00	0.00	0.00
	Subtotal					206.01					206.01					219.13					219.13		0.00
	FIFI AND OIL RECOVERY SYSTEM:																						
13	FIFI Pumps	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.90	0.81	97.20	0.90	1.00	0.90	0.81	97.20	0.00	0.00
14	Oil dispersant system	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.00	0.00
15	FIFI monitors	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.90	0.81	81.00	0.90	1.00	0.90	0.81	81.00	0.00	0.00
	Subtotal					0.00					0.00					178.20					178.20		0.00
	Pumps & Equipment (As per class)																						
16	Bilge & fire pump	0.95	0.50	0.50	0.24	7.13	0.95	0.50	0.50	0.24	7.13	0.95	0.50	0.80	0.38	11.40	0.95	0.50	0.80	0.38	11.40	0.00	0.00
17	Hot Water Circulating Pump	0.95	1.00	0.70	0.67	1.33	0.95	1.00	0.70	0.67	1.33	0.95	1.00	0.80	0.76	1.52	0.95	1.00	0.80	0.76	1.52	0.00	0.00
18	Fresh Water Cargo Pumps	0.90	1.00	0.65	0.59	17.55	0.90	1.00	0.65	0.59	17.55	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.00	0.00
19	Drill Water / Ballast Pump	0.90	1.00	0.20	0.18	5.40	0.90	1.00	0.20	0.18	5.40	0.90	1.00	0.20	0.18	5.40	0.90	1.00	0.20	0.18	5.40	0.00	0.00
20	Liquid Mud Pump	0.50	0.50	0.20	0.05	2.50	0.50	0.50	0.20	0.05	2.50	0.50	0.50	0.00	0.00	0.00	0.50	0.50	0.00	0.00	0.00	0.00	0.00
21	Dry bulk air compressors	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.00	0.00
22	Dry bulk air dryer	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.00	0.00	0.00	0.85	0.50	0.00	0.00	0.00	0.00	0.00
23	Fresh Water Pressure Set	0.90	0.50	1.00	0.45	2.25	0.90	0.50	1.00	0.45	2.25	0.90	0.50	0.10	0.05	0.23	0.90	0.50	0.10	0.05	0.23	0.00	0.00
24	Sea Water Pressure Set	0.90	0.50	1.00	0.45	2.25	0.90	0.50	1.00	0.45	2.25	0.90	0.50	0.10	0.05	0.23	0.90	0.50	0.10	0.05	0.23	0.00	0.00
25	Dirty Oil Pump	0.95	0.50	0.40	0.19	0.95	0.95	0.50	0.40	0.19	0.95	0.95	0.50	0.10	0.05	0.24	0.95	0.50	0.10	0.05	0.24	0.00	0.00
26	Oily water separator	0.95	1.00	0.80	0.76	0.91	0.95	1.00	0.80	0.76	0.91	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	1.00	1.20
27	Mud recirculation pumps	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.00	0.00
28	Hydraulic oil transfer pump	0.90	1.00	0.20	0.18	0.27	0.90	1.00	0.20	0.18	0.27	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.00	0.00
29	Dispersant pump	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.00	0.00
30	Fire & general services pump	0.95	1.00	0.20	0.19	0.38	0.95	1.00	0.20	0.19	0.38	0.95	1.00	0.40	0.38	0.76	0.95	1.00	0.40	0.38	0.76	1.00	2.00
31	Engine room ac cooling pump	0.95	1.00	0.20	0.19	0.38	0.95	1.00	0.20	0.19	0.38	0.95	1.00	0.10	0.10	0.19	0.95	1.00	0.10	0.10	0.19	0.00	0.00
32	LO heating	0.85	0.50	0.20	0.09	1.70	0.85	0.50	0.20	0.09	1.70	0.85	0.50	0.10	0.04	0.85	0.85	0.50	0.10	0.04	0.85	0.00	0.00
33	LO purifier	0.85	0.50	0.20	0.09	0.43	0.85	0.50	0.20	0.09	0.43	0.85	0.50	0.10	0.04	0.21	0.85	0.50	0.10	0.04	0.21	0.00	0.00
34	Hydraulic power unit cooling pump	0.90	1.00	0.50	0.45	3.38	0.90	1.00	0.50	0.45	3.38	0.90	1.00	0.10	0.09	0.68	0.90	1.00	0.10	0.09	0.68	1.00	7.50
35	SW cooling dry bulk system pump	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00	0.95	0.50	0.00	0.00	0.00	0.00	0.00
	Subtotal					43.42					43.42					21.02					21.02		3.20
	Deck, Towing / Anchor-handling & Mooring Equipment																						
36	Anchor Windlass	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.00	0.00
37	Anchor / Towing Winch	0.90	1.00	0.80	0.72	154.80	0.90	1.00	0.80	0.72	154.80	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.00	0.00
38	Capstans	0.90	1.00	0.40	0.36	14.40	0.90	1.00	0.40	0.36	14.40	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.00	0.00
39	Tugger Winch	0.90	1.00	0.40	0.36	21.60	0.90	1.00	0.40	0.36	21.60	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.00	0.00
40	Shark Jaw	0.90	1.00	1.00	0.90	18.00	0.90	1.00	1.00	0.90	18.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.00	0.00
41	Towing Pins	0.90	0.50	1.00	0.45	4.50	0.90	0.50	1.00	0.45	4.50	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.00	0.00
42	Lifeboat davit	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.90	0.50	0.00	0.00	0.00	0.00	0.00
43	Deck crane	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.00	0.00
	Subtotal					213.30					213.30					0.00					0.00		0.00
	Gallery / Provision Rooms:																						
44	Gallery general	0.90	1.00	1.00	0.90	63.00	0.90	1.00	1.00	0.90	63.00	0.90	1.00	1.00	0.90	63.00	0.90	1.00	1.00	0.90	63.00	0.00	0.00
45	Compressors of refrigerated provisions	0.90	0.67	1.00	0.60	15.60	0.90	0.67	1.00	0.60	15.60	0.90	0.67	1.00	0.60	15.60	0.90	0.67	1.00	0.60	15.60	0.00	0.00
46	Refeger plant cooling pump	0.95	2.00	0.40	0.76	2.28	0.95	2.00	0.40	0.76	2.28	0.95	2.00	0.40	0.76	2.28	0.95	2.00	0.40	0.76	2.28	0.00	0.00
47	Kitchen	0.90	1.00	1.00	0.90	45.00	0.90	1.00	1.00	0.90	45.00	0.90	1.00	1.00	0.90	45.00	0.90	1.00	1.00	0.90	45.00	0.00	0.00
48	General Bars	0.90	1.00	1.00	0.90	31.50	0.90	1.00	1.00	0.90	31.50	0.90	1.00	1.00	0.90	31.50	0.90	1.00	1.00	0.90	31.50	0.00	0.00
49	General Laundry	0.90	1.00	0.20	0.18	4.50	0.90	1.00	0.20	0.18	4.50	0.90	1.00	0.20	0.18	4.50	0.90	1.00	0.20	0.18	4.50	0.00	0.00
	Subtotal					161.88					161.88					161.88					161.88		0.00
	Lighting																						
50	Navigation lights	0.95	1.00	1.00	0.95	7.60	0.95	1.00	1.00	0.95	7.60	0.95	1.00	1.00	0.95	7.60	0.95	1.00	1.00	0.95	7.60	1.00	8.00
51	Interior lighting	0.95	1.00	0.65	0.62	3.71	0.95	1.00	0.80	0.76	4.56	0.95	1.00	0.65	0.62	3.71	0.95	1.00	0.80	0.76	4.56	1.00	6.00
52	Outside lighting	0.95	1.00	0.10	0.10	1.90	0.95	1.00	1.00	0.95	19.00	0.95	1.00	0.10	0.10	1.90	0.95	1.00	1.00	0.95	19.00	1.00	20.00
	Subtotal					13.21					31.16					13.21					31.16		34.00
	Emergency Load																						
53	Engine room ventilation fan	0.85	1.00	1.00	0.85	14.03	0.85	1.00	1.00	0.85	14.03	0.85	1.00	1.00	0.85	14.03	0.85	1.00	1.00	0.85	14.03	1.00	16.50
54	Emergency genset supply fan	0.85	1.00	0.50	0.43	1.70	0.85	1.00	0.50	0.43	1.70	0.85	1.00	0.50	0.43	1.70	0.85	1.00	0.50	0.43	1.70	1.00	4.00
55	Emergency lightning	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	1.00	2.40
56	Radio system	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	1.00	3.00
57	Navigation aids equipment	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	1.00	3.40
58	Communication equipment	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	0.90	1.00	0.00	0.00	0.00	1.00	4.50
59	Emergency genset services	0.85	1.00	0.00	0.00	0.00	0.85	1.00	0.00	0.00	0.00	0.85	1.00	0.00	0.00	0.00	0.85	1.00	0.00	0.00	0.00	1.00	16.00
60	Supply power for control equipment	0.75	1.00	0.00	0.00	0.00	0.75	1.00	0.00	0.00	0.00	0.75	1.00	0.00	0.00	0.00	0.75	1.00	0.00	0.00	0.00	1.00	8.00
61	emergency fire pump	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	1.00	15.00
62	Fire pump	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	0.95	1.00	0.00	0.00	0.00	1.00	37.00
63	Starting air compressor	0.95	0.50	0.20	0.10	2.38	0.95	0.50	0.20	0.10	2.38	0.95	0.50	0.20	0.10	2.38	0.95	0.50	0.20	0.10	2.38	1.00	25.00
64	Stand by sanitary/fresh water pump	0.90	1.00	0.20	0.18	0.40	0.90	1.00	0.20	0.18	0.40	0.90	1.00	0.20	0.18	0.40	0.90	1.00	0.20	0.18	0.40	0.00	0.00
	Subtotal					15.73					15.73					15.73					15.73		109.80
	Sanitary Services and Septic Services																						
65	Fresh water generator	0.90	1.00	0.60	0.54	3.24	0.90	1.00	0.60	0.54	3.24	0.90	1.00	0.60	0.54	3.24	0.90	1.00	0.60	0.54	3.24	0.00	0.00
66	Fresh water heater	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.60	0.54	27.00	0.90	1.00	0.60	0.54	27.00	0.00	0.00
67	Hydrophore freshwater pump	0.90	0.67	0.70	0.42	5.88	0.90	0.67	0.70	0.42	5.88	0.90	0.67	0.70	0.42	5.88	0.90	0.67	0.70	0.42	5.88	0.00	0.00
68	Sewage treatment plant	0.80	1.00	0.60	0.48	2.50	0.80	1.00	0.60	0.48	2.50	0.80	1.00	0.60	0.48	2.50	0.80	1.00	0.60	0.48	2.50	0.00	0.00
69	Garbage system crushers	0.85	1.00	0.30	0.26	3.83	0.85	1.00	0.30	0.26	3.83	0.85	1.00	0.30	0.26	3.83	0.85	1.00	0.30	0.26	3.83	0.00	0.00
70	Ballast Water Management System	0.85	1.00	0.00	0.00	0.00	0.85	1.00	0.00	0.00	0.00	0.85	1.00	0.00	0.00	0.00	0.85	1.00	0.00	0.00	0.00	0.00	0.00
71	Solid waste incinerator	0.85	1.00	0.30	0.26	1.71	0.85	1.00	0.30	0.26	1.71	0.85	1.00	0.30	0.26	1.71	0.85	1.00	0.30	0.26	1.71	0.00	0.00
72	Sludge/dirty oil pump	0.90	1.00	0.60	0.54	3.62	0.90	1.00	0.60	0.54	3.62	0.90	1.00	0.60	0.54	3.62	0.90	1.00	0.60	0.54	3.62	0.00	0.00
73	Sanitary pump	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.00	0.00
74	Potable water pump	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.95	1.00	0.40	0.38	0.84	0.00	0.00
	Subtotal					47.77					47.77					47.77					47.77		0.00
	Other services																						
75	Navigation instruments	0.85	1.00	1.00	0.85	10.20	0.85	1.00	1.00	0.85	10.20	0.85	1.00	1.00	0.85	10.20	0.85	1.00	1.00	0.85	10.20	1.00	12.00
76	Communications instruments	0.85	1.00	1.00	0.85	9.35	0.85	1.00	1.00	0.85	9.35	0.85	1.00	1.00	0.85	9.35	0.85	1.00	1.00	0.85	9.35	1.00	11.00
77	Cargo equipment	0.85	1.00	1.00	0.85	51.00	0.85	1.00	1.00	0.85	51.00	0.85	1.00	1.00	0.85	51.00	0.85	1.00	1.00	0.85	51.00	0.00	0.00
78	Workshop	0.50	1.00	1.00	0.50	32.50	0.50	1.00	1.00	0.50	32.50	0.50	1.00	1.00	0.50	32.50	0.50	1.00	1.00	0.50	32.50	0.00	0.00
	Subtotal					103.05					103.05					103.05					103.05		23.00
	Air-conditioning / Heating																						
79	Air conditioning plant	0.95	1.00	0.50	0.48	38.00	0.95	1.00	0.50	0.48	38.00	0.95	1.00	0.50	0.48	38.00	0.95	1.00	0.50	0.48	38.00	0.00	0.00
80	Electric heating	0.95	1.00	0.50	0.48	23.75	0.95	1.00	0.50	0.48	23.75	0.95	1.00	0.50	0.48	23.75	0.95	1.00	0.50	0.48	23.75	0.00	0.00
	Subtotal					61.75					61.75					61.75					61.75		0.00
	Total					1494.36					1512.31					1449.98					1467.94		170.00

ORDINARY AND WEB SECTION ARRANGEMENT

FRAME #52 - FRAME #53



FRAME #75 - FRAME #76



PRINCIPAL DIMENSIONS

LENGTH, OVERALL	66.30 m
LENGTH, BETWEEN PERPENDICULARS	57.80 m
LENGTH, WATERLINE	64.13 m
BEAM, MOULDED	16.10 m
DEPTH, MOULDED	6.90 m
FRAME SPACING	600 mm
DESIGN DRAFT	5.74 m
SCANTLING DRAFT	6.20 m

Notes:

- All sections are showing looking to aft.
- All steel used is grade A.
- Unless otherwise specified, all dimensions are in millimeters.

	Name:	Date:
Drawn by:	PG	27 May 2025
Checked by:	MS	01 Jun 2025
Approved by:	BH	02 Jun 2025

UTN.BA
UNIVERSIDAD TECNOLÓGICA NACIONAL
FACULTAD REGIONAL BUENOS AIRES

Scale: 1:100

Drawing: ANNEX G: MIDSHIP SECTION

Vessel: 75-TON BP GREEN POWERED AHTS

Classification: ✠ A1, Offshore Support Vessel (AH, Supply, Tow, FFV 1, OSP-S1), Methanol Fuel Ready, HYBRID [SCN], BWT, ✠DPS-2, ECG-SCR

Revision N°:	Size:	Sheet:
19	A3	01/01

Dwg N° AHTS75 - MS - 19

Date Issued: 03 Jun 2025

APPENDIX H - STRUCTURAL CALCULATION

1.1. Main dimensions

MAIN & SCANTLING DIMENSIONS			
Item	Symbol	Value	Unit
Breath	B	16.1	m
Molded Depth	D	6.9	m
Scantling Depth	Ds	6.9	m
Molded Draft	d	5.74	m
Scantling Draft	d_s	6.2	m
Freeboard Length	L_f	63.6768	m
Scantling Length	L	61.5648	m
Molded Displacement	Δ	4197	Ton
Block Coefficient	C_b	0.666	$-$

1.2. Longitudinal strength

MINIMUM SECTION MODULUS		
ABS 3-2-1/3.7.1 (b)		
$SM = C_1 \cdot C_2 \cdot L^2 \cdot B \cdot (C_b + 0.7)\ [cm^3 - m]$		
L	61.564	m
B	16.1	m
Cb	0.666	$-$
$C1$	30.84	$-$
$C2$	0.01	$-$
SM	25712	$cm^2 - m$

HULL GIRDER MOMENT OF INERTIA		
ABS 3-2-1/3.7.2		
$I = L \cdot \frac{SM}{33.3}\ [cm^2 - m^2]$		
L	61.5648	m
SM	25712	$cm^2 - m$
I	47535	$cm^2 - m^2$

1.3. Plating

SIDE SHELL PLATING FOR OFFSHORE SUPPORT VESSELS		
ABS 3-2-2/3.9.1		
$t_{shell1} = \left(\frac{s}{645}\right) \cdot \sqrt{(L - 15.2) \cdot \left(\frac{d_s}{D_s}\right)} + 2.5\ [mm]$		
s	600	mm
L	61.5648	m
d_s	6.2	m
D_s	6.9	m
t_{shell1}	8.50	mm
$t_{shell2} = 0.035 \cdot (L + 29) + 0.009 \cdot s\ [mm]$		
t_{shell2}	8.57	mm

BOTTOM SHELL PLATING AMIDSHIPS		
ABS 3-2-2/3.15.1		
$t_{trans} = \left(\frac{s}{519}\right) \cdot \sqrt{(L - 19.8) \cdot \left(\frac{d_s}{D_s}\right)} + 2.5\ [mm]$		
s	600	mm
L	61.5648	m
d_s	6.2	m
D_s	6.9	m
t_{trans}	9.58	mm

ABS 3-2-2/3.15.2		
$t_{trmin} = \frac{L + 45.73}{25 \cdot L + 6082}\ [mm]$		
s	600	mm
L	61.5648	m
t_{trmin}	8.45	mm
ABS 3-2-2/5.1		
$t = 0.0455 \cdot L + 0.009 \cdot s[mm]$		
s	600	mm
L	61.5648	m
t	8.29	mm

SHEER STRAKE		
ABS 3-2-2/3.2.2		
$t = \frac{s_b \cdot (L + 45.73)}{25 \cdot L + 6082}\ [mm]$		
L	61.5648	m
s_b	600	mm
t	8.45	mm

GENERAL SCANTLINGS OF SUPERSTRUCTURES AND DECKHOUSES		
ABS 3-2-11/1.3.1 ii) a)		
$t = \frac{s \cdot \sqrt{h}}{268} + 2.5\ [mm]$		
s	600	mm
h	7.316	m
t	8.56	mm

CARGO DECK PLATING THICKNESS		
ABS 3-2-3/5.1		
$t = \frac{s \cdot \sqrt{h}}{254} + 1.5\ [mm]$		
s	600	mm
p	73.5	$\frac{kN}{m^2}$
$h = p/7.01$	10.49	m
t	9.15	mm

1.4. Bottom structures

BOTTOM STRUCTURES		
Center girder thicknes		
ABS 3-2-4/3.3.1		
$t = 0.056 \cdot L + 5.5\ [mm]$		
L	61.5648	m
t	8.95	mm

Solid floors		
ABS 3-2-4/5.1		
$t = 0.036 \cdot L + 4.7 + c\ [mm]$		
L	61.5648	m
c	0	-
t	6.92	mm

Inner bottom plating thickness		
ABS 3-2-4/9.1		
$t = 0.037 \cdot L + 0.009 \cdot s - c\ [mm]$		
L	61.5648	m
s	600	mm
$c\ (at\ engine\ space)$	-1.5	mm
$c\ (elsewhere)$	0.5	mm
$t\ (at\ engine\ space)$	9.18	mm
$t\ (elsewhere)$	7.18	mm

Deep tanks plating		
ABS 3-2-10/3.1		
$t_{shmin} = \left(s \cdot k \cdot \frac{\sqrt{q \cdot h}}{C_1}\right) + C_2 [mm]$		
s	600	mm
k	1	-
q	1	$\frac{N}{mm^2}$
h	6.5	m
C_1	254	-
C_2	2.5	-
t_shmin	8.52	mm

Stiffeners for deep tanks		
ABS 3-2-10/3.3		
$SM = 7.8 \cdot c \cdot h \cdot s \cdot l^2\ [cm^3]$		
c	0.594	-
h	6.5	m
s	0.6	m
l	1.2	m
SM	26	$cm\^3$

1.5. Frames scantling

TRANSVERSE FRAMES MINIMUM SECTION MODULUS		
ABS 3-2-5/3.1		
$SM = s \cdot l^2 \cdot \left(h + b \cdot \frac{h_1}{C_1}\right) \cdot \left(C_2 + \frac{C_3}{l^3}\right) \cdot Q\ [cm^3]$		
Frames between double bottom and tween deck at #52		
s	0.6	m
l	3.3	m
h	3.115	m
h_{FB}	2.4	m
p	73.5	kN/m^2
$h_E = p/7.01$	10.49	m
b	1.55	m
h_1	12.885	m
C_1	30	$-$
C_2	7	$-$
C_3	45	$-$
Q	1	$-$
SM	204	cm^3

Frames between tween deck and main deck at #52		
s	0.6	m
l	2.4	m
h	1.2	m
h_{FB}	0	m
p	73.5	kN/m^2
$h_E = p/7.01$	10.485	m
b	1.55	m
h_1	10.485	m
C_1	30	-
C_2	7	-
C_3	45	-
Q	1	-
SM	62	cm^3

Frames between double bottom and main deck at #75		
s	0.6	m
l	2.9	m
h	4.35	m
h_{FB}	2.90	m
h_{P1}	2.70	m
h_{P2}	2.70	m
h_{P3}	2.70	m
h_{P4}	2.70	m
b	2.29	m
h_1	8.3	m
C_1	30	-
C_2	7	-
C_3	45	-
Q	1	-
SM	222	cm^3
$OSV\ factor$	1.25	-
SM	278	cm^3

TRANSVERSE TWEEN-DECK FRAMES		
ABS 3-2-5/5.3		
$SM = \left(7 + \frac{45}{l^3}\right) \cdot s \cdot l^2 \cdot K \cdot Q\ [cm^3]$		
Frames bellow exposed deck at #75		
l	2.7	m
s	0.6	m
K	0.884	-
Q	1	-
$OSV\ factor$	1.25	-
SM	44.9	cm^3
Frames above exposed deck at #75		
l	2.7	m
s	0.6	m
K	0.884	
Q	1	-
SM	36	cm^3

WEB FRAMES		
ABS 3-2-6/3.1		
$SM = 4.74 \cdot c \cdot s \cdot l^2 \cdot \left(h + b \cdot \frac{h_1}{45 \cdot K}\right)\ [cm^3]$		
Frames bellow exposed deck at #75		
c	1.5	–
s	2.4	m
l	2.185	m
h	2.85	m
b	2.42	m
h_1	5.4	m
K	4	–
$OSV\ factor$	1.25	–
SM	409	cm3
Frames for exposed deck at #75		
c	1.5	-
s	2.4	m
l	2.7	m
h	2.05	m
b	5.38	m
h_1	4.05	m
K	4	-
$OSV\ factor$	1.25	-
SM	620	cm^3

Frames for forecastle deck at #75		
c	1.5	-
s	2.4	m
l	2.7	m
h	2.05	m
b	5.38	m
h_1	2.7	m
K	4	-
$OSV\ factor$	1.25	-
SM	520	cm^3
Frames for upper forecastle deck at #75		
c	1.5	–
s	2.4	m
l	2.7	m
h	1.35	m
b	2.765	m
h_1	2.44	m
K	4	–
SM	243	cm^3
Frames for bridge deck at #75		
c	1.5	–
s	2.4	m
l	2.7	m
h	1.35	m
b	5.265	m
h_1	2.44	m
K	4	–
SM	310	cm^3

1.6. Decks supports

BEAMS AND LONGITUDINALS		
ABS 3-2-7/3.1		
$SM = 7.8 \cdot c \cdot h \cdot s \cdot l^2\ [cm^3]$		
Main deck longitudinals at #50		
c	0.7	–
p	73.50	kN/m^2
$h = p/7.01$	10.49	m
s	0.617	m
l	2.4	m
SM	203	cm^3
Tween deck longitudinals		
c	0.7	–
h	1.23	m
s	0.617	m
l	2.4	m
SM	23.8	cm^3
Main deck longitudinals at #50 (inside side tanks)		
c	0.7	–
p	73.50	kN/m^2
$h = p/7.01$	10.49	m
s	1.55	m
l	2.4	m
SM	511	cm^3
Main deck beams at #70		
c	0.6	–
h	1.226	m
s	0.6	m
l	5.5	m
SM	104	cm^3

Forescastle deck beams at #70		
c	0.6	–
h	0.916	m
s	0.6	m
l	5.3	m
SM	72.2	cm^3
Upper forecastle deck beams at #70		
c	0.6	–
h	0.9156	m
s	0.6	m
l	5.3	m
SM	72.2	cm^3
Bridge deck beams		
c	0.6	–
h	0.9156	m
s	0.6	m
l	2.9	m
SM	21.6	cm^3
Bridge deck ceiling beams		
c	0.6	–
h	0.6156	m
s	0.6	m
l	5.6	m
SM	54.21	cm^3

PILLARS PERMISSIBLE & CALCULATED LOAD		
ABS 3-2-8/3.1 & 3.3		
3-2-8/3.1: Permissible load: $W_a = \left(k - n \cdot \frac{l}{r}\right) \cdot A\ [kN]$		
3-2-8/3.3: Calculated load: $W = n \cdot b \cdot h \cdot s\ [kN]$		
Pillars at #50		
k	12.09	–
n	4.44	–
l	2.7	m
r	4.67	cm
A	39.5	cm^2
W_a	375.7	kN
n	7.01	–
b	4.687	m
h	3.679	m
s	2.4	m
W	290.1	kN
Pillars at #75 bellow Main deck		
k	12.09	–
n	4.44	–
l	2.7	m
r	4.67	cm
A	27.73	cm^2
W_a	266	kN
n	7.01	–
b	6.37	m
h	2.4	m
s	2.4	m
W	257	kN

Pillars at #75 above Main deck		
k	12.09	–
n	4.44	–
l	2.7	m
r	3.75	cm
A	28.44	cm^2
W_a	253	kN
n	7.01	–
b	5.76	m
h	2.35	m
s	2.4	m
W	228	kN

Pillars at #75 at bridge deck		
k	12.09	–
n	4.44	–
l	2.7	m
r	3.75	cm
A	28.44	cm^2
W_a	253	kN
n	7.01	–
b	6.145	m
h	2.35	m
s	2.4	m
W	243	kN

Deck Girders & Beams Clear of Tanks		
ABS 3-2-8/5.3		
$SM = 4.74 \cdot c \cdot b \cdot h \cdot l^2\ [cm^3]$		
Main deck beams at #50		
c	1	–
b	2.4	m
h	10.4850214	m
l	4.96	m
SM	2934	cm^3

Tween deck beams at #50		
c	1	–
b	2.4	m
h	1.226	m
l	4.96	m
SM	343	cm^3

Tween deck girders at #50		
c	1	–
b	2.45	m
h	1.226	m
l	2.4	m
SM	82.0	cm^3

Main & forecastle deck beams at #75		
c	1	–
b	2.4	m
h	1.226	m
l	5.55	m
SM	429.5	cm^3

Main & forecastle deck girders at #75		
c	1	–
b	5.4	m
h	1.226	m
l	2.4	m
SM	180.7	cm^3

deck beams between forescastle deck and bridge deck at #75		
c	1	–
b	2.4	m
h	0.916	m
l	5.35	m
SM	298.1	cm^3

deck girders between forescastle deck and bridge deck at #75		
c	1	–
b	4.21	m
h	0.916	m
l	2.4	m
SM	105	cm^3

deck beams of bridge deck ceiling at #75		
c	1	–
b	2.4	m
h	0.616	m
l	5.76	m
SM	232	cm^3

deck girders of bridge deck ceiling at #75		
c	1	–
b	5.76	m
h	0.616	m
l	2.4	m
SM	96.8	cm^3

1.7. Steerable thruster

HULL SUPPORT FOR AZIMUTHING POD		
ABS 3-2-14/25.15.3 iii) SUPPORT GIRDERS THICKNESS		
$t = 0.85 \cdot (0.056 \cdot L + 5.5)\ [mm]$		
L	61.5648	m
t	7.61	mm
ABS 3-2-14/25.15.3 iii) Shell plating thickness in way of hull primary support structure		
Shell plating thickness in way of hull primary support structure is to be at least 50% thicker than as required for the adjacent shell plating.		
t_{hull}	10	mm
$t_{support}$	15	mm

1.8. Deck plating

DECK PLATING			
ABS 3-2-3/5.1 TABLE 1 & 2			
Deck	Class	Equation	Min. thickness
Tween deck	D	3	6.9
Main deck (exposed)	A	$2a$	7.8
	–	$2b$	3.43
	–	–	9.15
Main deck (covered)	C	5	6.2
Forecastle deck	J	7	4.48
Upper Forecastle Deck	E	3	6.9
	J	7	4.48
Bridge deck	G	4	6.25
	H	5	6.2
Bridge deck ceiling	H	5	6.2

2. Final selection of structural components

2.1. Shell Plating

Plate	Min. thk. req. [mm]	Adopted thk. [mm]
Side Shell	8.57	9.5
Bottom plating	9.58	10
Sheer	8.45	9.5
Superstructure	8.56	9.5

2.2. Deck Plating

Deck	Min. thk. req. [mm]	Adopted thk. [mm]
Tween deck	6.90	8.00
Main deck (exposed)	9.15	9.50
Main deck (covered)	6.20	6.35
Forecastle deck	4.48	6.35
Upper forecastle deck (exposed)	6.90	8
Upper forecastle deck (covered)	4.48	6.35
Bridge deck (exposed)	6.25	6.35
Bridge deck (covered)	6.20	6.35
Bridge deck ceiling	6.20	6.35

2.3. Bottom structure

Item	Min. thk. req. [mm]	Adopted thk. [mm]
Center girder	8.95	9.5
Side girder	6.92	8
Open floor	6.92	8
Watertight floor	6.92	8
Double bottom ceiling at machinery room	9.18	9.5
Doble bottom ceiling elsewhere	7.18	8
Double bottom inside lateral tank	8.52	9.5

2.4. Frames

Frame Location between decks	Min. req. SM [cm³]	Adopted SM [cm³]	Adopted profile
Double bottom Tween deck At #52	203	231	L150×100×12
Tween deck Main deck At #52	61.7	71.6	L100×65×8
Double bottom Main deck At #76	278.0	294.4	L200×100×10
Main deck Forecastle deck	44.9	45.2	L80×60×7
Forecastle deck Upper forecastle deck	44.9	45.2	L80×60×7
Above upper forecastle deck	35.9	40.7	L75×50×8

2.5. Web Frames

Frame Location between decks	Min. req. SM [cm³]	Adopted SM [cm³]	Adopted profile
All bellow Main deck	409	415	T340×80×7
Main deck/forecastle deck	620	667	T340×160×8
Forecastle deck/Upper forecastle deck	520	597	T350×100×9
Upper forecastle deck/Bridge deck	243	272	T300×7 +50×6
Above bridge deck	310	335	T340×7 +50×6

2.6. Beams and Longitudinals

Beam/Longitudinal Location	Min. req. SM [cm³]	Adopted SM [cm³]	Adopted profile
Main Deck longitudinal	204	232	L150×100×12
Main longitudinal inside tanks	511	570	L200×150×15
Tween deck longitudinal	24	29	L70×50×6
Main deck beam at #76	104	122	L120×80×10
Forecastle deck beam	72	82	L100×65×10
Upper forecastle beam	72	78	L100×75×8
Bridge deck beam	22	28	L70×50×6
Bridge deck ceiling beam	54	58	L100×50×8

2.7. Deck transverses

Deck transverse Location	Min. req. SM [cm³]	Adopted SM [cm³]	Adopted profile
Main deck transverse at #52	2934	3116	T500×13 +360×15
Tween deck transverse	343	364	T280×60×10
Main deck transverse at #75	430	452	T300×10 +100×8
Forecastle deck (and above) transverse	299	322	T300×100×6
Bridge deck ceiling transverse	232	261	T300×60×6

2.8. Deck girders

Deck girder Location	Min. req. SM [cm³]	Adopted SM [cm³]	Adopted profile
Tween deck	82.0	84.2	T150×50×6
Main deck at #75	180.7	189.1	T200×60×8.5
Forecastle deck (and above)	105.2	106.1	T150×50×8
Bridge deck ceiling	96.8	104.7	T150×40×9

2.9. Pillars

Pillar Location between decks	Max. calculated load admited [kN]	Calculated load [kN]	Adopted profile
At #52			
Tween deck/ Main deck	375.7	290.1	DN125 SCH80
Double bottom ceiling/Tween deck	265.5	257.2	
At #75			
Bellow main deck	265.5	257.2	DN125 SCH40
Main deck/forecastle deck	252.9	227.5	DN115 SCH40
Forecastle deck/ Upper forecastle deck	252.9	227.5	DN115 SCH80
Upper forecastle deck/ Bridge deck	252.9	227.5	DN115 SCH80
Bridge deck/ Bridge deck ceiling	252.9	243.0	DN115 SCH80

ANNEX I

EXAMPLE VESSELS FOR AHTS

#	Name	Year	BP [MT]	LOA [m]	Lpp [m]	B [m]	D [m]	H [m]	DWT [MT]	BHP [kW]	Vs [knots]
1	Example vessel 1	2005	65.00	59.25	-	14.95	6.10	4.97	1400	3840	-
2	Example vessel 2	2006	87.30	64.30	-	15.00	6.70	5.78	2204	5220	-
3	Example vessel 3	2008	88.00	65.00	58.50	16.00	6.20	5.00	1800	4922	12.50
4	Example vessel 4	2008	125.00	66.00	-	16.00	7.30	6.20	2465	6570	10.00
5	Example vessel 5	2009	105.00	67.80	60.75	15.00	6.10	5.00	1700	5940	11.00
6	Example vessel 6	2009	84.00	63.00	55.70	15.00	6.10	5.20	1630	5280	10.00
7	Example vessel 7	2009	100.00	65.50	-	16.00	6.50	5.80	1713	6024	-
8	Example vessel 8	2010	69.40	58.70	53.20	14.60	5.50	4.50	1350	3840	12.00
9	Example vessel 9	2010	120.00	66.00	57.00	16.00	7.30	6.20	2500	6570	10.00
10	Example vessel 10	2011	108.00	70.05	66.00	17.00	7.50	6.10	2400	5966	10.00
11	Example vessel 11	2012	110.00	69.90	61.80	16.60	7.20	6.30	2570	6115	10.00
12	Example vessel 12	2012	60.00	58.70	53.20	14.60	5.50	4.75	-	3840	12.00
13	Example vessel 13	2014	66.00	58.70	53.20	14.60	5.50	4.76	1271	3840	13.00
14	Example vessel 14	2015	104.00	65.00	58.50	16.00	6.20	5.20	1930	4854	12.20
15	Example vessel 15	2017	86.00	65.00	57.47	16.00	6.20	5.00	1878	4412	12.00
16	Example vessel 16	-	90.00	66.00	62.42	16.40	6.80	5.20	1650	5110	13.60
17	Example vessel 17	-	65.00	58.70	-	14.60	5.50	4.75	1400	3840	-
18	Example vessel 18	-	65.00	60.50	54.30	15.80	6.50	5.20	1400	3840	10.00

#	Name	Year	Δ [MT]	LSW [MT]	LOA/B	Lpp/B	B/D	H/D	Cb	CN [m^3]	Deck Area [m^2]
1	Example vessel 1	2005	-	-	3.96	-	2.45	0.81	-	5403	350
2	Example vessel 2	2006	-	-	4.29	-	2.24	0.86	-	6462	-
3	Example vessel 3	2008	-	-	4.06	3.66	2.58	0.81	-	6448	435
4	Example vessel 4	2008	-	-	4.13	-	2.19	0.85	-	7709	416
5	Example vessel 5	2009	3544	1844	4.52	4.05	2.46	0.82	0.76	6204	425
6	Example vessel 6	2009	3343	1713	4.20	3.71	2.46	0.85	0.75	5765	-
7	Example vessel 7	2009	-	-	4.09	-	2.46	0.89	-	6812	435
8	Example vessel 8	2010	-	-	4.02	3.64	2.65	0.82	-	4714	350
9	Example vessel 9	2010	4599	2099	4.13	3.56	2.19	0.85	0.79	7709	425
10	Example vessel 10	2011	5036	2636	4.12	3.88	2.27	0.81	0.71	8931	500
11	Example vessel 11	2012	4820	2250	4.21	3.72	2.31	0.88	0.72	8354	470
12	Example vessel 12	2012	-	1391	4.02	3.64	2.65	0.86	-	4714	375
13	Example vessel 13	2014	-	-	4.02	3.64	2.65	0.87	-	4714	370
14	Example vessel 14	2015	-	-	4.06	3.66	2.58	0.84	-	6448	435
15	Example vessel 15	2017	3835	1956	4.06	3.59	2.58	0.81	0.81	6448	447
16	Example vessel 16	-	-	-	4.02	3.81	2.41	0.76	-	7360	-
17	Example vessel 17	-	-	-	4.02	-	2.65	0.86	-	4714	-
18	Example vessel 18	-	-	-	3.83	3.44	2.43	0.80	-	6213	-

GROSS AND NET TONNAGE COEFFICIENTS K1 AND K2

#	Name	GT	NT	CN [m^3]	K1	K2
1	Example vessel 1	-	-	5403.30	-	-
2	Example vessel 2	1811.00	-	6462.15	0.280	-
3	Example vessel 3	2281.00	684.00	6448.00	0.354	0.300
4	Example vessel 4	2147.00	-	7708.80	0.279	-
5	Example vessel 5	1951.00	580.00	6203.70	0.314	0.297
6	Example vessel 6	1815.00	544.00	5764.50	0.315	0.300
7	Example vessel 7	2416.00	-	6812.00	0.355	-
8	Example vessel 8	1532.00	461.00	4713.61	0.325	0.301
9	Example vessel 9	2147.00	664.00	7708.80	0.279	0.309
10	Example vessel 10	2763.00	829.00	8931.38	0.309	0.300
11	Example vessel 11	2605.00	781.00	8354.45	0.312	0.300
12	Example vessel 12	-	-	4713.61	-	-
13	Example vessel 13	1564.00	-	4713.61	0.332	-
14	Example vessel 14	2267.00	680.00	6448.00	0.352	0.300
15	Example vessel 15	2237.00	671.00	6448.00	0.347	0.300
16	Example vessel 16	-	-	7360.32	-	-
17	Example vessel 17	1500.00	-	4713.61	0.318	-
18	Example vessel 18	-	-	6213.35	-	-
					0.319	**0.301**

ANNEX J

VESSEL LOADING CONDITIONS

	ABS - Loadcase 1						ABS - Loadcase 2					
Item Name	Qty.	Total Mass [MT]	Total Volume $[m^3]$	LCG [m]	TCG [m]	VCG [m]	Qty.	Total Mass [MT]	Total Volume $[m^3]$	LCG [m]	TCG [m]	VCG [m]
Lightship	1	1414		27.9	0	5.32	1	1414		27.9	0	5.32
Subtotal LSW		1414		27.9	0	5.32		1414		27.9	0	5.32
.												
Crew	1	3.52		46	0	7.9	1	3.52		45.914	0	7.907
Food	1	4.8		48	0	8.7	0.1	0.48		47.714	0	9.117
Subtotal Crew & Food		8.32		47.154	0	8.362		4		46.13	0	8.052
.												
NO.1 Methanol Tk (P)	98%	135.75	180.567	22.206	-6.339	3.988	10%	13.852	18.425	22.25	-6.32	1.489
NO.1 Methanol Tk (S)	98%	135.75	180.567	22.206	6.339	3.988	10%	13.852	18.425	22.25	6.32	1.489
NO.2 Methanol Tk (P)	98%	72.721	96.729	14.072	-6.267	3.613	10%	7.42	9.87	15.638	-4.495	1.194
NO.2 Methanol Tk (S)	98%	72.721	96.729	14.072	6.267	3.613	10%	7.42	9.87	15.638	4.495	1.194
NO.3 Methanol Tk (S)	98%	59.327	78.913	9.032	4.056	4.529	10%	6.054	8.052	9.25	2.446	2.259
NO.3 Methanol Tk (P)	98%	59.735	79.455	9.032	-4.057	4.544	10%	6.095	8.108	9.249	-2.452	2.262
Subtotal Methanol	98%	536.003	712.96	17.072	-0.003	4.008	10%	54.694	72.751	17.568	-0.003	1.58
.												
MDO Tk (P)	98%	18.283	21.765	19.699	-4.499	0.692	10%	1.866	2.221	20.146	-3.561	0.161
MDO Tk (S)	98%	18.283	21.765	19.699	4.499	0.692	10%	1.866	2.221	20.146	3.561	0.161
Subtotal MDO	98%	36.566	43.531	19.699	0	0.692	10%	3.731	4.442	20.146	0	0.161
.												
Lube Oil Tk (P)	98%	7.752	8.426	31.5	-7.266	5.916	10%	0.791	0.86	31.5	-7.266	5.093
Lube Oil Tk (S)	98%	7.752	8.426	31.5	7.266	5.916	10%	0.791	0.86	31.5	7.266	5.093
Hyd. Oil Tk (P)	98%	6.844	7.439	27.6	-6.341	5.916	10%	0.698	0.759	27.6	-6.341	5.093
Hyd. Oil Tk (S)	98%	4.651	5.056	29.1	7.266	5.916	10%	0.475	0.516	29.1	7.266	5.093
Subtotal Oil	98%	26.999	29.346	30.098	-0.356	5.916	10%	2.755	2.995	30.098	-0.356	5.093
.												
NO.2 Fresh Water Tk (P)	100%	48.735	48.735	45.476	-6.578	4.625	10%	4.873	4.873	45.21	-6.293	2.384
NO.2 Fresh Water Tk (S)	100%	48.735	48.735	45.476	6.578	4.625	10%	4.873	4.873	45.21	6.293	2.384
Subtotal Fresh Water	100%	97.47	97.47	45.476	0	4.625	10%	9.747	9.747	45.21	0	2.384
.												
Potable Water Tk	100%	23.424	23.424	48.965	0	1.259	10%	2.342	2.342	48.966	0	0.291
Subtotal Potable Water	100%	23.424	23.424	48.965	0	1.259	10%	2.342	2.342	48.966	0	0.291
.												
Urea Tk (P)	100%	17.416	15.832	22.808	-4.828	0.642	10%	1.742	1.583	22.83	-4.007	0.105
Urea Tk (S)	100%	17.416	15.832	22.808	4.828	0.642	10%	1.742	1.583	22.83	4.007	0.105
Subtotal Urea	100%	34.831	31.665	22.808	0	0.642	10%	3.483	3.166	22.83	0	0.105
.												
Fore Peak Tk	100%	172.842	168.626	57.628	0	5.953	100%	172.842	168.626	57.628	0	5.953
NO.1 Ballast/Drill Water Tk (P)	100%	20.662	20.158	54.554	-3.863	5.051	100%	20.662	20.158	54.554	-3.863	5.051
NO.1 Ballast/Drill Water Tk (S)	100%	20.662	20.158	54.554	3.863	5.051	100%	20.662	20.158	54.554	3.863	5.051
NO.2 Ballast/Drill Water Tk (P)	100%	40.239	39.258	45.429	-2.427	1.236	100%	40.239	39.258	45.429	-2.427	1.236
NO.2 Ballast/Drill Water Tk (S)	100%	40.239	39.258	45.429	2.427	1.236	100%	40.239	39.258	45.429	2.427	1.236
NO.3 Ballast/Drill Water Tk (P)	100%	60.144	58.677	38.254	-3.027	0.691	100%	60.144	58.677	38.254	-3.027	0.691
NO.3 Ballast/Drill Water Tk (S)	100%	60.144	58.677	38.254	3.027	0.691	100%	60.144	58.677	38.254	3.027	0.691
NO.4 Ballast/Drill Water Tk (P)	100%	54.557	53.226	31.155	-3.772	0.636	100%	54.557	53.226	31.155	-3.772	0.636
NO.4 Ballast/Drill Water Tk (S)	100%	54.557	53.226	31.155	3.772	0.636	100%	54.557	53.226	31.155	3.772	0.636
NO.5 Ballast/Drill Water Tk (P)	0%	0	0	26.099	-0.094	0	0%	0	0	26.099	-0.094	0
NO.5 Ballast/Drill Water Tk (S)	0%	0	0	26.099	0.094	0	0%	0	0	26.099	0.094	0
NO.6 Ballast/Drill Water Tk	0%	0	0	17.382	0	0.024	0%	0	0	17.382	0	0.024
NO.7 Ballast/Drill Water Tk (P)	0%	0	0	7.78	-0.179	1.45	0%	0	0	7.78	-0.179	1.45
NO.7 Ballast/Drill Water Tk (S)	0%	0	0	7.78	0.179	1.45	0%	0	0	7.78	0.179	1.45
NO.1 Aft. Peak Tk (P)	0%	0	0	-6.373	0	3.757	0%	0	0	-6.373	0	3.757
NO.1 Aft. Peak Tk (S)	0%	0	0	-6.373	0	3.757	0%	0	0	-6.373	0	3.757
NO.2 Aft. Peak Tk	0%	0	0	-6.373	0	4.444	0%	0	0	-6.373	0	4.444
Subtotal Ballast/Drill Water	63%	524.047	511.266	45.553	0	2.843	63%	524.047	511.266	45.553	0	2.843
.												
NO.1 Fresh Water Tk (P)	100%	79.499	79.499	50.404	-4.956	4.747	100%	79.499	79.499	50.404	-4.956	4.747
NO.1 Fresh Water Tk (S)	100%	79.499	79.499	50.404	4.956	4.747	100%	79.499	79.499	50.404	4.956	4.747
NO.3 Fresh Water Tk (P)	100%	73.206	73.206	38.542	-7.233	4.164	100%	73.206	73.206	38.542	-7.233	4.164
NO.3 Fresh Water Tk (S)	100%	73.206	73.206	38.542	7.233	4.164	100%	73.206	73.206	38.542	7.233	4.164
NO.1 Mud Tk (P)	100%	433.108	173.243	13.856	-3.257	4.638	100%	433.108	173.243	13.856	-3.257	4.638
NO.1 Mud Tk (S)	100%	433.108	173.243	13.856	3.257	4.638	100%	433.108	173.243	13.856	3.257	4.638
NO.1 Dry Bulk Tk (P)	100%	71.12	51.536	45.586	-3.3	4.272	100%	71.12	51.536	45.586	-3.3	4.272
NO.1 Dry Bulk Tk (S)	100%	71.12	51.536	45.586	3.3	4.272	100%	71.12	51.536	45.586	3.3	4.272
NO.2 Dry Bulk Tk (P)	100%	85.345	61.844	19.567	-2.776	3.872	100%	85.345	61.844	19.567	-2.776	3.872
NO.2 Dry Bulk Tk (S)	100%	84.781	61.436	19.563	2.776	3.884	100%	84.781	61.436	19.563	2.776	3.884
Subtotal Below Deck Cargo	100%	1483.990	878.247	23.903	-0.001	4.481	100%	1483.990	878.247	23.903	-0.001	4.481
.												
Deck Cargo	12%	122		20.074	0	8.207	12%	122		20.074	0	8.207
Subtotal Deck Cargo		122		20.074	0	8.207		122		20.074	0	8.207
.												
Detergent (S)	100%	10.475	10.475	32.1	7.266	3.101	100%	10.475	10.475	32.1	7.266	3.101
Foam (P)	100%	10.475	10.475	32.1	-7.266	3.101	100%	10.475	10.475	32.1	-7.266	3.101
Sewage Water Tk (P)	0%	0	0	30.6	-7.263	1.2	100%	6.288	6.987	30.6	-7.266	3.1
Sewage Water Tk (S)	0%	0	0	30.6	7.263	1.2	100%	6.288	6.987	30.6	7.266	3.1
Grey Water Tk (P)	0%	0	0	27.6	-6.341	2.4	100%	10.554	10.554	27.6	-6.341	3.7
Grey Water Tk (S)	0%	0	0	29.1	7.265	1.2	100%	10.482	10.482	29.1	7.266	3.1
Dirty Oil Tk	0%	0	0	23.493	0	0	98%	10.381	11.284	22.8	0	0.588
Bilge Tk (P)	0%	0	0	21.561	-0.425	0.001	100%	8.361	9.954	19.512	-0.998	0.607
Sludge Tk (S)	0%	0	0	21.561	0.425	0.001	100%	9.158	9.954	19.512	0.998	0.607
Subtotal Misc.	25.34%	20.95	20.95	32.1	0	3.101	99.74%	82.463	87.152	27.069	0.122	2.331
.												
Total Loadcase		4328.601	2348.859	27.576	-0.003	4.536		3707.253	1572.108	28.434	0.002	4.589
FS correction						0						0.174
VCG fluid						4.536						4.763

	ABS - Loadcase 3						ABS - Loadcase 4					
Item Name	Qty.	Total Mass [MT]	Total Volume $[m^3]$	LCG [m]	TCG [m]	VCG [m]	Qty.	Total Mass [MT]	Total Volume $[m^3]$	LCG [m]	TCG [m]	VCG [m]
Lightship	1	1414		27.9	0	5.32	1	1414		27.9	0	5.32
Subtotal LSW		1414		27.9	0	5.32		1414		27.9	0	5.32
.												
Crew	1	3.52		45.914	0	7.907	1	3.52		45.914	0	7.907
Food	1	4.8		47.714	0	9.117	0.1	0.48		47.714	0	9.117
Subtotal Crew & Food		8.32		46.953	0	8.605		4		46.13	0	8.052
.												
NO.1 Methanol Tk (P)	98%	135.75	180.567	22.206	-6.339	3.988	10%	13.852	18.425	22.25	-6.32	1.489
NO.1 Methanol Tk (S)	98%	135.75	180.567	22.206	6.339	3.988	10%	13.852	18.425	22.25	6.32	1.489
NO.2 Methanol Tk (P)	98%	72.721	96.729	14.072	-6.267	3.613	10%	7.42	9.87	15.638	-4.495	1.194
NO.2 Methanol Tk (S)	98%	72.721	96.729	14.072	6.267	3.613	10%	7.42	9.87	15.638	4.495	1.194
NO.3 Methanol Tk (S)	98%	59.327	78.913	9.032	4.056	4.529	10%	6.054	8.052	9.25	2.446	2.259
NO.3 Methanol Tk (P)	98%	59.735	79.455	9.032	-4.057	4.544	10%	6.095	8.108	9.249	-2.452	2.262
Subtotal Methanol	98%	536.003	712.96	17.072	-0.003	4.008	10%	54.694	72.751	17.568	-0.003	1.58
.												
MDO Tk (P)	98%	18.283	21.765	19.699	-4.499	0.692	10%	1.866	2.221	20.146	-3.561	0.161
MDO Tk (S)	98%	18.283	21.765	19.699	4.499	0.692	10%	1.866	2.221	20.146	3.561	0.161
Subtotal MDO	98%	36.566	43.531	19.699	0	0.692	10%	3.731	4.442	20.146	0	0.161
.												
Lube Oil Tk (P)	98%	7.752	8.426	31.5	-7.266	5.916	10%	0.791	0.86	31.5	-7.266	5.093
Lube Oil Tk (S)	98%	7.752	8.426	31.5	7.266	5.916	10%	0.791	0.86	31.5	7.266	5.093
Hyd. Oil Tk (P)	98%	6.844	7.439	27.6	-6.341	5.916	10%	0.698	0.759	27.6	-6.341	5.093
Hyd. Oil Tk (S)	98%	4.651	5.056	29.1	7.266	5.916	10%	0.475	0.516	29.1	7.266	5.093
Subtotal Oil	98%	26.999	29.346	30.098	-0.356	5.916	10%	2.755	2.995	30.098	-0.356	5.093
.												
NO.2 Fresh Water Tk (P)	100%	48.735	48.735	45.476	-6.578	4.625	10%	4.873	4.873	45.21	-6.293	2.384
NO.2 Fresh Water Tk (S)	100%	48.735	48.735	45.476	6.578	4.625	10%	4.873	4.873	45.21	6.293	2.384
Subtotal Fresh Water	100%	97.47	97.47	45.476	0	4.625	10%	9.747	9.747	45.21	0	2.384
.												
Potable Water Tk	100%	23.424	23.424	48.965	0	1.259	10%	2.342	2.342	48.966	0	0.291
Subtotal Potable Water	100%	23.424	23.424	48.965	0	1.259	10%	2.342	2.342	48.966	0	0.291
.												
Urea Tk (P)	100%	17.416	15.832	22.808	-4.828	0.642	10%	1.742	1.583	22.83	-4.007	0.105
Urea Tk (S)	100%	17.416	15.832	22.808	4.828	0.642	10%	1.742	1.583	22.83	4.007	0.105
Subtotal Urea	100%	34.831	31.665	22.808	0	0.642	10%	3.483	3.166	22.83	0	0.105
.												
Fore Peak Tk	100%	172.842	168.626	57.628	0	5.953	100%	172.842	168.626	57.628	0	5.953
NO.1 Ballast/Drill Water Tk (P)	100%	20.662	20.158	54.554	-3.863	5.051	100%	20.662	20.158	54.554	-3.863	5.051
NO.1 Ballast/Drill Water Tk (S)	100%	20.662	20.158	54.554	3.863	5.051	100%	20.662	20.158	54.554	3.863	5.051
NO.2 Ballast/Drill Water Tk (P)	100%	40.239	39.258	45.429	-2.427	1.236	100%	40.239	39.258	45.429	-2.427	1.236
NO.2 Ballast/Drill Water Tk (S)	100%	40.239	39.258	45.429	2.427	1.236	100%	40.239	39.258	45.429	2.427	1.236
NO.3 Ballast/Drill Water Tk (P)	100%	60.144	58.677	38.254	-3.027	0.691	0%	0	0	37.768	-0.03	0
NO.3 Ballast/Drill Water Tk (S)	100%	60.144	58.677	38.254	3.027	0.691	0%	0	0	37.768	0.03	0
NO.4 Ballast/Drill Water Tk (P)	0%	0	0	30.93	-0.086	0	100%	54.557	53.226	31.155	-3.772	0.636
NO.4 Ballast/Drill Water Tk (S)	0%	0	0	30.93	0.086	0	100%	54.557	53.226	31.155	3.772	0.636
NO.5 Ballast/Drill Water Tk (P)	0%	0	0	26.099	-0.094	0	0%	0	0	26.099	-0.094	0
NO.5 Ballast/Drill Water Tk (S)	0%	0	0	26.099	0.094	0	0%	0	0	26.099	0.094	0
NO.6 Ballast/Drill Water Tk	0%	0	0	17.382	0	0.024	0%	0	0	17.382	0	0.024
NO.7 Ballast/Drill Water Tk (P)	0%	0	0	7.78	-0.179	1.45	100%	18.451	18.001	6.924	-5.585	4.445
NO.7 Ballast/Drill Water Tk (S)	0%	0	0	7.78	0.179	1.45	100%	18.451	18.001	6.924	5.585	4.445
NO.1 Aft. Peak Tk (P)	0%	0	0	-6.373	0	3.757	0%	0	0	-6.373	0	3.757
NO.1 Aft. Peak Tk (S)	0%	0	0	-6.373	0	3.757	0%	0	0	-6.373	0	3.757
NO.2 Aft. Peak Tk	0%	0	0	-6.373	0	4.444	0%	0	0	-6.373	0	4.444
Subtotal Ballast/Drill Water	50%	414.933	404.813	49.339	0	3.423	53%	440.66	429.912	44.311	0	3.564
.												
NO.1 Fresh Water Tk (P)	100%	79.499	79.499	50.404	-4.956	4.747	100%	79.499	79.499	50.404	-4.956	4.747
NO.1 Fresh Water Tk (S)	100%	79.499	79.499	50.404	4.956	4.747	100%	79.499	79.499	50.404	4.956	4.747
NO.3 Fresh Water Tk (P)	100%	73.206	73.206	38.542	-7.233	4.164	100%	73.206	73.206	38.542	-7.233	4.164
NO.3 Fresh Water Tk (S)	100%	73.206	73.206	38.542	7.233	4.164	100%	73.206	73.206	38.542	7.233	4.164
NO.1 Mud Tk (P)	0%	0	0	17.239	-1.98	2.2	0%	0	0	17.239	-1.98	2.2
NO.1 Mud Tk (S)	0%	0	0	17.239	1.98	2.2	0%	0	0	17.239	1.98	2.2
NO.1 Dry Bulk Tk (P)	100%	71.12	51.536	45.586	-3.3	4.272	100%	71.12	51.536	45.586	-3.3	4.272
NO.1 Dry Bulk Tk (S)	100%	71.12	51.536	45.586	3.3	4.272	100%	71.12	51.536	45.586	3.3	4.272
NO.2 Dry Bulk Tk (P)	100%	85.345	61.844	19.567	-2.776	3.872	100%	85.345	61.844	19.567	-2.776	3.872
NO.2 Dry Bulk Tk (S)	100%	84.781	61.436	19.563	2.776	3.884	100%	84.781	61.436	19.563	2.776	3.884
Subtotal Below Deck Cargo	42%	617.775	531.761	37.991	-0.003	4.26	41.63%	617.775	531.761	37.991	-0.003	4.26
.												
Deck Cargo	100%	1000		20.074	0	8.207	100%	1000		20.074	0	8.207
Subtotal Deck Cargo		1000		20.074	0	8.207		1000		20.074	0	8.207
.												
Detergent (S)	100%	10.475	10.475	32.1	7.266	3.101	100%	10.475	10.475	32.1	7.266	3.101
Foam (P)	100%	10.475	10.475	32.1	-7.266	3.101	100%	10.475	10.475	32.1	-7.266	3.101
Sewage Water Tk (P)	0%	0	0	30.6	-7.263	1.2	100%	6.288	6.987	30.6	-7.266	3.1
Sewage Water Tk (S)	0%	0	0	30.6	7.263	1.2	100%	6.288	6.987	30.6	7.266	3.1
Grey Water Tk (P)	0%	0	0	27.6	-6.341	2.4	100%	10.554	10.554	27.6	-6.341	3.7
Grey Water Tk (S)	0%	0	0	29.1	7.265	1.2	100%	10.482	10.482	29.1	7.266	3.1
Dirty Oil Tk	0%	0	0	23.493	0	0	98%	10.381	11.284	22.8	0	0.588
Bilge Tk (P)	0%	0	0	21.561	-0.425	0.001	100%	8.361	9.954	19.512	-0.998	0.607
Sludge Tk (S)	0%	0	0	21.561	0.425	0.001	100%	9.158	9.954	19.512	0.998	0.607
Subtotal Misc.	25.34%	20.95	20.95	32.1	0	3.101	99.74%	82.463	87.152	27.069	0.122	2.331
.												
Total Loadcase		4231.271	1895.92	28.735	-0.003	5.378		3635.651	1144.268	29.346	0.002	5.579
FS correction						0						0.178
VCG fluid						5.378						5.756

	ABS - Loadcase 5						ABS - Loadcase 6						ABS - Loadcase 7					
Item Name	Qty.	Total Mass [MT]	Total Volume $[m^3]$	LCG [m]	TCG [m]	VCG [m]	Qty.	Total Mass [MT]	Total Volume $[m^3]$	LCG [m]	TCG [m]	VCG [m]	Qty.	Total Mass [MT]	Total Volume $[m^3]$	LCG [m]	TCG [m]	VCG [m]
Lightship	1	1414		27.9	0	5.32	1	1414		27.9	0	5.32	1	1414		27.9	0	5.32
Subtotal LSW		1414		27.9	0	5.32		1414		27.9	0	5.32		1414		27.9	0	5.32
.																		
Crew	1	3.52		45.914	0	7.907	1	3.52		46	0	7.9	1	3.52		46	0	7.9
Food	1	4.8		47.714	0	9.117	0.1	0.48		48	0	8.7	0.1	0.48		48	0	8.7
Subtotal Crew & Food		8.32		46.953	0	8.605		4		46.24	0	7.996		4		46.24	0	7.996
.																		
NO.1 Methanol Tk (P)	98%	135.75	180.567	22.206	-6.339	3.988	10%	13.852	18.425	22.25	-6.32	1.489	10%	13.852	18.425	22.25	-6.32	1.489
NO.1 Methanol Tk (S)	98%	135.75	180.567	22.206	6.339	3.988	10%	13.852	18.425	22.25	6.32	1.489	10%	13.852	18.425	22.25	6.32	1.489
NO.2 Methanol Tk (P)	98%	72.721	96.729	14.072	-6.267	3.613	10%	7.42	9.87	15.638	-4.495	1.194	10%	7.42	9.87	15.638	-4.495	1.194
NO.2 Methanol Tk (S)	98%	72.721	96.729	14.072	6.267	3.613	10%	7.42	9.87	15.638	4.495	1.194	10%	7.42	9.87	15.638	4.495	1.194
NO.3 Methanol Tk (S)	98%	59.327	78.913	9.032	4.056	4.529	10%	6.054	8.052	9.25	2.446	2.259	10%	6.054	8.052	9.25	2.446	2.259
NO.3 Methanol Tk (P)	98%	59.735	79.455	9.032	-4.057	4.544	10%	6.095	8.108	9.249	-2.452	2.262	10%	6.095	8.108	9.249	-2.452	2.262
Subtotal Methanol	98%	536.003	712.96	17.072	-0.003	4.008	10%	54.694	72.751	17.568	-0.003	1.58	10%	54.694	72.751	17.568	-0.003	1.58
.																		
MDO Tk (P)	98%	18.283	21.765	19.699	-4.499	0.692	10%	1.866	2.221	20.146	-3.561	0.161	10%	1.866	2.221	20.146	-3.561	0.161
MDO Tk (S)	98%	18.283	21.765	19.699	4.499	0.692	10%	1.866	2.221	20.146	3.561	0.161	10%	1.866	2.221	20.146	3.561	0.161
Subtotal MDO	98%	36.566	43.531	19.699	0	0.692	10%	3.731	4.442	20.146	0	0.161	10%	3.731	4.442	20.146	0	0.161
.																		
Lube Oil Tk (P)	98%	7.752	8.426	31.5	-7.266	5.916	10%	0.791	0.86	31.5	-7.266	5.093	10%	0.791	0.86	31.5	-7.266	5.093
Lube Oil Tk (S)	98%	7.752	8.426	31.5	7.266	5.916	10%	0.791	0.86	31.5	7.266	5.093	10%	0.791	0.86	31.5	7.266	5.093
Hyd. Oil Tk (P)	98%	6.844	7.439	27.6	-6.341	5.916	10%	0.698	0.759	27.6	-6.341	5.093	10%	0.698	0.759	27.6	-6.341	5.093
Hyd. Oil Tk (S)	98%	4.651	5.056	29.1	7.266	5.916	10%	0.475	0.516	29.1	7.266	5.093	10%	0.475	0.516	29.1	7.266	5.093
Subtotal Oil	98%	26.999	29.346	30.098	-0.356	5.916	10%	2.755	2.995	30.098	-0.356	5.093	10%	2.755	2.995	30.098	-0.356	5.093
.																		
NO.2 Fresh Water Tk (P)	100%	48.735	48.735	45.476	-6.578	4.625	10%	4.873	4.873	45.21	-6.293	2.384	10%	4.873	4.873	45.21	-6.293	2.384
NO.2 Fresh Water Tk (S)	100%	48.735	48.735	45.476	6.578	4.625	10%	4.873	4.873	45.21	6.293	2.384	10%	4.873	4.873	45.21	6.293	2.384
Subtotal Fresh Water	100%	97.47	97.47	45.476	0	4.625	10%	9.747	9.747	45.21	0	2.384	10%	9.747	9.747	45.21	0	2.384
.																		
Potable Water Tk	100%	23.424	23.424	48.965	0	1.259	10%	2.342	2.342	48.966	0	0.291	10%	2.342	2.342	48.966	0	0.291
Subtotal Potable Water	100%	23.424	23.424	48.965	0	1.259	10%	2.342	2.342	48.966	0	0.291	10%	2.342	2.342	48.966	0	0.291
.																		
Urea Tk (P)	100%	17.416	15.832	22.808	-4.828	0.642	10%	1.742	1.583	22.83	-4.007	0.105	10%	1.742	1.583	22.83	-4.007	0.105
Urea Tk (S)	100%	17.416	15.832	22.808	4.828	0.642	10%	1.742	1.583	22.83	4.007	0.105	10%	1.742	1.583	22.83	4.007	0.105
Subtotal Urea	100%	34.831	31.665	22.808	0	0.642	10%	3.483	3.166	22.83	0	0.105	10%	3.483	3.166	22.83	0	0.105
.																		
Fore Peak Tk	100%	172.842	168.626	57.628	0	5.953	100%	172.842	168.626	57.628	0	5.953	100%	172.842	168.626	57.628	0	5.953
NO.1 Ballast/Drill Water Tk (P)	100%	20.662	20.158	54.554	-3.863	5.051	100%	20.662	20.158	54.554	-3.863	5.051	100%	20.662	20.158	54.554	-3.863	5.051
NO.1 Ballast/Drill Water Tk (S)	100%	20.662	20.158	54.554	3.863	5.051	100%	20.662	20.158	54.554	3.863	5.051	100%	20.662	20.158	54.554	3.863	5.051
NO.2 Ballast/Drill Water Tk (P)	100%	40.239	39.258	45.429	-2.427	1.236	100%	40.239	39.258	45.429	-2.427	1.236	100%	40.239	39.258	45.429	-2.427	1.236
NO.2 Ballast/Drill Water Tk (S)	100%	40.239	39.258	45.429	2.427	1.236	100%	40.239	39.258	45.429	2.427	1.236	100%	40.239	39.258	45.429	2.427	1.236
NO.3 Ballast/Drill Water Tk (P)	100%	60.144	58.677	38.254	-3.027	0.691	0%	0	0	37.768	-0.03	0	100%	60.144	58.677	38.254	-3.027	0.691
NO.3 Ballast/Drill Water Tk (S)	100%	60.144	58.677	38.254	3.027	0.691	0%	0	0	37.768	0.03	0	100%	60.144	58.677	38.254	3.027	0.691
NO.4 Ballast/Drill Water Tk (P)	100%	54.557	53.226	31.155	-3.772	0.636	100%	54.557	53.226	31.155	-3.772	0.636	100%	54.557	53.226	31.155	-3.772	0.636
NO.4 Ballast/Drill Water Tk (S)	100%	54.557	53.226	31.155	3.772	0.636	100%	54.557	53.226	31.155	3.772	0.636	100%	54.557	53.226	31.155	3.772	0.636
NO.5 Ballast/Drill Water Tk (P)	0%	0	0	26.099	-0.094	0	0%	0	0	26.099	-0.094	0	0%	0	0	26.099	-0.094	0
NO.5 Ballast/Drill Water Tk (S)	0%	0	0	26.099	0.094	0	0%	0	0	26.099	0.094	0	0%	0	0	26.099	0.094	0
NO.6 Ballast/Drill Water Tk	0%	0	0	17.382	0	0.024	0%	0	0	17.382	0	0.024	0%	0	0	17.382	0	0.024
NO.7 Ballast/Drill Water Tk (P)	0%	0	0	7.78	-0.179	1.45	0%	0	0	7.78	-0.179	1.45	0%	0	0	7.78	-0.179	1.45
NO.7 Ballast/Drill Water Tk (S)	0%	0	0	7.78	0.179	1.45	0.00%	0	0	7.78	0.179	1.45	0.00%	0	0	7.78	0.179	1.45
NO.1 Aft. Peak Tk (P)	0%	0	0	-6.373	0	3.757	100%	44.73	43.639	0.363	-6.525	5.848	0%	0	0	-6.373	0	3.757
NO.1 Aft. Peak Tk (S)	0%	0	0	-6.373	0	3.757	100%	44.73	43.639	0.363	6.525	5.848	0%	0	0	-6.373	0	3.757
NO.2 Aft. Peak Tk	0%	0	0	-6.373	0	4.444	0%	0	0	-6.373	0	4.444	0%	0	0	-6.373	0	4.444
Subtotal Ballast/Drill Water	63%	524.047	511.266	45.553	0	2.843	59%	493.219	481.189	39.136	0	3.913	63%	524.047	511.266	45.553	0	2.843
.																		
NO.1 Fresh Water Tk (P)	0%	0	0	49.7	-4.031	2	0%	0	0	49.7	-4.031	2	0%	0	0	49.7	-4.031	2
NO.1 Fresh Water Tk (S)	0%	0	0	49.7	4.031	2	0%	0	0	49.7	4.031	2	0%	0	0	49.7	4.031	2
NO.3 Fresh Water Tk (P)	0%	0	0	37.136	-7.068	1.2	0%	0	0	37.136	-7.068	1.2	0%	0	0	37.136	-7.068	1.2
NO.3 Fresh Water Tk (S)	0%	0	0	37.136	7.068	1.2	0%	0	0	37.136	7.068	1.2	0%	0	0	37.136	7.068	1.2
NO.1 Mud Tk (P)	0%	0	0	17.239	-1.98	2.2	0%	0	0	17.239	-1.98	2.2	0%	0	0	17.239	-1.98	2.2
NO.1 Mud Tk (S)	0%	0	0	17.239	1.98	2.2	0%	0	0	17.239	1.98	2.2	0%	0	0	17.239	1.98	2.2
NO.1 Dry Bulk Tk (P)	0%	0	0	45.632	-2.2	2.001	0%	0	0	45.632	-2.2	2.001	0%	0	0	45.632	-2.2	2.001
NO.1 Dry Bulk Tk (S)	0%	0	0	45.632	2.2	2.001	0%	0	0	45.632	2.2	2.001	0%	0	0	45.632	2.2	2.001
NO.2 Dry Bulk Tk (P)	0%	0	0	19.565	-2.333	1.201	0%	0	0	19.565	-2.333	1.201	0%	0	0	19.565	-2.333	1.201
NO.2 Dry Bulk Tk (S)	0%	0.000	0	19.556	2.768	1.3	0%	0.000	0	19.556	2.768	1.3	0%	0.000	0	19.556	2.768	1.3
Subtotal Below Deck Cargo	0%	0.000	0	0	0	0	0%	0.000	0	0	0	0	0%	0.000	0	0	0	0
.																		
Deck Cargo	0%	0		20.074	0	8.207	0%	0		20.074	0	8.207	100%	1000		20.074	0	8.207
Subtotal Deck Cargo		0		0	0	0		0		0	0	0		1000		20.074	0	8.207
.																		
Detergent (S)	0%	0	0	32.098	7.257	1.2	0%	0	0	32.098	7.257	1.2	0%	0	0	32.098	7.257	1.2
Foam (P)	0%	0	0	32.098	-7.257	1.2	0%	0	0	32.098	-7.257	1.2	0%	0	0	32.098	-7.257	1.2
Sewage Water Tk (P)	0%	0	0	30.6	-7.263	1.2	100%	6.288	6.987	30.6	-7.266	3.1	100%	6.288	6.987	30.6	-7.266	3.1
Sewage Water Tk (S)	0%	0	0	30.6	7.263	1.2	100%	6.288	6.987	30.6	7.266	3.1	100%	6.288	6.987	30.6	7.266	3.1
Grey Water Tk (P)	0%	0	0	27.6	-6.341	2.4	100%	10.554	10.554	27.6	-6.341	3.7	100%	10.554	10.554	27.6	-6.341	3.7
Grey Water Tk (S)	0%	0	0	29.1	7.265	1.2	100.0%	10.482	10.482	29.1	7.266	3.1	100.0%	10.482	10.482	29.1	7.266	3.1
Dirty Oil Tk	0%	0	0	23.493	0	0	98.00%	10.381	11.284	22.8	0	0.588	98.00%	10.381	11.284	22.8	0	0.588
Bilge Tk (P)	0%	0	0	21.561	-0.425	0.001	100%	8.361	9.954	19.512	-0.998	0.607	100%	8.361	9.954	19.512	-0.998	0.607
Sludge Tk (S)	0%	0	0	21.561	0.425	0.001	100%	9.158	9.954	19.512	0.998	0.607	100%	9.158	9.954	19.512	0.998	0.607
Subtotal Misc.	0%	0	0	0	0	0	74.40%	61.513	66.202	25.355	0.163	2.069	74.40%	61.513	66.202	25.355	0.163	2.069
.																		
Total Loadcase		2701.661	1449.662	29.897	-0.004	4.412		2049.485	642.835	30.374	0.004	4.751		3080.313	672.911	28.21	0.003	5.682
FS correction						0						0.315						0.21
VCG fluid						4.412						5.066						5.892