Concept design of a Fast Inspection Repair and Maintenance vessel

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K.W. van der Leij

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Technical University Delft
Damen Shipyard Gorinchem

Abstract

This report describes the design of an Inspection, Repair and Maintenance (IRM) vessel for the offshore oil and gas market with the possibility to sail at a maximum speed of 25 knots. The idea came from an operator who wanted to investigate the possibility of a relatively high speed offshore vessel to decrease the transit time in order to increase the amount of working days and in case of emergency response. The problem that arose was that existing IRM vessels have a hull shape which is not built for speed, it had to be investigated which design is suitable for both speed and stationary crane operations at sea.

All the requirements of the vessels were summed up and a market analysis of the offshore oil and gas market was made to get an insight of the operations and supporting vessels, this resulted in the design of two concept vessels, a mono-hull and a catamaran. Both mono-hull and catamaran were designed as a displacement type vessel. The two concepts vessels were tested to each other on several criteria and eventually the mono-hull was chosen because of a significantly lower resistance.

Subsequently the mono-hull concept was evaluated and improvements have been made to solve some problems that arose for the first design. Eventually a final concept vessel was designed. Initially the linesplan was based on a fast displacement parent hull form developed by Marwood and Bailey. The lines were altered to fit all the components, but still very slim for an offshore vessel. Over the length of the work deck "sponsoons" were integrated in the hull, so the operator can increase the waterplane area and displacement of the vessel during hoisting operations and create extra transverse stability by increasing the draft of the vessel.

It can be concluded that a Fast Inspection Repair and Maintenance vessel with a speed requirement of 25 knots is technically possible. However it is very likely that about 90% of the operational time only a limited percentage of the entire installed propulsion power is used, making it a very expensive vessel to buy and operate. On the other hand the day rates of these vessels are in the order of millions, which makes it possible to earn back the investment.

The report is subdivided into six chapters. The first chapter provides an introduction into the offshore oil and gas market through a market analyses. This market analyses together with the initial requirements for the vessel will form the design questions for this project. Chapter two covers the design process of a mono-hull concept. All design aspects like for instance hull form design, resistance calculation, stability calculations and seaway calculations are discussed. The third chapter covers the same design process but now for a catamaran design. Eventually these two concepts are compared to each other in Chapter 4 from which one design is chosen. This design is than evaluated and improved in Chapter 5 leading to the final design for this vessel. The last chapter provides a conclusion and future recommendations for this project.

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1. Main challenges and problem description

The goal for this thesis is to design a concept vessel of an Inspection Repair & Maintenance vessel (IRM) for the offshore oil and gas market. These vessels are deployed worldwide and often have to cope with large transit distances. The idea for this concept is a vessel with all the capabilities of a regular IRM vessel and the ability to sail at 25 knots. This new type of vessel will be called FIRM, Fast Inspection Repair and Maintenance vessel. The speed of 25 knots should give this vessel an advantage over other competitive vessels and will be unique in the offshore oil and gas market.

The main challenge for this concept vessel lies in the speed requirement. Current IRM vessels sail at a maximum speed which lies around 16 knots; this is significantly lower than the required 25 knots for this vessel. Resulting in a design that has to be able to reach this speed and has enough stability to perform crane operations while stationary at sea.

To be able to design a concept vessel, first a market analyses was made which covers the oil and gas winning processes and supporting vessels. This market analyses together with the initial requirements from Damen leads to a series of design questions. On the basis of these criteria and questions the design process is started.

1.1 Market analyses: The offshore oil and gas market

To get a good picture of the offshore oil and gas industry a market analyses has been made. This market analyses is performed to get a better insight of the offshore oil and gas market. Is gives an overview of the processes involved and the vessels used in the support of these processes.

The offshore oil and gas winning process is depending on a variety of technically advanced vessels. Each step of the process, from locating the fields till supplying the rigs, needs dedicated vessels to make offshore oil and gas winning possible. To get a good impression of the entire process an overview is made that shows each step in the chain with the corresponding vessels and their specific tasks. This way it is possible to “fit” the FIRM into the chain and see where the concept can be implemented.

The process of finding and producing oil and bringing it to shore are categorized into upstream and downstream activities. In case of offshore oil and gas winning, all activities from searching and finding hydrocarbons and/or gas till production and bringing it to shore are called upstream activities. Downstream activities cover the moment the product reaches the refinery till the final product flows into for example a car. This analysis focuses on the offshore activities, so downstream activities are not considered.

1.1.1 Processes and supporting vessels

Upstream activities are categorized in two main activities, exploration and exploitation. In order to complete the chain of offshore activities, also decommissioning, abandonment and removal off offshore installations is added.

Exploration

Exploration starts with a geological study of the environment, if geologists conclude that oil and gas may have formed in that area seismic research vessels will perform a seismic investigation to visualize the layers of the earth’s crust. If the outcome of this investigation reveals the potential entrapment of hydrocarbons, it is necessary to perform exploration drillings. These drillings are the only irrefutable way to prove the presence of oil and gas. Drilling an exploration well on the seabed requires a platform above water with a drilling rig.

Geophysical survey/seismic surveying

Oil companies’ basic assets are oil and gas containing reservoirs, and detection of these fields by geophysical research are of vital importance. There are several tools available to carry out such a research, variations in the earth gravity- or magnetic field can be measured with airborne equipment and air photographs. More precise are seismic surveys, which in case of an offshore field have to be carried out by seismic research vessels. Reflected seismic waves are used to reveal the earth layers, called horizons by geologists, in order to find in particular anticline structures, faults, salt dome outcroppings etc.

Exploration drilling

If a geophysical survey gives an expectation of a possible oil or gas accumulation under the sea bed a test drill is made to determine the size, potential productivity and to test the formation. This procedure can be carried out by rigs or Mobile Drilling Units (MODU). A MODU is an integrated unit with a drilling rig and all necessary auxiliaries, accommodation and stores. This type of rig was first used in the 1950s and costs far less money than a standard drilling rig, because it can easily be relocated and used for several drillings.

There is a significant difference between shallow water drilling on bottom supported rigs and deep water on floating rigs. Drilling on bottom supported rigs resembles drilling on land and is less complex than drilling on floating rigs or vessels. This is because the drilling process largely determines the machinery and stores on a rig or vessel, and this is far greater on a floating platform.

Exploitation

If exploration determines the presence of hydrocarbons and it is economically attractive to extract these from the earth, a production platform is placed to start exploitation of the well. There are several types of production platforms of witch the jacket is the most common. A jacket is a steel structure that is piled into the seabed and has a platform well above the highest wave crests. Other types of platforms are: Compliant towers; Gravity based structures; Tension leg-platforms; Semi-submersible platforms; Spar platforms; Sub-sea installations. After drilling a production well the actual production process starts. This consists of bringing the oil or gas to the surface, transporting it to shore and refining it to an end product. In this thesis, refining is not considered because it's an on shore process and the focus is on off shore activities.

Production drilling

Production drilling is the same operation as explorations drilling, only know it is sure that hydrocarbons are present and the best location in the field is chosen for the placement of the production platform. There are several types of platforms, as explained above, and they are either floating or non-floating. For deep water offshore operations, non-floating platform are required. Shallow water operations usually have a non-floating platform, which is more stable than a floating one.

Production

Production of oil and gas is process from bringing the product from the underground reservoirs to the sales point. Drilling, both onshore and offshore, forms a major cost and time expense in the development of oil and gas fields, but offshore and especially in deep water may be multiple of land drilling costs. The exploration wells which were used to determine the presence and quality of hydrocarbons are not used for production, because their position in the field isn't optimized for flow. Therefore a number of so called development wells are drilled, mostly vertical or even horizontally. For both well types, the drilling technology is identical, the difference starts with the well completion, when one or more tubes are lowered into the cased hole and the casing is perforated to provide access for the reservoir fluids to the hole.

Transportation

There are basically two ways of transporting the oil and gas to shore. First is a pipeline, but is often commercially or technically impossible, because of the temperature that is needed to keep the oil liquid. Second is the use of vessels, the oil and gas is then transported by shuttle tankers, this is the most common used method.

Decommissioning

Like all marine constructions, an offshore oil platform also has an economical or technical lifetime. Regardless of the reason, if one of these lifetimes has come to an end the structure has to be removed. The easiest way is to abandon the platform and leaf it to the elements, or to destroy it with explosives and let it sink to the sea floor. This was a common method in former timer, but nowadays with increasingly stringent environmental regulations most governments demand that the platform is decommissioned properly to minimize the damage to the environment. This process can be done by heavy lift semi-submersible cranes, which are also used during hook-up. Momentarily the Dutch offshore company Allseas is working on the world's first purpose built decommissioning vessel, which is able to remove old production platforms in an economically efficient way.

1.1.2 Offshore (support) vessels

Offshore oil and gas winning is dependent on a variety of vessels supporting the different processes. An overview of the processes and vessels is given below.

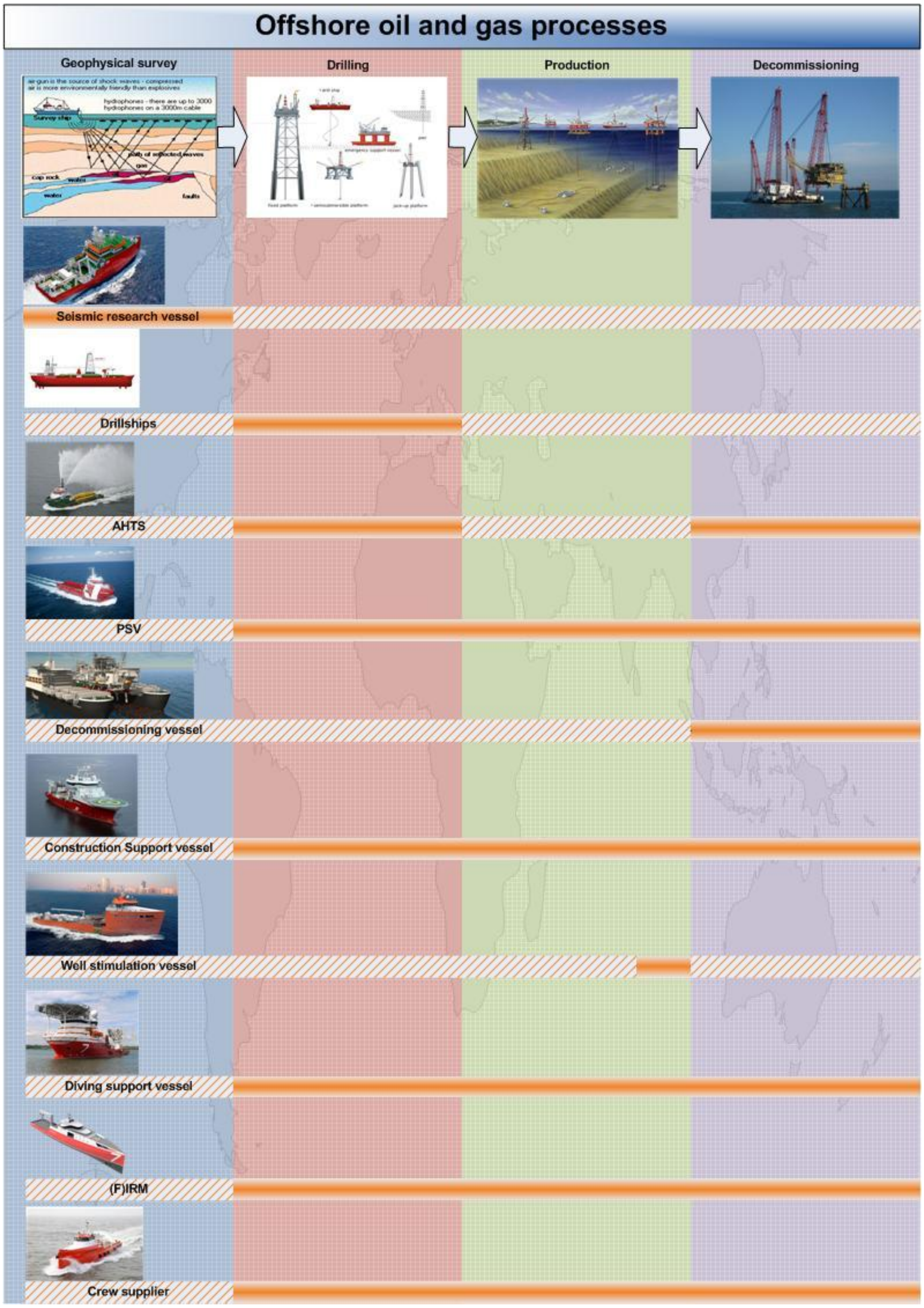


Figure 1, Offshore oil and gas processes and supporting vessels

Seismic research vessels

Seismic research vessels are specialized ships, purpose-built for seismic survey of the ocean floor, often characterized by a wide stern. Streamers containing hydrophones are towed behind the vessel. While the vessel works a grid at a steady speed, an air gun generates sound waves directed towards the seabed. Echo's retuning from the seabed are detected by the hydrophones and recorded for further analyses. These recordings are used to map the seabed and detect deeper layers in the earth's crust.

PSV's and AHTS

The Platform Supply Vessel (PSV) and Anchor Handling Towing Supplier (AHTS) are the workhorses of the industry. They are characterized by a superstructure on the bow and a long, low freeboard aft deck to transport containers, anchors, chains etc. The vessels are used to supply platforms with all kind of supplies like equipment, powdered products for the drilling process like cement and bentonite, but also fuel and fresh water. Equipment is stored on the aft deck, while other products are stored below deck in dedicated tanks. In case of an AHTS the vessel has a large towing winch aft of the superstructure to hoist and move the anchors of a platform.

Crew transportation vessels

This are small high speed vessels used to bring relieve crews and small supplies to offshore platform. They are used for short daily trips only and mostly in benign areas like the Gulf of Mexico and Lake Maracaibo. On the North Sea, helicopters are mostly used to perform crew changes.

Accommodation jack-ups and semi submersibles/vessels (flotels)

During hook-up a lot of temporary crew like welders, electricians and fitters work on the platform. It wouldn't be logical to provide accommodation for these workmen on the production platform itself and waste valuable space. Therefore mobile crew accommodation is provided in the form of a jack-up in shallow waters and semi-submersibles (flotels) in deeper waters. These structures are placed alongside and connected to the production platform by a walk bridge. In case of a flotel a telescopic bridge is used to compensate the relative motions between the platform and the floating structure.

Repair and maintenance jack-ups, semi's

Special designed jack-ups and semi submersibles are used to repair and do maintenance of offshore platforms. These platforms often have a large accommodation area to provide accommodation for the platform's crew. Other distinct features are usually a large crane with a wide reach and sometimes a diving system with a decompression chamber, so special deep sea divers can do inspection and repair at great depths.

ROV support vessels

Nowadays a lot of subsea installation, inspection and maintenance is done by remotely operated vehicles or ROV's instead of divers. These ROV's are operated from a vessel through an umbilical which is connected to both the vessel and ROV. Vessel used for these operations are called ROV support vessels and have a crane or A frame for launching and recovery of the ROV, often through a moon pool.

Heavy lift cranes

For the installation of jacket platforms a floating crane in needed for lifting and positioning the jacket, driving piles, deck structures and modules containing for example the living quarters. Hook-up at sea is very expensive, so pre assembly of modules on shore will gain a lot of money. The size of these floating cranes has increased in time together with the increasing size of the platforms. The first heavy lift floating cranes had a mono hull ship-shaped floater with a large crane at the aft of the vessel, leaving deck space for the transportation of equipment. This design was due to a limited breadth of the vessel very sensitive to sea motions and because positioning a module on a jacket is a very precise and subtle job, the weather frame especially on the North Sea was limited. More recent crane vessels are semi submersibles and have the virtue of a large breadth, so the weather downtime was decreased significantly.

The design of a semi-submersible crane vessel is a compromise between a high GM for slewing under load and a preferred low GM for the rolling behavior of the vessel. This can be problem can be solved by using an active healing system that can move ballast water quickly to prevent healing without the need of a high GM. Modern crane vessels like the Balder and Hermod use this system.

Pipe laying vessels

When there is a need for a pipeline from an offshore structure or well you need a pipe laying vessel. There are basically two different techniques of pipe laying, J-lay and S-lay. Reeling or J-lay, is used for small pipes up to about 19” in diameter. The standard 12m pipe lengths are joined together on shore and spooled into a reel, which is later unreeled onto the sea floor. This technique forms less horizontal tension on the pipe than S-lay and is therefore preferred for deep-water applications. J-lay vessels are characterized by a large reel on deck, which can be unreeled amidships under and angle of about 45 degrees. S-lay requires a long vessel with a pipe assembly line onboard, where the 12 meter sections of up to 60” are assembled and lowered as a continues pipe onto the sea floor. S-lay vessels are characterized by the large stinger on the front or aft of the vessel that guides the pipe from the vessel to the bottom.

Well stimulation vessels

This are dedicated vessels used for cleaning and stimulation production wells. There are only a limited number of vessels in the world and only a few companies who offer this specialized work. The vessels have a laboratory onboard, high pressure pumps for fracturing rock and tanks for chemicals.

Trenchers and rock dumpers

To protect or thermally isolate pipelines it is possible to bury the pipeline. In some areas like the North Sea it is even required the bury pipelines up to 16” in diameter. Two types of vessel are needed for this process, a trencher and a rock dumper. Trenchers use several techniques to make a trench like water jets, mechanical cutting with cutters or chain cutters, ploughs and cutter-suction dredgers. Each technique requires a different kind of vessels which aren’t discussed in this thesis. If the trench is made a rock dumper, which is a large vessel due to the amount of rocks needed, covers the trenched pipeline with rocks. The rocks are dumped through a fall pipe, often with thrusters at the end to precisely maneuver the fall pipe over the trench.

Semi sub transport vessels

To transport large modules or complete offshore units like jack-ups or semi submersibles special ships have been built, which can submerse to some 10-12 meter water above deck. The loading and unloading operation is always performed in calm waters due to the high risk of the procedure. When fully submersed, only the forecastle and the aft funnels of the vessel remain above the water. Once emerged the vessel can support huge loads and has sufficient initial stability. Only the dynamical stability is limited due to the low freeboard of the vessel, however the load (e.g. a semi-submersible platform) adds to the stability at large rolling angles. The vessels are characterized by a large breadth, superstructure at the front and the funnels at the aft. The design is governed by stability considerations, the ballast tanks have to be subdivided in such a way that free surface effects during (de)ballasting are limited. The deck has to be able to handle high local loads and the hull has to have sufficient collapse resistance to be submersed.

Diving support vessels

The first diving support vessels were built in the 1960s, until than diving operations were performed from mobile oil platforms or vessels like pipe-layers and crane barges. Because the deck space of an oil platform is very valuable and the expectation of continuing diving operations is low, specialized ships for diving operations emerged. Key components of a diving support vessel are dynamic positioning to maintain a position without the use of anchors and a saturation diving system. This system is used for diving operations in deep water. Below 50m divers use a mixture of helium and oxygen to eliminate the narcotic effect of nitrogen under pressure. The divers are lowered trough a moon pool in the bottom of the vessel to the site in a diving bell. Besides these two systems, diving support vessels often have a ROV and also heavy lifting equipment onboard.

Construction support vessels

Construction support vessels or CSV's are generally significantly larger (size between 110-160 meters in length) and more specialized than other offshore support vessels and are principally used to support complex deep water sub-sea construction, installation, maintenance, repair decommissioning and other sophisticated operations. CSVs also support remotely operated vehicles (ROV's), diving activities, well intervention, platform decommissioning and other complex construction operations. Generally, AHTSs and CSVs command higher day rates than PSVs due to their larger relative size and versatility, as well as higher construction and operating costs.

Main tasks of a construction support vessel are: Support in pipe laying; burial and the installation of flowlines; laying control umbilical's as an umbilical lay vessel; installation of distribution pipelines and subsea connections; monitoring of Touch Down Point (TDP); subsea preparation.

1.1.3 Inspection Repair and Maintenance

The goal of Inspection, Repair and Maintenance (IRM) is to maximize the economic returns from an offshore field development by optimizing the production available from a reservoir. The practice extends throughout the whole life of the field and encompasses the offloading of production reserves, integrity monitoring of risers and seabed settlement monitoring.

IRM activities are conducted in an on-going program of inspection, repair and maintenance. Vessels require subsea positioning for divers and ROVs undertaking surveys whilst dedicated well stimulation vessels require wireless control of bespoke tooling deployed to revitalize production from ageing wells.

Vessel tasks:

- Pipeline inspection, repair and maintenance
- Cable inspection, repair and maintenance
- Structure inspection
- Emergency response
- ROV operations
- Repair and maintenance of subsea systems
- Equipment transportation
- General repair operations

IRM vessel comparison

A few modern IRM vessels are listed in the table below

Vessel name	Loa [m]	B [m]	T [m]	D [m]	Crane	ROV	Moonpool	Deck area [m^2]	Personnel	Speed [kn]
Acercy Petrel	76.45	15	-	8.8	27t AHC	Yes	Yes	350	50	11.5
Acercy Viking	98	20	7.3	9.6	100t AHC	Yes	Yes	770	60	16
Acercy legend	64.8	18.9	4.1	5.03	30t and 40t A-frame	Yes	No	450	54	10
Island Enforcer	122.4	23	6		100t and 200t	Yes	Yes	1100	120	17
Seisranger	85	20	6.56	10	50t and 40t A-frame	Yes	Yes	520	69	14

Table 1, IRM vessels

An analysis of the vessels in table 1 shows that IRM vessels have a crane for (subsea) hoisting operations; launch and recovery systems (LARS) for ROV operations; a moonpool; working deck area and a large accommodation. Figure 2 is a photo of the Acercy Viking and shows the typical lay-out of an IRM vessel.

Figure 2, Modern IRM vessel

1.2 Initial requirements / Design criteria FIRM

Next to the market analyses and IRM vessel comparison there is a set of initial requirements for the concept vessel, which will form the design criteria of the vessel. The requirements are limited leaving space to design any kind of vessel that meets these requirements and is practical for the purpose of the vessel. The list below sums up the requirements as set by Damen for this project

Basic function of vehicle

1. Required dead-weight, volume and area's
    - 600 m² deck area;
    - 600 ton deck load, CoG 1m above deck;
    - Approximately 1450 ton max deadweight.
2. Required speed
    - To be at least 25 knots maximum speed.
3. Dynamic Positioning
    - DP 2 notation;
    - Sea state 4/5;
    - North sea area, (JONSWAP spectrum);
    - 30kn wind speed;
    - 2kn current;
    - $H_{1/3}$ 2,5m, with a period of (7-11) seconds.
4. Range of vessel and operational profile
    - Endurance 30 days
        i. 5% full speed (25 knots)
        ii. 15% cruising speed (15 knots)
        iii. 70% DP
        iv. 10% Harbor
5. Special tasks
    - ROV operations, fully enclosed LARS (Launch And Recovery System);
    - Lifting operations, Offshore crane, 100 ton at 15m and 30 ton at 3000m depth AHC (Active heave Compensation);
    - Subsea inspection, repair and maintenance operations;
    - Transport of supplies and crew to offshore production platforms;
    - Emergency response
6. Passengers and level of luxury
    - +- 70 personnel
    - Maximum of 2 persons per cabin
7. Maneuverability
    - Dynamic Positioning capabilities

Economic environment

1. Goods to be carried
    - Supplies for oil and gas platforms
    - Equipment
    - Containers
2. Added value of speed or other specific vehicle qualities
    - Use high speed to arrive quickly at the site to save money and time.
3. Possible unique selling points of vessel
    - Significant higher speed than current Inspection Repair and Maintenance vessels
4. Available budget
    - No restrictions

Crew

1. Number
    - 19
2. Level of luxury
    - Western European standard

Sailing area

1. Traffic intensity
    - North/Norwegian sea
2. No limitations of main dimensions by means of canals, locks, harbors etc.
3. No wash and wake limitations
4. Sailing limitations due to wind are allowed

All of the requirements for the FIRM can be related to the IRM vessels in table 1, except the speed requirement that stands out. It can be concluded that the vessel distinguishes itself from other IRM vessels due to the requirement to sail at 25 knots.

1.3 Design questions:

In addition to the design criteria a series of design questions are formulated. The answer to these questions will help in the design process of the concept vessel.

- Hull form design.
  How to get both speed and stability?
  Enough space to fit all the equipment?
- Resistance calculation, which method can best be applied?
- How to get a good approximation of the lightweight of the vessel?
- Which stability rules have to be complied to?
- How will the vessel behave in seaway?
- Choice of propulsion system, how much power is needed for maximum speed and dynamic positioning?
- Which type of crane is most suitable for subsea hoisting operations?

1.4 Concepts

Two possible concept vessels have been investigated for this project. At first a mono-hull concept, current IRM vessels are all mono-hulls and this is therefore the most obvious option for this vessel. The mono-hull is based on a fast displacement hull form and is described in chapter 2. The second option is a catamaran, because catamarans are known for their high speeds and good transverse stability. Catamarans haven't been applied as IRM vessels yet and little is known about the applicability for this purpose, making it a unique design.

2. Design mono-hull concept

This chapter describes the design process of the mono-hull concept. First the choice of hull form and hull form design are described, followed by calculations concerning resistance; propulsion; weight; hydrostatics; stability; seakeeping and dynamic positioning.

It should be mentioned that the design of a vessel is an iterative process in which many aspects of the design are done parallel to each other. To make this report clearly the different parts of design are ordered by chapter, this should not always be taken as the chronological order of the total design process.

2.1 Choice of hull form type and linesplan

Most IRM vessels are set to sail at low speeds (10 to 16 knots maximum) and are able to use a hull form with a high block coefficient and low L/B value, which is beneficial for the space onboard. For this design we had to look for a hull form that is suitable to sail at 25 knots. Considering the speed range of the vessel a decision had to be made to use a displacement, semi-displacement or maybe even a planing hull-form. The so-called Telfer Coefficient (Telfer 1963) is considered to be a convenient method to compare resistance data for different types of vessels.

Below a graph is shown for a number of vessel types versus the Froude number. It can be seen that a displacement hull form shows superior resistance characteristics over planning and semi-displacement hull forms up to a Froude number of F_N = 0.45. For Froude numbers over F_N = 0.45, semi-displacement and fully planning hulls perform better, in this area the wave making resistance becomes far too high for a displacement vessel.

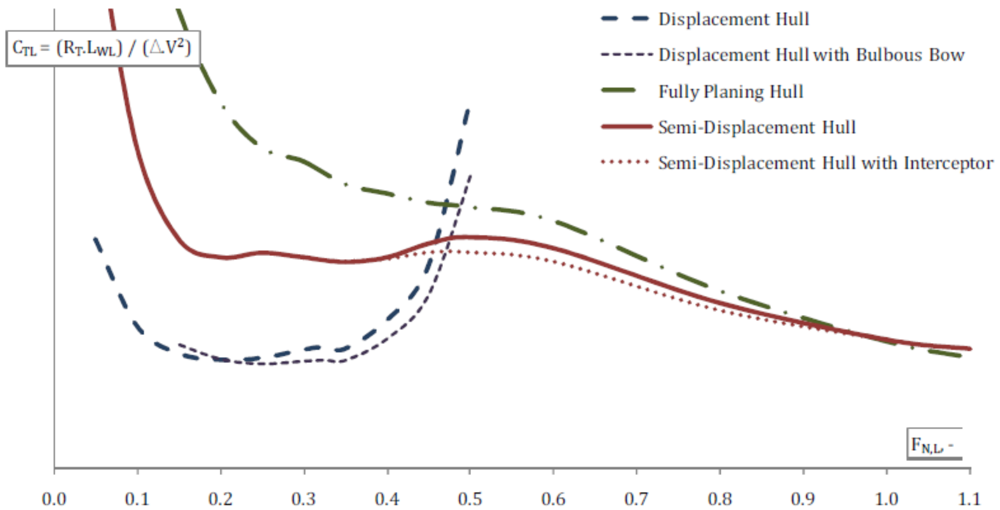


Figure 3, Typical curves of C_{TL} for a displacement hull, a semi-displacement hull and a fully planing hull. Reprinted from "Motor yacht hull form design for the displacement to semi-displacement speed range," by Perry van Oossanen, Justus Heimann, Juryk Henrichs and Karsten Hochkirch, 2009, p631.

Preliminary layout and main dimensions assessment

The main particulars of this vessel are based on a few requirements. First the vessel has to be large enough to meet the requirements and fit all equipment and personnel. Second the vessel has to be able to reach the speed of 25 knots and be stable enough for crane operations.

The basic layout (side view) of the vessel is given in figure 4, which is based on other IRM vessels like the ones in table 1. The hull up to the main deck is divided into three decks, the tanktop, a tween deck and the main deck. The superstructure of the vessel is located in front of the working deck area. The superstructure consists of the ROV hangar and deployment system, accommodation (together with offices and other facilities) and bridge deck.

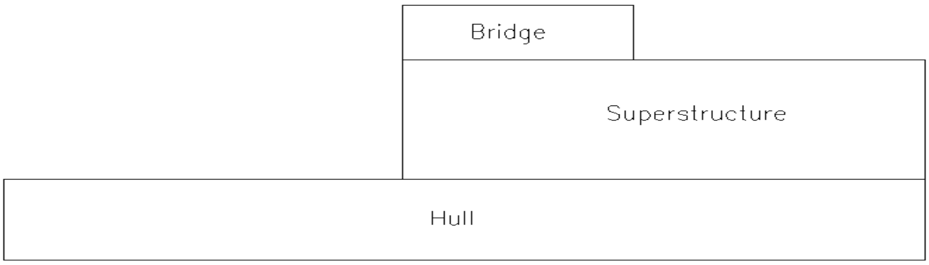


Figure 4, Basic layout IRM vessel

A preliminary deck layout which is given in table 2 gives an impression of the subdivision of the ship's compartments. At the main deck the 600 m^2 of deck area is situated aft of the superstructure. The superstructure includes a bridge and three decks for mostly accommodation space, 70 personnel and 19 crew members require about 2225 m^2 of accommodation space. This includes all spaces like cabin space, mesh rooms, etc. 25 m^2 per person is a rule of thumb used at Damen to estimate accommodation space in a preliminary design stage.

The ROV hangar with the deployment davit and the moonpool is a large installation which covers three decks, main- A- and B-Deck (the moonpool also takes up space below the main deck) over a length of approximately 20 meters. This system should be located around the CoG of the vessel where the ship motions are lowest. It is therefore placed between the accommodation area and the work deck of the vessel.

Deck	Compartments/spaces/equipment
Tanktop	Tanks, ballast water; fuel oil; fresh water Engine room Bowthruster room Moonpool
Tween deck	Tanks, ballast water; fresh water Engine room Switchboard room ECR Workshop(s) Steering gear room Moonpool
Main deck	Work deck Accommodation space (+-30%) ROV deployment system Moonpool Crane
A-Deck	Accommodation space (+-30%) ROV deployment system
B-deck	Accommodation space (+/-20%) ROV deployment system Life boats
C-Deck	Accommodation space (+/-20%) Life boats
Bridge	

Table 2, Deck layout

Figure 3 showed that displacement vessels are superior to semi-displacement vessels up to a Froude number of F_N =0.45. For a speed of 25 knots the waterline length at this Froude number is 83 meters, below this length a semi-displacement vessel is better, above this length a (fast) displacement vessel is the better choice.

An analysis of the main deck layout in figure 5 leads to a rough estimate of the minimum length of the vessel. The average breadth of the vessel is set at 15 meters, this is based on the vessels in table 1 and compensates for the lost space in the forward section of the vessel and cargo rails at the aft.

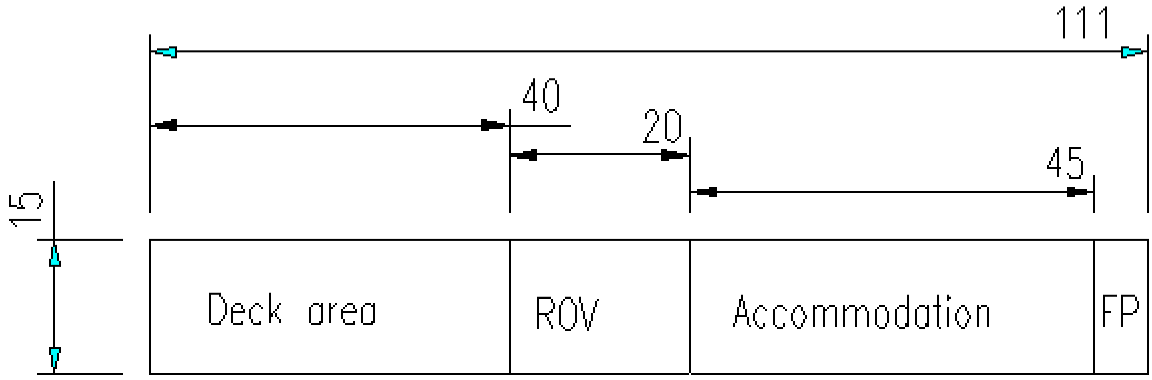


Figure 5, Basic layout main deck

This first assessment indicated that the waterline length of the vessel would be over 83 meters and a (fast) displacement hull form is most suitable for this concept.

2.1.1 Marwood and Bailey hull

The decision for a (fast) displacement hull form lead to two possibilities, a hard chine or a round bilge hull. Significant research has been carried out regarding the advantages and disadvantages of round bilge and hard chine hull forms by Bailey (1974) and Blount (1995 and 2009). Blount stated that from a seakeeping point of view, round bilge hulls are supposed to be superior at displacement speeds, but at semi-displacement speeds there is no consensus about the superiority of round bilge or hard chine hulls. This same conclusion is drawn by Keuning (1984). An advantage of a hard chine hull is the lower building costs compared to a round bilge. However the savings are minimal compared to the total costs of such a vessel and better seakeeping performances are considered far more important. Considering the above a round bilge hull has been adopted for this design.

The initial linesplan was based on a Marwood and Bailey type vessel, which is a round bilge high speed displacement hull form, suitable for speeds ranging from F_N 0.3 to 1.2. In 1969 Marwood and Bailey published test results of a systematic series of 22 models, carried out at the Ship Division of the British National Physical Laboratory. In this series L/B and B/T values were varied, other main hull parameters were kept constant, see table 3. Figure 8 displays the linesplan which was used as a parent for this concept design, throughout the design process this parent has evolved into the hull form which will be discussed in chapter 2.2.2.

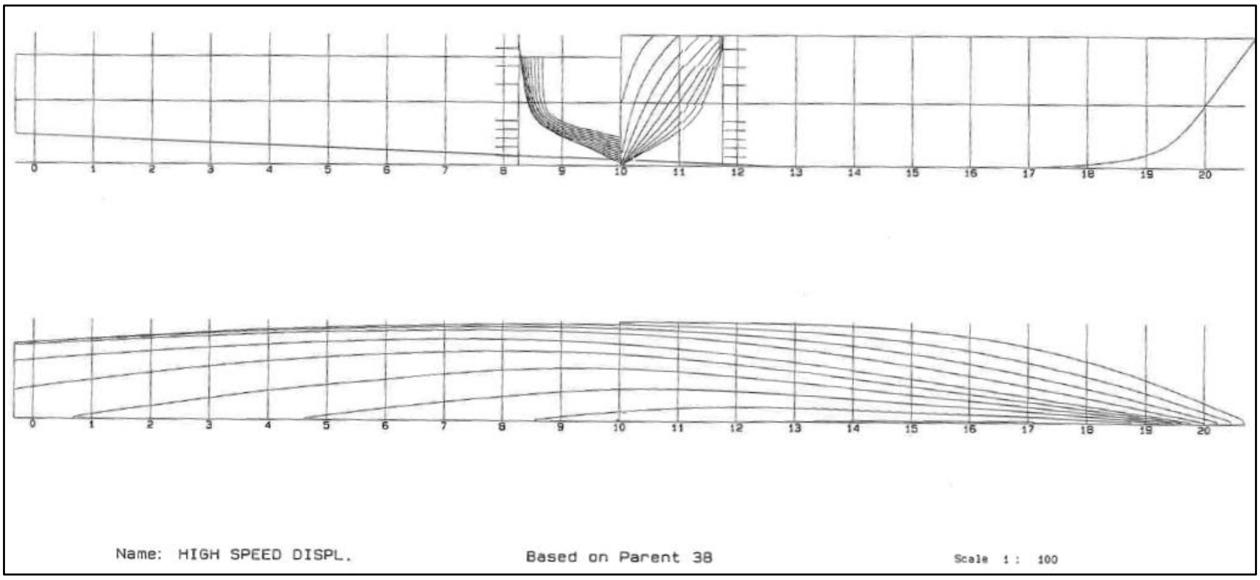


Figure 6, Linesplan Marwood and Bailey parent hull form

Distinctive parameters Marwood and Bailey systematic series are:

Fixed parameters		
C_B	0.4	[-]
C_P	0.69	[-]
C_X	0.57	[-]
LCB/L	0.44 fwd. AP	[-]
L_E/L	0.60	[-]
Variable parameters		
F_{nL}, L, L/B, B/T, $L/\nabla^{1/3}$, i_e		[-]

Table 3, Parameters Marwood and Bailey parent hull form

2.2.2 Linesplan

The design of the linesplan started out with the parent hull form given in figure 6 and evolved during the design process of the vessel. The main focus was to minimize the resistance and comply with all the design criteria. During this iterative process it is important to have a good insight in the weight, stability, resistance and general arrangement of the vessel. In order to find the right balance between these design aspects the linesplan was constantly adjusted until the best compromise was found.

The design challenges involved the following main considerations:

Vessel characteristics	Design challenge	Design aspects involved
Length	Long waterline to reduce resistance, higher hull speed Don't oversize the vessel	Resistance calculation General arrangement
Breadth	Narrow to reduce resistance Wide for more transverse stability	Resistance calculation Stability calculation Weight calculation General arrangement
Draught	Low to reduce resistance High enough for propeller Comply to deadweight requirement	Resistance calculation Hydrostatics calculation
Depth	High freeboard to optimize working conditions on deck Low freeboard the increase stability	Stability calculation Weight calculation Freeboard calculation
C_B	Low to reduce resistance High to maximize space High enough to comply with the deadweight requirement	Weight calculation Resistance calculation Hydrostatics calculation
LCB	About 6% aft of L/2 for speed Maintain the trim as close to 0 as possible	Weight calculation, CoG Hydrostatics calculation

Table 4, Design challenges

The outcome of this design process is the linesplan in figure 7, which eventually deviated from an original Marwood and Bailey hull form to make it suitable for the purpose of an IRM vessel. Even though some distinctive characteristics like the low block coefficient, narrow lines and backward center of buoyancy are still present.

The design aspects like weight- and resistance calculation which are covered in the next chapters all relate to this hull form.

Main particulars		
L_{oa}	120	[m]
L_{pp}	116	[m]
L_{wl}	115	[m]
B	19	[m]
T_{design}	6	[m]
D	8	[m]
Displacement, at T_{design}	6256	[t]
C_b	0.4462	[-]
C_p	0.642	[-]
Wetted area	2288.2	[m²]
Waterplane area	1715.3	[m²]
LCB	-4.347	%

Table 5, Main particulars mono-hull concept

The complete list of the hull properties can be found in Appendices I.

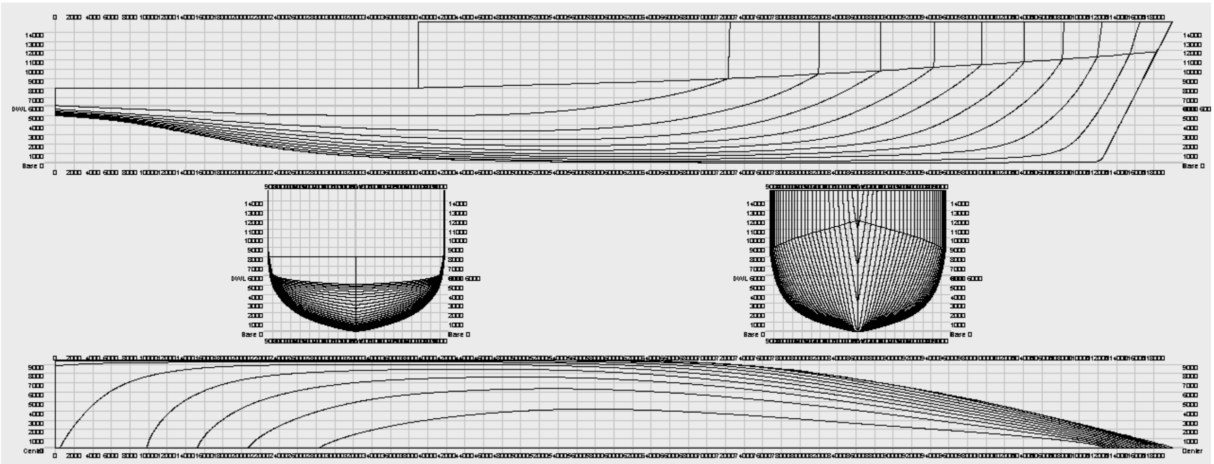


Figure 7, Linesplan mono-hull concept

2.2.3 Preliminary general arrangement plan

The preliminary general arrangement plan for the vessel is given below, the lines follow from the hull form of Chapter 2.2.2. Figure 8 and 9 give a top view of the preliminary deck arrangement. This is still a basic layout to check if all systems and compartments will fit. The total available space for accommodation and deck area comply with the requirements given in Chapter 1.2.

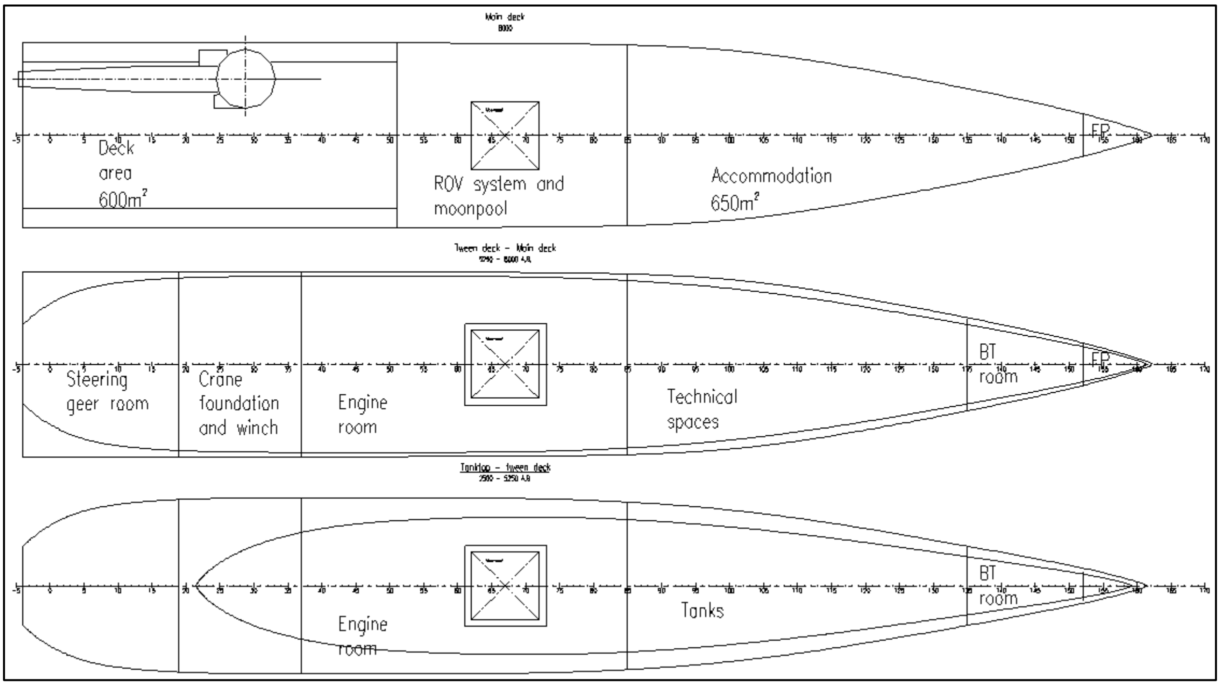


Figure 8, Tanktop, Tween deck and Main deck

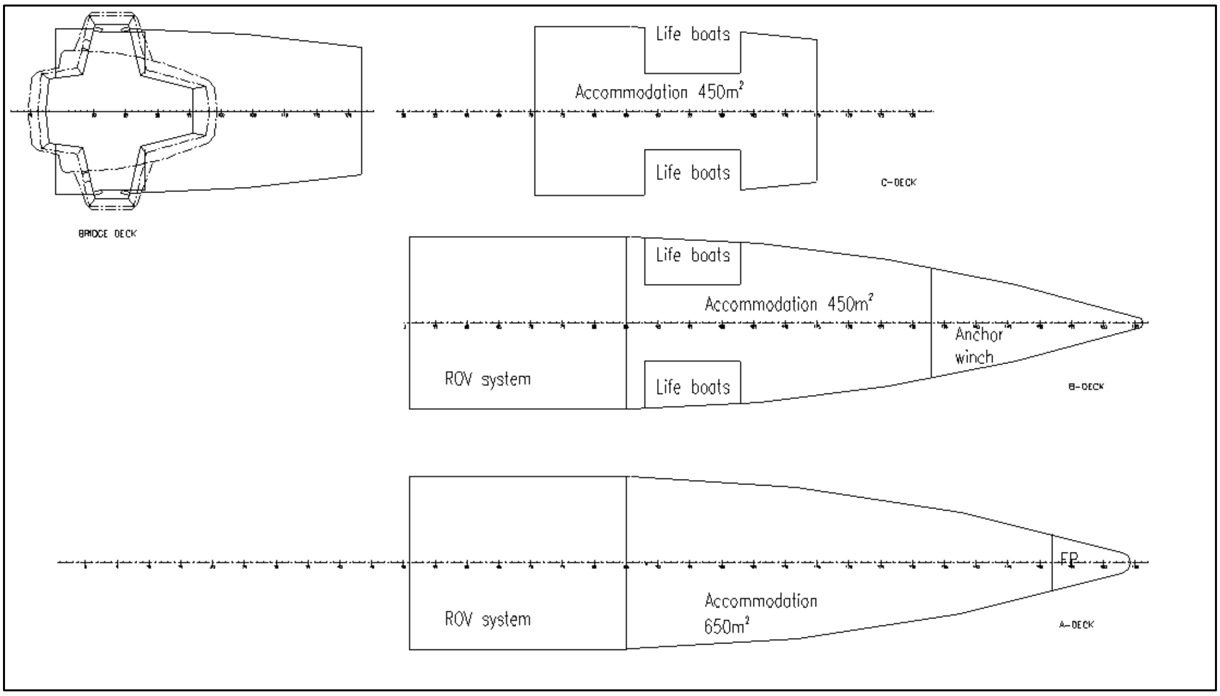


Figure 9, A- B- C- and Bridge deck

2.2 Resistance calculation

The hull form design is derived of a systematic series of hull forms which have been tested in a model basin, the Marwood Bailey series. Therefore it seems to be logical to use this data for the resistance prediction of the concept vessel. However due to alterations to the hull-form, fixed parameters like for instance C_B and LCB, deviate from a standard Bailey hull. Making this a hull form that has a lot of resemblance with a Bailey hull, but doesn't meet the exact requirements and therefore another method has been used to predict the resistance of the vessel.

In the past a number of methods have been developed of which the method of Holtrop and Mennen is probably the best known. J. Holtrop and G.G.J. Mennen have developed a resistance prediction method through regression analyses of random model experiments and full scale data. The method uses a subdivision of the total resistance in several components:

$R_{total} = R_F(1+k_1) + R_{APP} + R_W + R_B + R_{TR} + R_A$

R_F = Frictional resistance according to the ITTC-1957 formula

$(1+k_1)$ = Form factor describing the viscous resistance of the hull form in relation to R_F

R_{APP} = Resistance of appendages

R_W = Wave-making and wave-breaking resistance

R_B = Additional pressure resistance of bulbous bow near the water surface

R_{TR} = Additional pressure resistance of immersed transom stern

R_A = Model-ship correlation resistance

The summation of these individual resistance components forms the total resistance of the vessel. For the entire method and explanation of the calculation of the resistance components we refer to the publication of Holtrop and Mennen (1982/1984). This method has been implemented into an Excel sheet to quickly calculate the resistance of the concept.

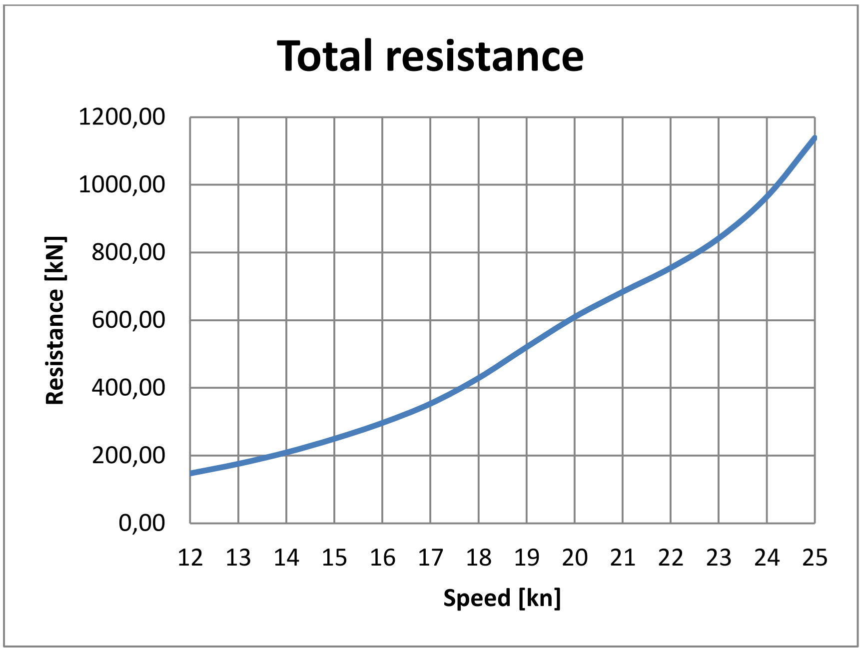
The reason to use this particular method for the concept vessel is because the hull form characteristics fit into applicability area and its past proven accuracy.

Midship coefficient	between	0.5 and 1.0
L_{wl}/B	between	3.5 and 9.5
L_{CB}	between	-5% and +5% wrt L/2
C_P	between	0.40 and 0.93
Fn	Up to	0.45

Table 6, Holtrop and Mennen applicability area

Results

The resistance curve of the vessel in for a speed range between 12 and 25 knots is given below.



V	Rtotal
[knots]	[kN]
12	147
13	176
14	209
15	250
16	297
17	353
18	429
19	520
20	609
21	684
22	755
23	842
24	964
25	1139

Figure 10, Resistance mono-hull concept

2.3 Power speed analyses and propulsion system

With the resistance prediction and speed requirement one can calculate the required power of the vessel by starting at the propeller side of the propulsion train. For this concept a diesel direct propulsion system with open propellers is chosen. A diesel direct system is more efficient and cheaper than a diesel electric system and open propellers are most suitable for the speed range. The power speed calculation for this concept is considered to be basic but sufficient for this stage of the vessel design.

The effective power (P_E) or required thrust is calculated by multiplying the speed (in m/s) with the resistance (kN). The desired break power (P_B) and amount of propellers is calculated by taking efficiency losses into account for the propeller, shaft and gearbox. Values for the efficiencies follow from the book of Klein Woud and Stapersma (2002).

After the calculations the main engines and gearboxes are chosen which are suitable for this propulsion concept. The reason to choose a specific engine and gearbox in this early design stage is primarily for the weight calculation in Chapter 2.6. Finally a schematic overview of the complete propulsion system is given to give a visual impression.

Effective power

The effective power versus the speed is displayed in figure 11.

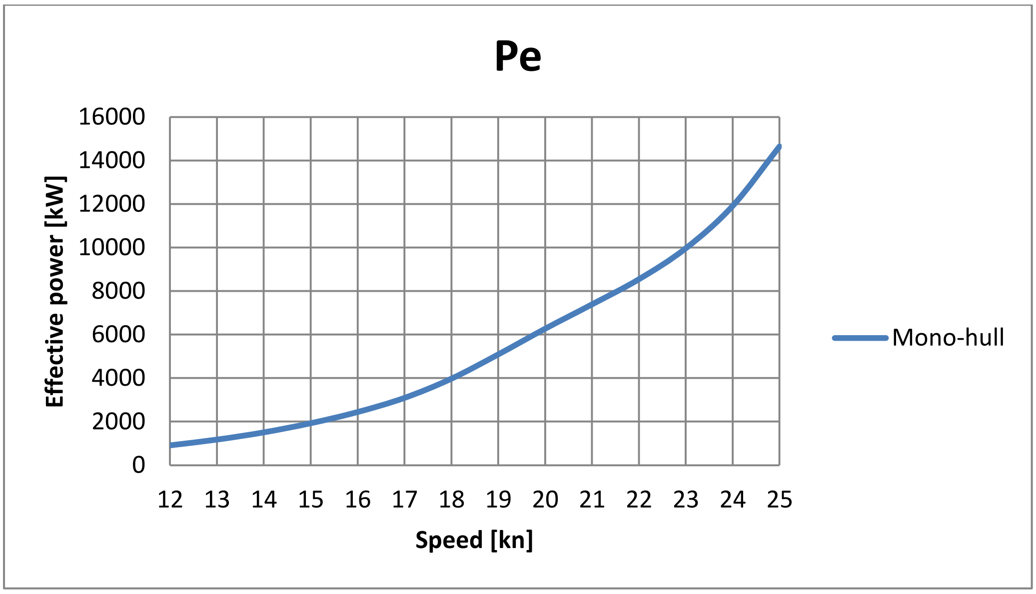


Figure 11, Effective power mono-hull concept

Propellers

The maximum propeller diameter of the design is 4 meters. In propeller design the aim is always to keep the propeller diameter as large as possible to lower the propeller load, which results in lower fuel consumption and less power needed for propulsion.

Damen has developed a set of guidelines for maximum propeller load, based on the diameter of the propeller; these guidelines are used to determine the amount of propellers. For practical reasons (efficiency, vibrations, noise) it is recommended that larger displacement vessels should not exceed ca. 400 kW/m², which is shaft power (P_S) divided by the diameter squared. The maximum propeller load is to some extend related to the Damen Standard blade area ratio's A_E/A_0. With higher blade area ratio's, higher propeller loads can be allowed to some extent. However, higher propeller loads at low speed will generate less tons thrust per kW. Damen standard creates an acceptable efficiency combined with acceptable noise and vibration levels.

- Assuming an estimated propulsive efficiency of 0.65 and shaft efficiency of 0.98:

  P_E = 15000 kW

  P_S = 23500 kW

- Number of propellers:

  Max prop load = $400\dfrac{kW}{m^2}$

  Max propeller diameter = $4m$

  $P_S \max = 400 \cdot 4^2 = 6400kW$

  $$\frac{23500}{6400} = 3.67$$

  The minimum amount of propellers is 4.

Power calculation main engines.

To determine the total break power of the main engines we consider a basic diesel direct concept with four shaft lines, four main engines and reduction gear. The calculation below deals with a maximum speed of 25 knots at trial condition.

Given a shaft loss of 2%, a gearbox loss of 3% and propulsive efficiency of 0.65

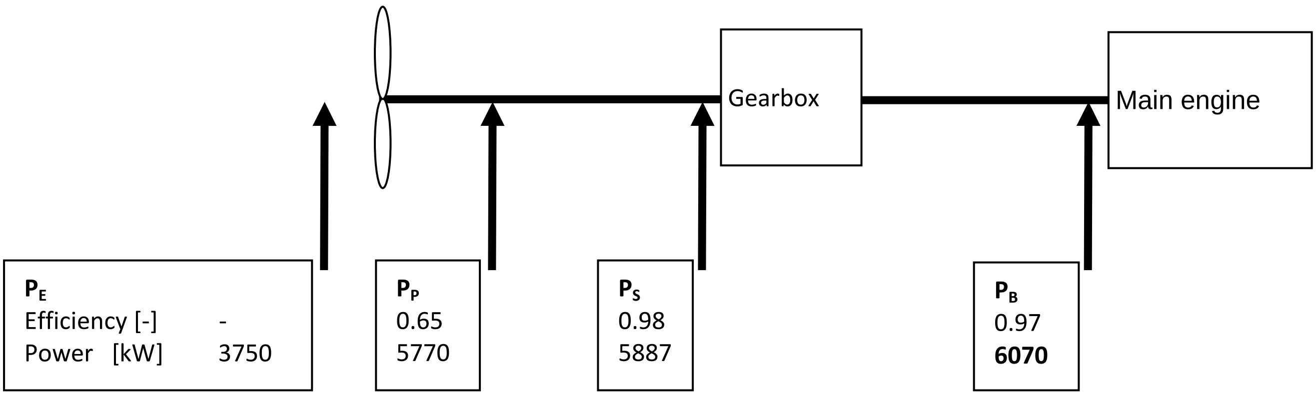


Figure 12, Schematic overview propulsion power and efficiencies

$P_E = 15000kW$

$\eta_D = 0.65$

$\eta_S = 0.98$

$\eta_{GB} = 0.97$

For one shaftline:

$$P_P = \frac{(P_E / 4)}{\eta_D} = 5770kW$$

$$P_S = \frac{P_P}{0.98} = 5888kW$$

$$P_B = \frac{P_S}{0.97} = 6070kW \text{ (shaft and gearbox losses included)}$$

$P_B total = 24280kW$

Main engines

Four diesel engines, with a minimum power of 6070kW each are required according to the power calculation. The Wärtsila 9L38 is a medium speed diesel engine with 6525kW output and suitable for this concept.

Make	Wärtsila
Type	9L38
Output	6525kW
Speed	600 rpm
Specific fuel consumption	176 g/kWh
Weight	72 ton

Table 7, Main engines mono-hull

Gearbox

4x single in, single out Wärtsila SCV85, weight 14.5 ton each.

Propulsion system layout

The propulsion system layout is given in a sketch in figure 13. This figure shows one shaft line and the electrical system together with the bow and stern thrusters. The main components of the propulsion system and power generating system are listed below:

4 main engines
4 shaft lines
4 gearboxes
4 propellers
2 Bow thrusters
2 Stern thrusters
4 generator sets
1 Emergency generator set

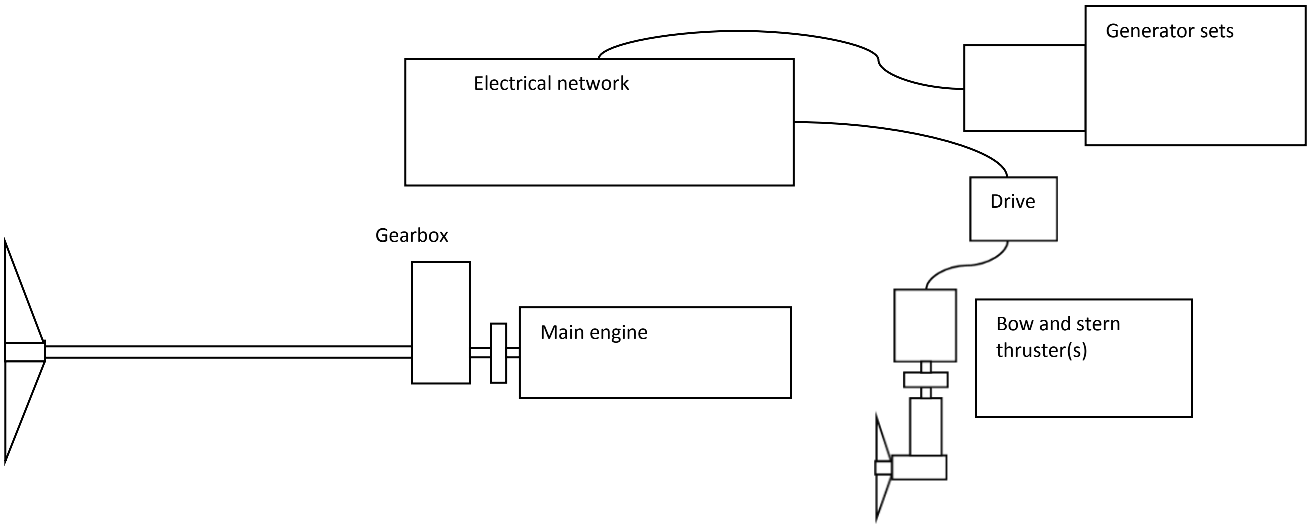


Figure 13, Schematic overview propulsion system mono-hull

2.4 Auxiliary Systems and electric load balance

The schematic overview in the past chapter already showed generator sets which are needed to provide power to the auxiliary systems. An electric load balance leads up to the total amount of power which is needed. In this load balance the main consumers are listed, together with a post "hotel load" which covers all small consumers.

For this basic load balance we consider a DP condition, with a crane operation. In this condition all relevant consumers should be able to be turned on at full power at the same time. Because the tunnel thrusters and crane are the main electrical consumers, the amount of power that has to be installed for this condition is considered to be sufficient for all other conditions as well.

Load balance

Three main consumers are listed in table 8. The power for the hotel load is based on a comparable Damen vessel. The power for the tunnel thrusters is the maximum power needed for station keeping, calculated in Chapter 2.10 (DP calculations mono-hull). The power needed for the crane is based on the technical tender document from Cargotec for a knuckle boom crane which complies with the crane requirements stated in Chapter 1.2. The complete tender for the crane with all the specifications can be found in Appendices XXIII.

Consumer	Power
Hotel load	500 kW
Crane	1661 kW
Tunnel thrusters	5400 kW
Total	7561 kW

Table 8, Main consumers mono-hull

Generators

Based on the electric load balance a set of generator sets is chosen to provide the electrical power for the vessel. Two large generators and two smaller ones are installed which allows the operator to switch between different settings, based on the amount of power needed at the time. The emergency generator set for the vessel is given in table 11, it is mandatory to have one onboard according to class.

Make	Wärtsila
Type	8L20
Output	1405 ekW
Speed	900-1000 rpm
Specific fuel consumption	185g/kWh
Weight	20.7 t

Table 9, Auxiliary generator sets mono-hull 1 (2x)

Make	Wärtsila
Type	8L26
Output	2495 ekW
Speed	900-1000 rpm
Specific fuel consumption	184g/kWh
Weight	45 t

Table 10, Auxiliary generator sets mono-hull 2 (2x)

Make	Caterpillar
Type	C18
Output	547 ekW
Speed	1800 rpm
Specific fuel consumption	133.2 l/h
Weight	1.9 t

Table 11, Emergency generator set mono-hull

2.5 Tank capacity

The tank capacity calculation involves the main consumables, fuel oil and fresh water, which are needed to comply with the endurance requirement of 30 days operation and contributes to two aspects of the vessel design. First of all does the outcome give an insight of the size of the fuel oil and fresh water tanks, which have to be taken into account in the tank arrangement. Second it contributes to the deadweight requirement of the vessel. This being a conceptual design we only consider main consumables and sewage capacity which are the largest tanks, other small tanks like for instance lubrication oil and sludge tanks are left outside the scope.

Fuel capacity

The fuel oil capacity is related to the operational profile of the vessel. The specific fuel consumption of the engines is based on data given by the engine manufacturer, 175g/kWh for the main engines and 185g/kWh for the auxiliary generator sets. The amount of kW's used per operational state are based on the power speed curve and DP analyses.

Operational profile:
Endurance 30 days, 24 hours per day

- 5% full speed (25 knots)
- 15% economical speed (14 knots)
- 70% Dynamic Positioning
- 10% Harbor

Operational state	Percentage of time	Fuel consumption
Full speed	5%	160 ton
Economical speed (14 knots)	15%	57 ton
Dynamic Positioning	70%	420 ton
Harbor	10%	2 ton
Total	100%	639 ton

Table 12, Fuel consumption mono-hull

Fresh water capacity

The capacity of the fresh water tanks is calculated for 89 persons, 19 crew members and 70 special personnel. The consumption per person is set at 135 liters per day, which is based on standard Damen figures. The range is the same as previously mentioned in the fuel oil capacity calculation, 30days. A fresh water generator with a capacity of 12000 L/day is installed and taken into the calculation. This means that the fresh water generator can generate the same amount of water per day as the maximum amount of water that will be used by crew and passengers. To create a buffer the fresh water tank capacity is set at 100 m^3 which is sufficient to provide water to all persons onboard for over a week.

Total fresh water capacity: 100 m^3

Sewage capacity

The sewage tank is calculated for 4 days with maximum amount of crew and special personnel. A sewage treatment plant is necessary to minimize the size of the sewage tank. The amount of sewage per person onboard per day is equal to the amount of fresh water used, 135 liter.

Sewage tank capacity: 50 m^3
Sewage treatment plant capacity: 12000 L/day

2.6 Weight calculation

The weight estimation is used to determine the center of gravity and the light ship weight of the vessel. The center of gravity of the vessel is essential for other calculations like stability, dynamic positioning and seaway. The light ship weight plus the required deadweight has to equal the displacement at a certain draft, if this is not the case the designer has to alter the vessels geometry, and it is therefore essential to make a reliable weight estimation.

There are many methods developed to estimate the steel weight of the vessel. These methods can be very useful if the designer has no or little information about weights of comparable vessels. Damen Shipyards has built a lot of vessels of all kinds in the past and has therefore a database of “as built” vessel weights which are very accurate. Based on this information the company had established weight factors for all kinds of vessels. This means that the steel weight of the vessel is estimated by multiplying the volume with a weight factor (kg/m^3).

Besides the steel weight of the hull and superstructure, other components like for instance the main engines are listed and accumulated to the bare hull weight. Also the positions of the components in the vessel are taken into account to calculate the CoG. Most of the components have known weights, others like for instance piping are taken as a percentage of the total equipment weight which uses the piping. The percentage is again based on experience within the company.

Eventually all individual weights are summed up and will form the total light ship weight, for safety a margin of 5% is taken over the total weight. This 5% margin is the result of experience with previously built vessels, most of the time the actual weight of the vessel turns out to be higher than the original estimation. The center of gravity of the vessel is the result of the sum of all the separate components, again for safety a margin of 30cm is added to the vertical center of gravity (VCG), stability calculations are made with this safety margin.

To verify the method with weight factors the steel weight estimation method of Westers, which is a weight estimation method for the early design stage, is used.

2.6.1 Results

The weight components of the vessel are subdivided into 8 weight groups (100-800), this is a standard within the Damen company and makes the calculation clearer. The first weight group is the steel weight of the hull and superstructure, this group is compared and checked with the method of Westers. The other weight groups contain components of the vessel like main machinery, electrical systems and deck equipment.

Hull weight estimation

The weight factors for the hull and superstructure are divided into four groups, hull; superstructure (steel); superstructure (aluminum) and bridge. The weight factor for the hull is calculated by taking the average weight factor of built offshore vessels, see Appendices III. The other weight factors are standard Damen and based on experience within the company. The total hull weight is compared to the Westers calculation, the difference between the two methods is 92 tons, on a total of 2430 tons this is a difference of 3.8%. The method with the weight factor gives a slightly higher steel weight, but the margin is small. To be on the save side the method with the highest outcome is choses throughout the rest of the project.

Total light ship weight

The complete detailed weight calculation can be found in Appendices III, the table below gives the results of the weight calculation and CoG of the vessel.

Weight group	**Weight [t]**	**VCG [m]**	**LCG [m]**	**TCG [m]**
100 Shipbuilding	2,430	7.07	59.21	0.00
100 Shipbuilding (Westers, not included in total LSW)	*2,338*	*6.74*	*58.35*	*0.00*
200 Main machinery	710	3.13	27.24	0.00
300 Primary ship systems	284	6.93	56.36	0.00
400 Electrical system	237	5.77	57.27	0.00
500 Deck equipment	403	15.04	34.93	0.00
600 Secondary ship systems	51	7.35	46.09	0.00
700 Joinery and arrangement of accommodation	333	12.63	73.75	0.00
800 Nautical, navigation and communication equipment	3	20.50	60.00	0.00
Margins lightship weight	*222 (5%)*	*0.30*	*0.00*	*0.00*
Light ship weight (inclusive 5% weight and 30cm VCG margin)	4,674	7.81	52.56	0.00

Table 13, Total light ship weight and CoG mono-hull

The values of the total light ship weight and CoG are used to perform further calculations concerning stability, sea keeping and dynamic positioning.

2.7 Hydrostatics

The hull form, light ship weight and deadweight requirement are now known. This chapter sums up all the components to display if the vessel complies with the deadweight requirement. The results are presented in table 14.

HYDROSTATICS				LCG	VCG	
Light ship weight (incl margin)		4,674	t	52.56	7.81	m
Deadweight						
Deck cargo		600	t	23.00	9.00	m
Fuel oil		639	t	62.28	4.40	m
Fresh water		100	t	96.18	5.43	m
Sewage		50	t	55.00	1.75	m
Crew and stores		15	t	75.00	14.00	m
Total		1404	t	47.78	6.45	m
Displacement (wanted)		6,078	t			
				LCB	**VCB**	
Available displacement (T = 6.00 m)		6,253	t	52.19	3.81	m
Margin		175	t			

Table 14, Hydrostatics mono-hull

The results show a margin of 175 ton, which can be used as ballast water to adjust the trim of the vessel. A complete list of the vessel hydrostatics for several drafts is given in Appendices IV.

2.8 Stability calculations

Because of safety requirements the vessel has to comply with stability regulations, which are divided into intact and damage stability calculations. The requirements vary with the type and purpose of a vessel, this concept vessel has to comply to the intact stability code for vessels with a large B/H ratio and with the code for special purpose ships (SPS2008) for damage stability because of the number of special personnel onboard. The consequence of the SPS2008 code is that we have to cope with probabilistic damage stability calculations instead of deterministic calculations. These calculations are extensive, especially during this stage of the design process. To make sure the vessel will comply with probabilistic calculations a simple method is developed based on minimum G'M values of the loading conditions.

Additional to the intact and damage stability calculations and because the vessel has to handle high loads and makes use of counter ballast, a "Loss of load" calculation is made. The rules regarding this matter are not mandatory and only Det Norske Veritas (DNV) have made a set of regulations which are given in Appendices VI.B.

2.8.1 Intact stability calculations

The concept vessels have to apply to standard stability criteria for vessels with a large B/H value. These criteria are used for all offshore vessels designed at Damen, and consist of the General intact stability criteria for all ships (IMO Resolution A.749(18)), with addition of IMO's A.562 weather criteria and a maximum statical angle restricted by deck immersion, see table 15. For the calculations a wind pressure of 51.40 kg/m² is used.

Intact Stability Code for vessels with a large B/H ratio		
	Criterion	
Minimum metacentric height G'M	0.150	meter
Maximum GZ at 30 degrees or more	0.200	meter
Top of the GZ curve at least at	15.000	degrees
Area under the GZ curve up to 30 degrees	0.055	mrad
Area under the GZ curve between 30 and 40 degrees	0.030	mrad
Maximum angle of inclination acc. to IMO's A.562 weather criterion	50.000	degrees
Maximum statical angle due to wind	16^{o} or 0.8*angle of deck immersion, whichever is less.	degrees
Maximum statical angle 80% of angle of deck immersion	0.8*angle of deck immersion	degrees

Table 15, Intact stability criteria

The stability calculations are made with PIAS. This requires a transformation of the hull form into PIAS, a tank arrangement, light ship weight and CoG of the vessel and definition of the openings. An overview of the tank arrangement is given in figure 16. The light ship weight and CoG of the vessel follow directly from the weight calculation.

A set of loading conditions is made for the most common and most extreme cases the vessel will have to cope with during its lifespan.

- 1.1 Ballast condition T_{design} = 6m
- 2.1 Departure 100% consumables
- 2.2 Arrival 10% consumables
- 3.1 Departure 100% consumables 600t deck load, 1m above main deck
- 3.2 Arrival 10% consumables 600t deck load, 1m above main deck
- 4.1 Crane operation 100t@15m, Departure 100% consumables (heel compensated)
- 4.2 Crane operation 100t@15m, Arrival 10% consumables (heel compensated)

(Note: 100t@15m means 100t at 15m outreach of the crane, this is 20.5m out of the centerline of the ship).

RESULTS

The extensive results of the intact stability calculations can be found in Appendices VII, below in table 16 a summary of the results is given.

Condition	Tmean [m]	Trim [m]	Min G'M [m]	Max GZ [m]	Top GZ [degrees]	Area under GZ up to 30^0 [mrad]	Area under GZ between 30^0 and 40^0 [mrad]	Max angle of inclination [degrees]	Max. stat. angle [degrees]
1.1	6.000	0.026	3.430	1.352	51.040	0.368	0.206	25.731	1.833
2.1	5.605	0.036	3.138	1.090	51.466	0.325	0.173	26.405	2.310
2.2	5.173	-0.268	2.970	0.938	52.475	0.302	0.155	28.763	2.876
3.1	5.983	-0.017	3.017	1.032	48.589	0.313	0.164	27.225	2.097
3.2	5.768	0.055	2.879	0.905	49.017	0.292	0.148	27.421	2.373
4.1	5.969	-0.279	2.644	0.741	44.956	0.260	0.124	29.537	2.405
4.2	5.747	-0.411	2.657	0.698	45.885	0.260	0.120	29.493	2.585

Table 16, Intact stability calculation mono-hull results

The vessel complies with all the intact stability criteria. It is notable that the G'M values are high for this kind of vessel, this could lead to high transvers accelerations which is unpleasant for crew and passengers.

2.8.2 Accidental loss of load stability calculation

The crane operations, loading condition 4.1 and 4.2, have also been subjected to a loss of load calculation. The regulations, made by DNV, are given in Appendices VI.B. These regulations had to be implemented into the stability calculation program (PIAS), we interpreted the rules as follows.

Implementation of the rules

We assume the vessel has no heel angle during the hoisting operation due to counter ballast, than the moment on the vessel (tonm) due to the load in the crane is calculated. This means that the first static angle (QL) should be zero in reality. However the calculation made in PIAS is static and the lost load is not included, therefore we use a trick to solve the calculation. A new loading condition is made without the load in the crane and without counter ballast. This results in a small heeling angle QL, due to the boom of the crane which is still outside the vessel. Now the moment which was initially induced by the load is applied the other way around on the vessel, this results in the second static angle (Qe).

The restoring energy represented by area A2 is to be at least 40% in excess of the potential energy represented by area A1. The angle of static equilibrium Qe after loss of crane load shall not be more than 15 degrees from the upright

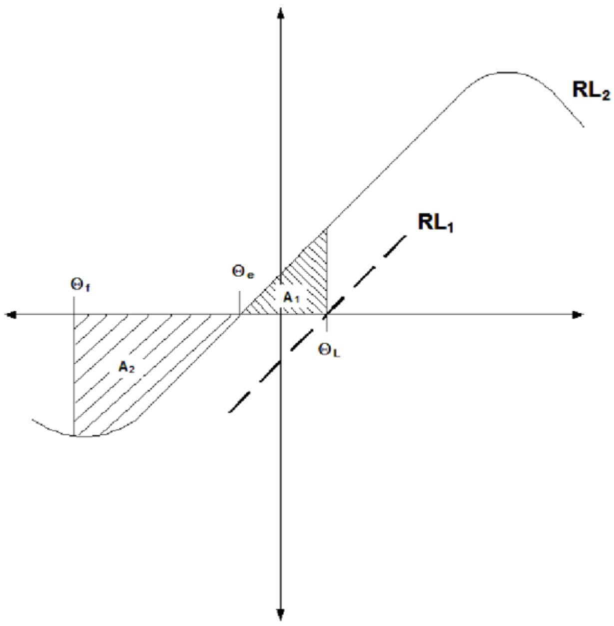


Figure 14, GZ curve DNV loss of load calculation

Results

A summary of the results is presented in table 16, detailed results can be found in Appendices VIII.

The moment on the vessel:
100 tons load at 20.5 meters out of heart ship results in a moment of 2,050tonm, or 10,055kNm

Loading condition	Statical angle of inclination (QL)	Statical angle of equilibrium Qe	Area A2>1.40*A1
4.1	2.060	5.743	Yes
4.2	2.220	6.269	Yes

Table 17, Results loss of load calculation mono-hull

The vessel complies with the regulations for loss of load. The final statical angle of equilibrium for the two loading conditions is around 6^0, which is a lot when you're on the vessel, but below the safety margin of 15 degrees given in the regulations.

2.8.3 Damage stability calculations

One of the requirements of the vessel is to accommodate 70 special personnel. A consequence of this requirement is that the vessel has to comply with the code of safety for special purpose ships 2008 (SPS 2008), which requires probabilistic damage stability calculations. Because of the extensive nature of these calculations they are not yet done in this stage of the design process. To be sure the vessel will comply with these regulations in the future we developed a simple method based on the G'M values of the loading conditions and experience with these calculations.

It is mandatory for probabilistic calculations make a G'M limit curve, based on the loading conditions. The graph, given in figure 15, shows the G'M values for all loading conditions versus the draft of the vessel for that specific loading condition. Probabilistic damage stability calculations are performed for three drafts of the vessel, the lightest service draft; the design draft and a condition at 60% between the two previous drafts. For each of these drafts the minimum G'M is determined using the G'M limit curve. Experience with probabilistic damage calculations tells us that the minimum G'M value for this kind of vessels should be higher than 1.5 meter. If this is the case the vessel layout can be assigned in such a way that it will comply with the regulations

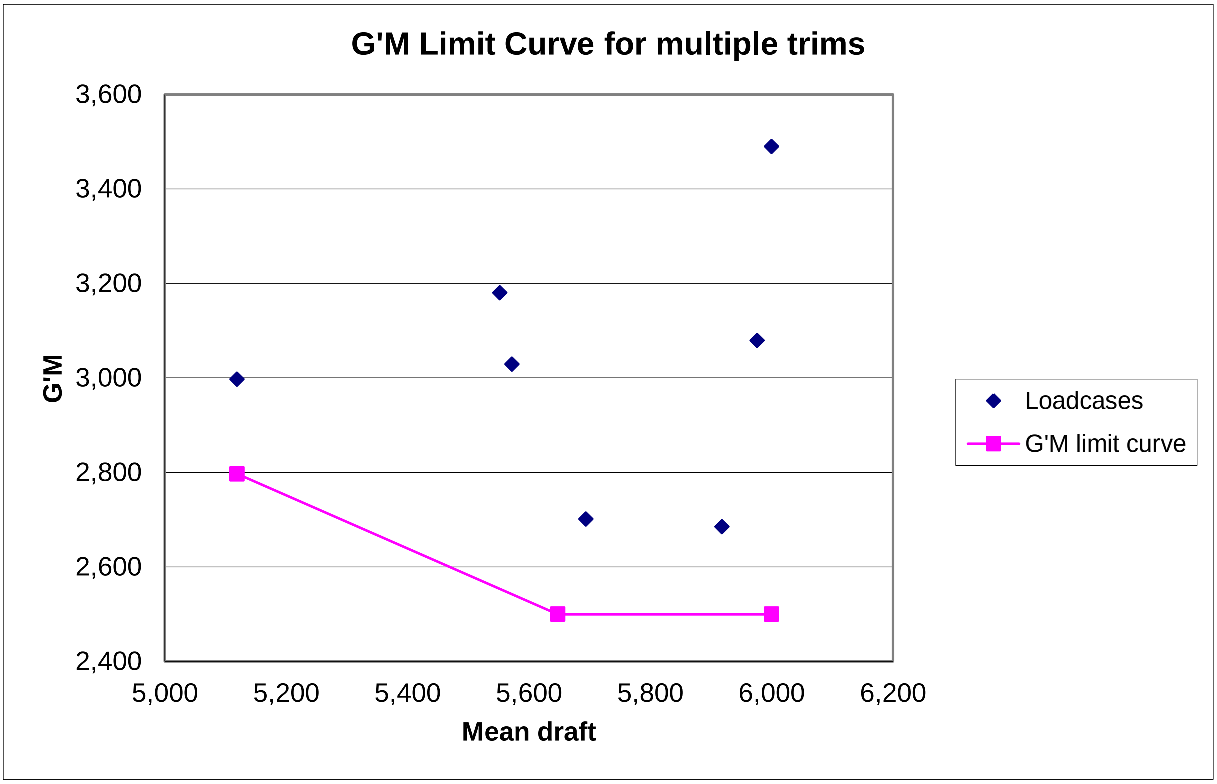


Figure 15, G'M limit curve mono-hull

Condition	Tmean	G'M
Lightest service draft (dl)	5.215	3.220
Partial subdivision draft (dp)	5.686	3.000
Deepest subdivion draft (ds)	6.000	3.300

Table 18, Drafts and G'M values for probabilistic damage stability calculation

For all three drafts the G'M value is significantly higher than 1.5 meters, therefore it should comply with the regulations of the SPS code for damage stability.

2.8.4 Tank arrangement

This is the tank arrangement and vessel contour used for the stability calculations.

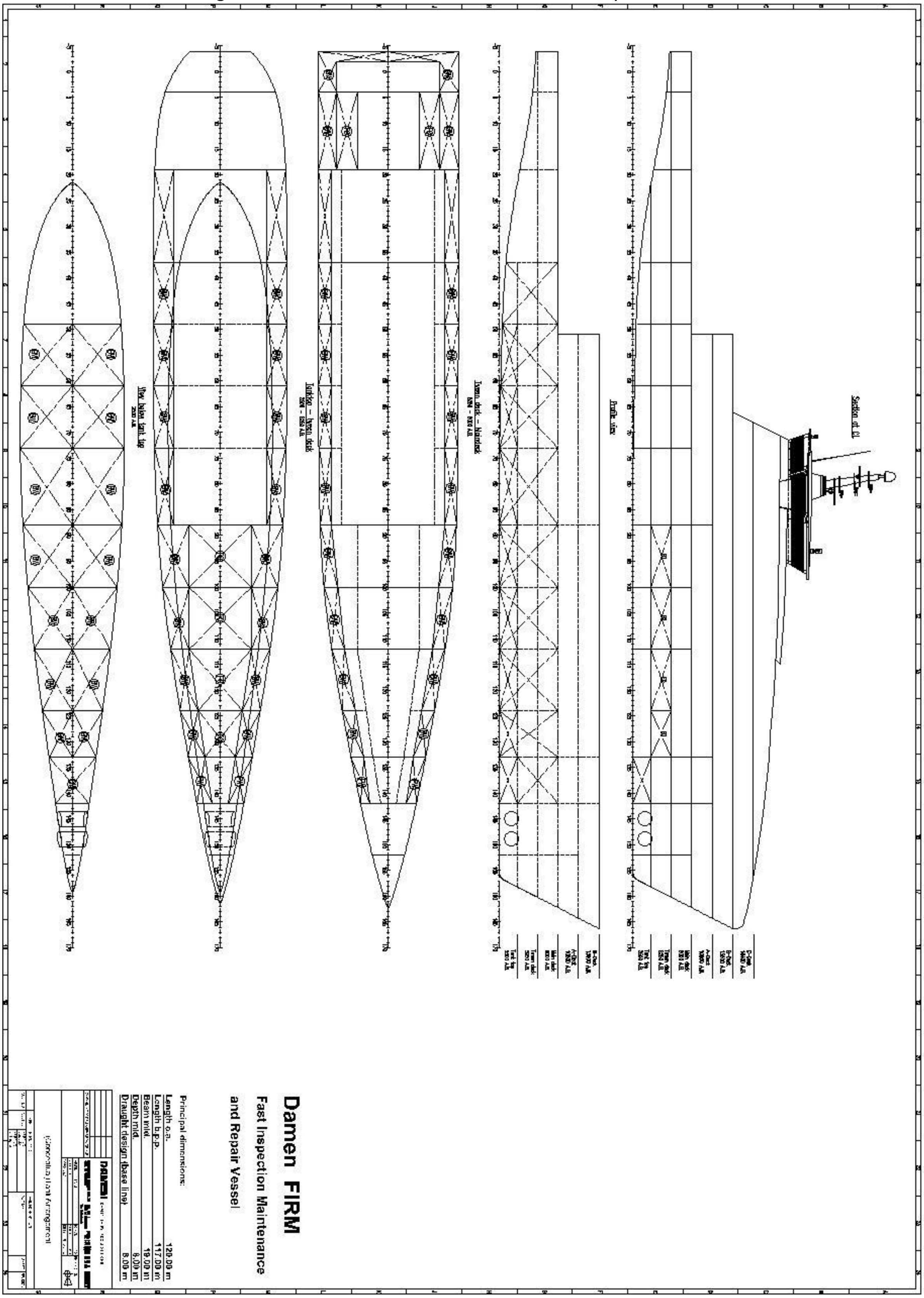


Figure 16, Tank arrangement mono-hull

2.9 Seakeeping

The seakeeping behavior of the concept vessel is predicted using the computer program OCTOPUS, which uses strip theory. The reason to use this method is because it has proven to be very accurate for slender bodies, like this concept vessel, and it can deliver results quickly. A short background on strip theory can be found in Appendices IX.

2.9.1 Approach and criteria

In order to get results regarding the see keeping characteristics of the concepts vessel there are a few steps that need to be taken within the program. Because these steps give a better insight of the calculations, but aren't very important for this thesis, they are only covered shortly.

- Import hull model into Octopus.
  The hull model made in DelftShip is imported to Octopus as a .dxf file and later meshed. Only the part of the hull below the waterline is used, because strip theory only deals with this part of the hull. Besides the actual hull form also all the parameters of the hull like main dimensions and displacement are entered.
- Calculate RAO's.
  The program than calculates the Response Amplitude Operators (RAO's) for all ship motions and for several speeds and headings.
- Simulate waves.
  There are a few possibilities to simulate the waves that encounter the vessel, both regular and irregular. It was decided to specify a the sailing area (North- and Norwegian- sea) and use the corresponding wave scatter diagram to simulate the situation as accurate as possible.
- Specify points on the vessel to calculate motions, velocities and accelerations.
  As a result of the sea keeping calculations we want to know the magnitude of the motions, velocities and accelerations at a certain point on the vessel. One can imagine that for instance vertical accelerations at the bow are higher than at the bridge which is closer to the CoG.
- Determine operability by use of criteria set by Nordforsk (1987).
  In the 70's a group of Norwegian scientists at Marintek have determined a set of criteria for ship motions which are still used today. These criteria give a maximum acceleration or motion for a certain space on the vessel and type of work done at that space. A copy of the paper can be found in Appendices X. These criteria are used to determine the operability of the vessel for the given region expressed in a percentage of the total operating time.
- Visualize results.
  After the calculation is made and the motions and accelerations of the vessel for a variety of speeds at the given points are known the results are plotted in the wave scatter diagram. This shows the maximum significant wave height for a certain wave period in which the vessel can still operate.

Note: The calculations can be considered conservative because all possible headings are taken into account which means that the worst possible heading will give the outcome of the operability. In practice a captain has, and most certainly will also use, the ability to change course in order to avoid the worst scenario.

2.9.2 Results

The results of the sea keeping calculations are visualized in a table and a graph per operational state, dynamic positioning; transit speed and full speed. The table shows the criteria and location for which the criterion is calculated. Example, “Vert. acc. Rms, FP” means the Rms (root mean square) value of the vertical acceleration at the bow. The limit for this criterion as set by Nordforsk is given in the second column and the third column describes the type of work that should be possible at this position, which is also normative for the limit. Finally the last column shows the possible operability of the vessel as a percentage of the total operating time.

The graph visualizes the limiting criteria vs the wave scatter diagram which was used for the calculations. This gives a good impression of the critical significant wave height and period for this vessel.

Operability limiting criteria FIRM DP (0 knots)	Limit	Description	Operability
Vert. acc. Rms, FP	0.15g	Heavy manual work	99.00%
Vert. acc. Rms, Bridge	0.15g	Merchant vessel criteria	100.00%
Lat. Acc. Rms, Bridge	0.12g	Merchant vessel criteria	84.00%
Roll rms	4 deg	Heavy manual work	57.00%
Slamming, bow, crit prob	0.01	Merchant vessel criteria	97.00%
Deck wetn. Crit. Prob. 1/3L	0.05	Merchant vessel criteria	63.00%
Deck wetn. Crit. Prob. 1/2L	0.05	Merchant vessel criteria	64.00%
Vert. acc. Rms. 1/3L	0.15g	Heavy manual work	95.00%
Vert. acc. Rms. 1/2L	0.15g	Heavy manual work	95.00%
Lat. Acc. Rms. 1/3L	0.07g	Heavy manual work	99.00%
Lat. Acc. Rms. 1/2L	0.07g	Heavy manual work	99.00%
Vert. acc. Rms. Accommodation	0.15g	Merchant vessel criteria	93.00%
Lat. acc. Rms. Accommodation	0.12g	Merchant vessel criteria	98.00%

Table 19, Operability mono-hull, 0 knots

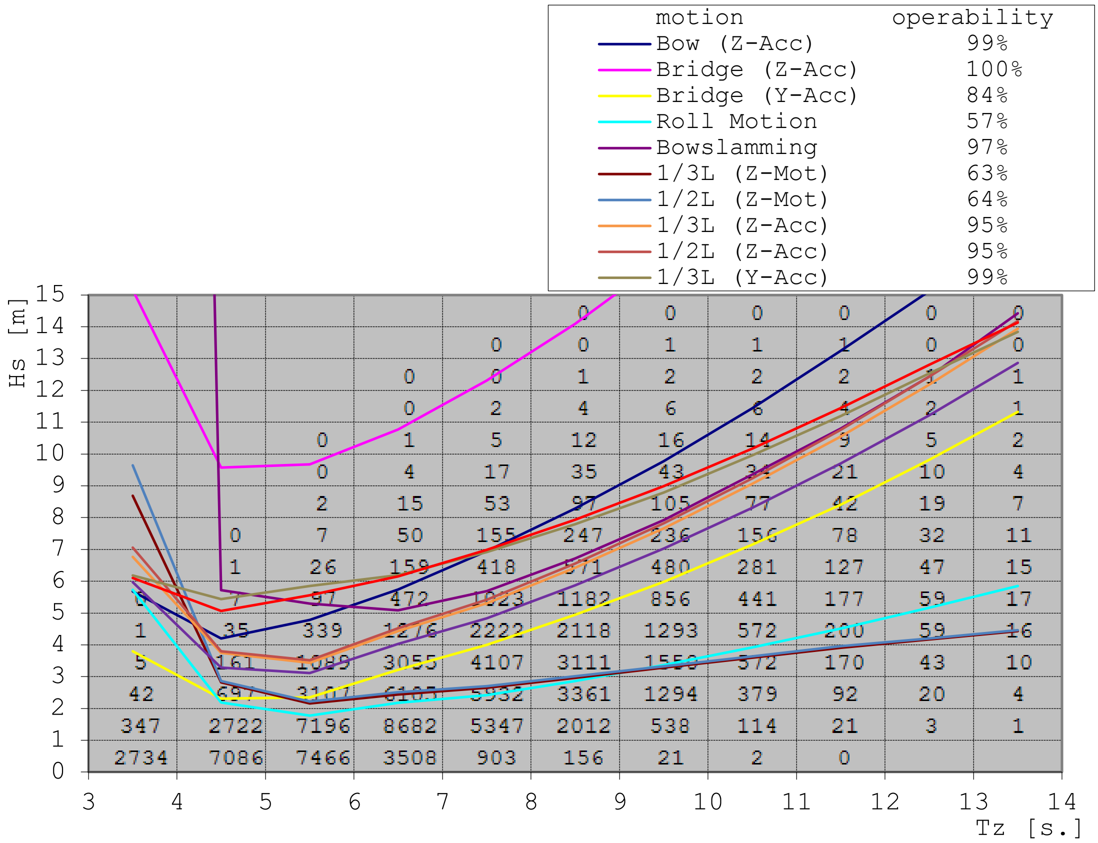


Figure 17, Operability mono-hull, 0 knots

Operability limiting criteria FIRM transit (15 knots)	Limit	Description	Operability
Vert. acc. Rms, FP	0.2g	Light manual work	84.00%
Vert. acc. Rms, Bridge	0.15g	Merchant vessel criteria	100.00%
Lat. Acc. Rms, Bridge	0.12g	Merchant vessel criteria	82.00%
Roll rms	6 deg	Light manual work	87.00%
Slamming, bow, crit prob	0.01	Merchant vessel criteria	84.00%
Deck wetn. Crit. Prob. 1/3L	0.05	Merchant vessel criteria	65.00%
Deck wetn. Crit. Prob. 1/2L	0.05	Merchant vessel criteria	66.00%
Vert. acc. Rms. Accommodation	0.15g	Merchant vessel criteria	88.00%
Lat. acc. Rms. Accommodation	0.12g	Merchant vessel criteria	99.00%

Table 20, Operability mono-hull, 15 knots

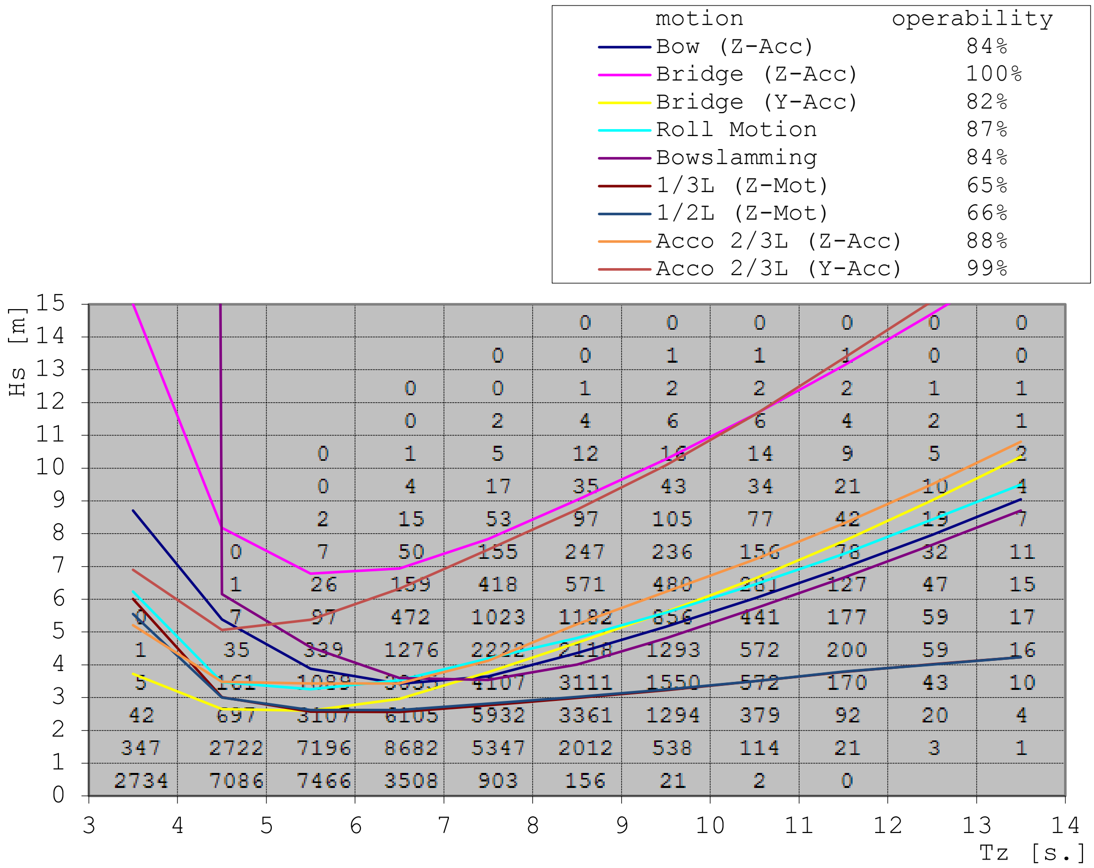


Figure 18, Operability mono-hull, 15 knots

Operability limiting criteria FIRM transit (25 knots)	Limit	Description	Operability
Vert. acc. Rms, FP	0.2g	Light manual work	69.00%
Vert. acc. Rms, Bridge	0.15g	Merchant vessel criteria	93.00%
Lat. Acc. Rms, Bridge	0.12g	Merchant vessel criteria	81.00%
Roll rms	6 deg	Light manual work	89.00%
Slamming, bow, crit prob	0.01	Merchant vessel criteria	77.00%
Deck wetn. Crit. Prob. 1/3L	0.05	Merchant vessel criteria	65.00%
Deck wetn. Crit. Prob. 1/2L	0.05	Merchant vessel criteria	65.00%
Vert. acc. Rms. Accommodation	0.15g	Merchant vessel criteria	75.00%
Lat. acc. Rms. Accommodation	0.12g	Merchant vessel criteria	100.00%

Table 21, Operability mono-hull, 25 knots

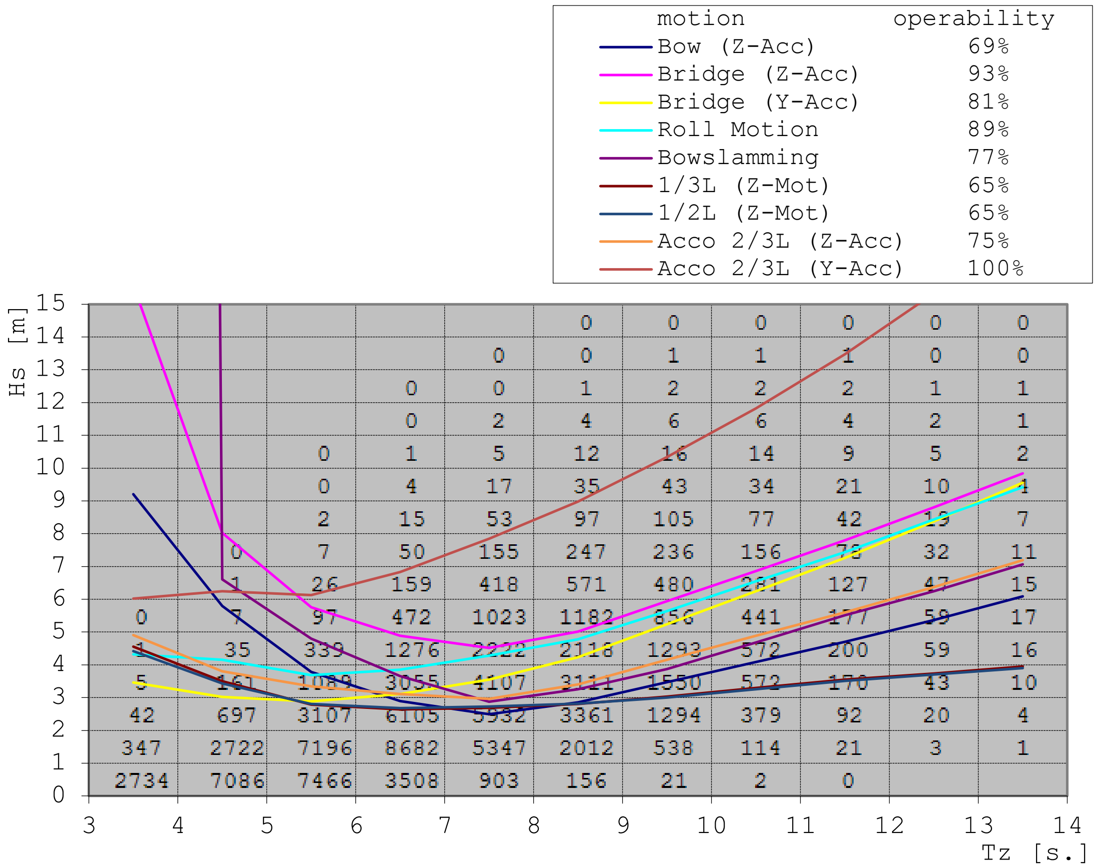


Figure 19, Operability mono-hull, 25 knots

The results show that the rolling motions at DP and deck wetness are the major limiting factors for the operability. At DP the captain is often not able to adjust the heading of the vessel due to the proximity of a platform. The low operability for transit and full speed due to vertical accelerations can be assigned to bad headings and can most of the time be corrected by intervention of the captain. The lateral accelerations at transit also contribute to a decline of operability, this is most likely the result of the high G’M of the vessel.

2.10 Dynamic positioning

The operational profile indicates that the vessel will be at DP for 70% of the time. It is therefore necessary to investigate the environmental forces on the vessel in order to determine the amount, size and power of the transverse tunnel thrusters. In Appendices X.A a short overview of the theoretical background on dynamic positioning is given.

The best way to calculate the environmental forces on a vessel is to perform model tests or make 3D diffraction calculations at zero speed. Both of these recourses where unavailable, making it impossible to come up with the right transfer functions for the mean second order wave drift forces. This meant that one of the three environmental forces couldn't be calculated. The other two, wind and current, could be estimated to certain accuracy. Based on these two forces it was possible to make an estimation of the required thruster power by adding 20% for the unknown wave drift forces.

2.10.1 Calculation of forces and moments

The results of the forces and moments calculation for current and wind are listed below, the complete detailed calculation can be found in Appendices X.B.

Current

The current force (F_C) is calculated with Bernoulli's law, the moment induced by this force M_C is a result of the force times the distance from L/2.

$$F_C(dX) = \frac{1}{2}\rho v^2 A C_D \qquad M_C = F_C \cdot n \cdot dX$$

The velocity v of the current was set in Chapter 1.4 at a speed of 2 knots.

The cross section of a vessel varies over its length, in order to define the right drag coefficient (C_D) the vessel has been subdivided into sections dX of 5 meter in length and the drag coefficient per section is determined. Various shapes have been tested in the past and the C_D value of a certain (2D) shape for a certain Reynolds number can be read from a graph. The mono-hull concept has an ellipse shape and the corresponding C_D coefficient per section depends on the ratio B/2T (see Appendices). The determined C_D coefficients for this vessel are given in figure 20.

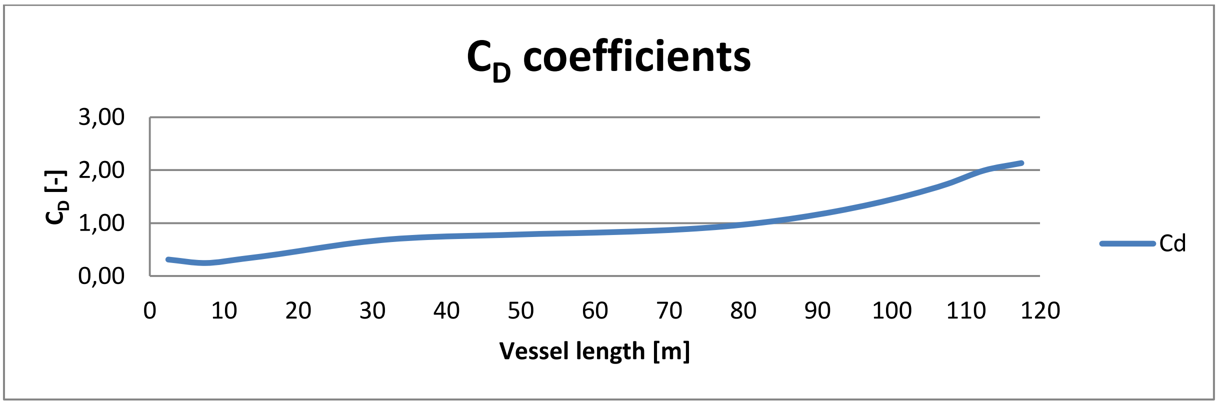


Figure 20, Cd coefficients mono-hull

The current force and moment on the vessel are calculated for a 90^0 heading, the reason to look only at this heading is that 90^0 is in most cases the worst possible heading and the worst case is decisive for the thruster choice. Calculating other headings requires other C_D coefficients which is a time-consuming effort and not relevant for this case.

Wind

Wind forces on the lateral plane of the vessel (90^0 heading), at the design draft T=6m, are also calculated with Bernoulli. The C_D coefficient is determined at 1.2 and the wind speed is given in Chapter 1.2 (30 knots). See Appendices X.B for the complete calculation.

$$F_W = \frac{1}{2}\rho v^2 A C_D$$

The vessel has been subdivided in the same way as for current calculations, the vessel contour with subdivision of the section is given in figure 21.

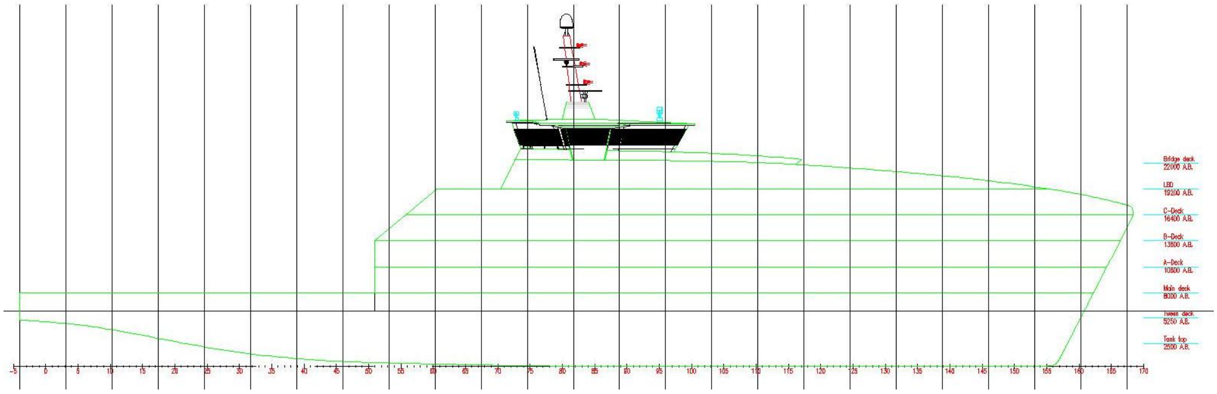


Figure 21, Contour mono-hull

Results

The forces and moments for wind and current are visualized in the graphs below. It shows the force on the vessel induced by wind and current at a specific part on the vessel. It becomes clear that the force on the front is larger than the force at the aft of the vessel. This corresponds to the expectation one has when looking at the vessel contour.

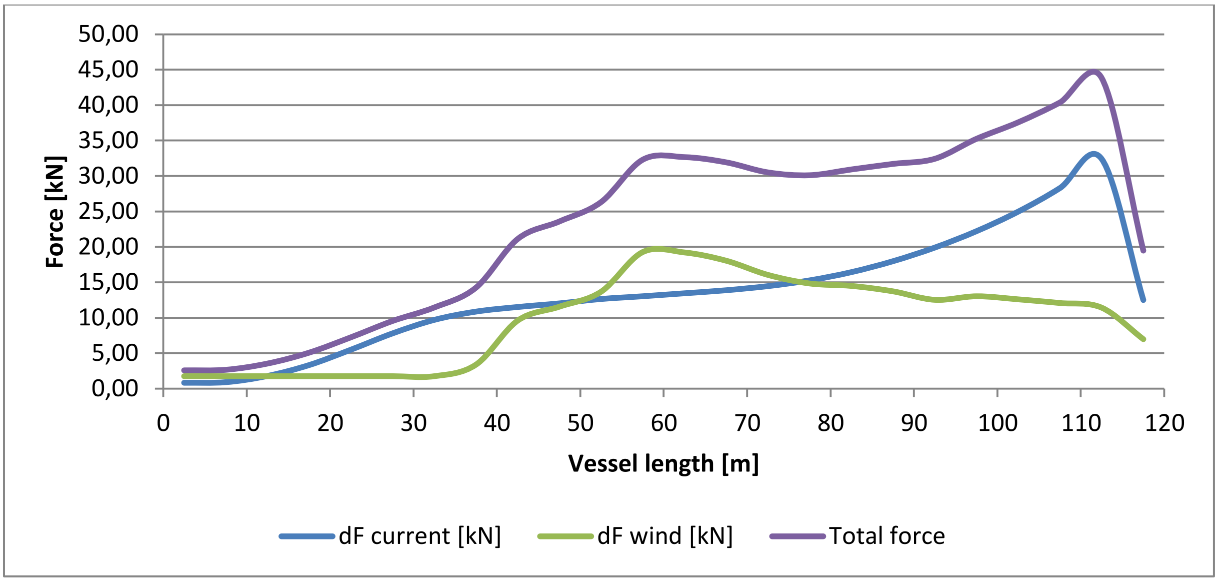


Figure 22, Forces on mono-hull

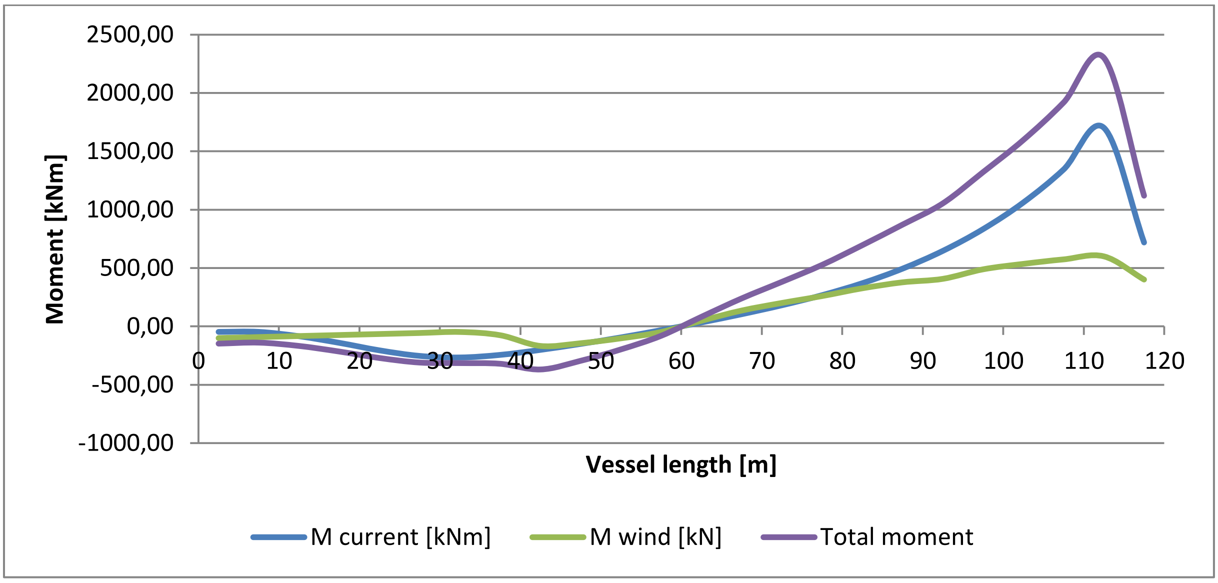


Figure 23, Moments on mono-hull

2.10.2 Thruster forces and static equilibrium

The environmental forces on the vessel have to be counteracted by the vessels thrusters. We use a static approach of the problem and calculate the amount of thrust by finding a static equilibrium; the sum of the force and moment on the vessel has to be 0. Table 22 shows the total applied environmental force and moment on the vessel.

Forces wrt COG					
	waves	current	wind	total	
Fx	0	0	0	0	kN
Fy	0	322	235	557	kN
Mz	0	5984	3292	9276	kNm

Table 22, Environmental forces and moments mono-hull

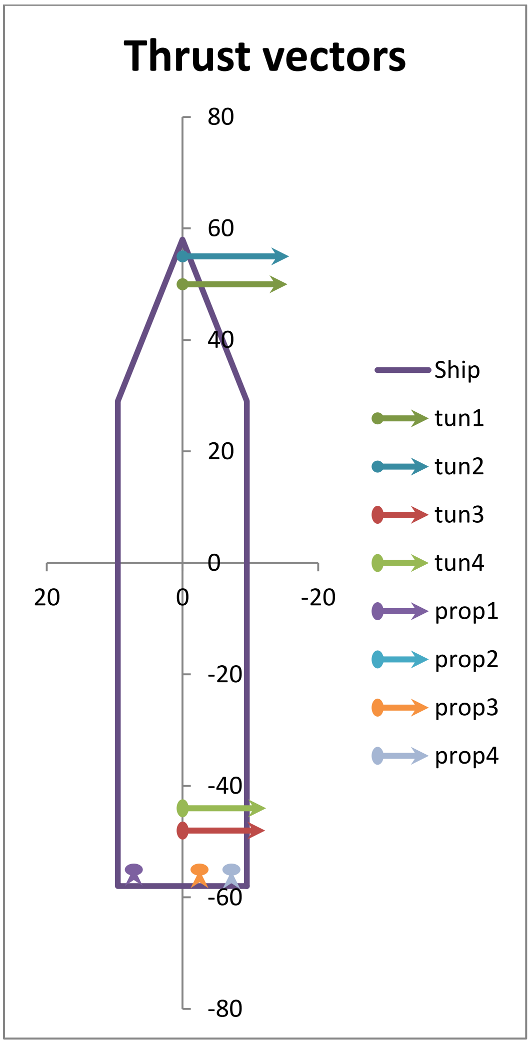


Figure 24, Thrust vectors mono-hull

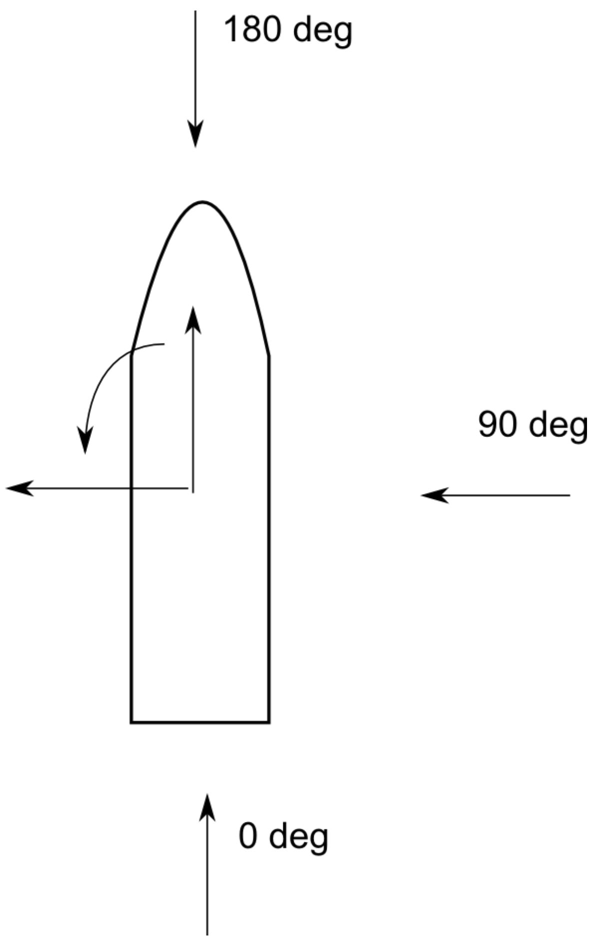


Figure 25, Orientation forces, moments and heading

Thruster forces:

Because we only look at an incoming angle of 90^0 for both current and wind there is no thrust delivered by the main propulsion. The amount of power installed to reach 25 knots is considered to be more than sufficient for station keeping in the X direction. The 5400kW installed for bow- and stern thrusters is used for 80% in this situation and leaves 20% margin for mean wave drift forces.

	actual	min	max		
Thrust tunnel 1	-154.6	-191.3	191.3	kN	-81%
Thrust tunnel 2	-157.1	-191.3	191.3	kN	-82%
Thrust tunnel 3	-121.6	-153	153	kN	-79%
Thrust tunnel 4	-122.1	-153	153	kN	-80%
Total applied power	4457	0	30600	kW	15%

Table 23, Thruster forces mono-hull

The propulsion configuration will be:

4x Propellers with rudders for forward and backward thrust 6300kW each
2x Bow thruster 1500kW each
2x Stern thruster 1200kW each

3. Design catamaran concept

This chapter describes the design process of the catamaran concept. The structure of the chapter is similar to the previous in which the mono-hull design was described. The methods used in the design of the catamaran are similar to the methods used for the mono-hull, unless otherwise indicated, and are therefore not described and substantiated in this chapter.

A multi-hull design like a catamaran has several positive characteristics that are favorable for the FIRM concept. Catamarans have a larger breadth compared to mono-hull vessel, this leads to a lower overall length and higher transverse GM of the vessel. The hull forms are usually slim, have a large L/B ratio and are therefore able to reach high speeds. These characteristics make it possible to design a smaller vessel in length if compared to a similar mono-hull vessel. A disadvantage of catamaran vessels is the lower deadweight capability.

In this chapter a design for a FIRM catamaran is made to investigate the possibilities of a multi hull for this concept. The final catamaran design is than compared to the mono hull design and a choice is made between the two concept vessels.

3.1 Catamaran comparison and main dimension estimation

A catamaran design of an IRM vessel currently does not exist; all known IRM vessels and comparable offshore vessels are mono-hulls. The idea to analyze the possibility for a catamaran design is the speed requirement of the vessel, possible good transverse stability characteristics and possible decrease in size. The resistance for conventional displacement vessels steeply increases beyond a certain point which usually corresponds with F_N=0.4, which is close to the F_N of the previous mono-hull design. This suggests that for this vessel and speed the mono-hull design is still in the good area. A catamaran has a larger breadth than a mono-hull and can therefore be smaller in length and will operate at higher Froude numbers for the same speed. The resistance hump that mono-hulls experience when sailing over F_N=0.40 is attributed to the generation of increasingly large gravity waves in the free surface. Catamarans minimize the waves generated in the free surface by having extremely slender hulls.

Catamarans as mono-hull vessels can be categorized in displacement, semi-displacement and planning types. The type of vessel depends on the Froude number the vessel operates at. For low to moderate Froude numbers (F_N<0.7) catamarans tend to be of displacement form. In this region the phenomenon of destructive interference is of great importance, which is particularly severe for Froude numbers between 0.3<F_N<0.4 and should be avoided. For higher Froude numbers (F_N>0.7) catamarans generate dynamic lift and become semi-displacement or planning vessels. To get an impression of the region this vessel is in the Froude numbers for a range of waterline lengths for the top speed of 25 knots is plotted in figure 26.

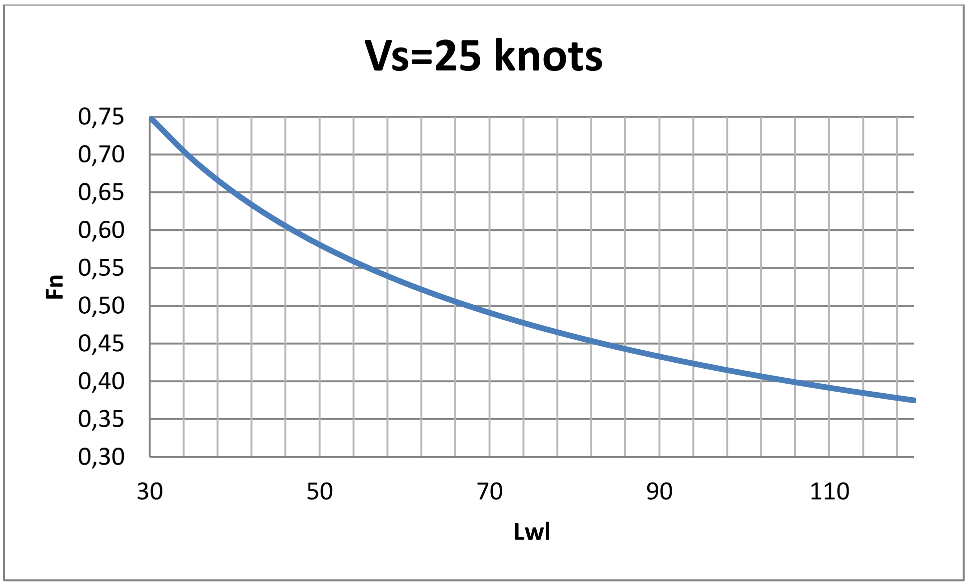


Figure 26, Catamaran Fn vs Lwl

A quick interpretation of the graph and knowledge above shows that the concept design will likely be a displacement catamaran with a maximum waterline length of 100 meters. Above 100 meters the vessel enters the region of destructive interference and only below a waterline length of 35 meters, which is very small for the purpose, the catamaran becomes a semi-displacement craft.

Catamaran comparison analyses

A wide range of catamarans used for different purposes and lengths ranging from 30 up to 125 meters has been collected and put into a database in order to estimate the main dimensions and other characteristics of the vessel. This database can be found in Appendices XI. In Appendices XI.A a number of trend lines are produced with the data of the catamaran database. These trend lines have been used to determine the design parameters of the FIRM catamaran.

An analysis of the data resulted in the following findings:

- All catamarans in the database sail at a higher maximum speed than the speed required for the FIRM, resulting in higher Froude numbers.
- The majority of the catamarans are semi-displacement hull forms.
- Only 5 have a higher deadweight capability than 1000 ton and none of the catamarans have a deadweight capability as high as the mono-hull design.
- Almost all catamarans in the database have water jet propulsion

These findings lead to the conclusion that most catamarans are high speed marine craft, designed to transport people and/or low weight loads. The purpose of the FIRM catamaran is completely different and the design will therefore deviate from most current catamarans. Still the possible advantages of a catamaran as stated in the beginning of this chapter make it worthwhile to design a catamaran concept of the FIRM which can be compared to the mono-hull design.

3.2 Determination of main particulars

The initial requirements for the catamaran design are similar to the mono-hull design. The main requirements which are determinative for the size of the vessel are:

- 600m² deck area
- 2225m² of accommodation space
- ROV handling system and moonpool
- Offshore crane 100t @ 15m
- +- 1450 ton deadweight

As a design start a few assumptions were made, these assumptions are based on information on catamaran design, consultation with the Damen Ferries and Damen Research departments and the catamaran database in Appendices XI.

- The L/B ratio (for 1 demi-hull) for this catamaran should be chosen between 9 and 12, below 8 results in increased wave making and above 12 are values for racing catamarans (Woods). The Damen database of built catamarans shows L/B ratios between 10 and 13. Initially set at 11.5.
- The L/B ratio (for the overall breadth) was initially set at 3.5, based on the trend lines in Appendices XII.A.
- The B/T value should be between 1.5 and 2.8; a value near 2 minimizes the friction resistance (Woods). Initially set at 2.
- The depth equals the draft plus the significant wave height of 2.5 meter for minimum wet deck clearance and an additional meter for the structure between the demi-hulls. The significant wave height of 2.5m is given in the initial requirements of Chapter 1.2.
- The C_B value of one demi-hull is initially set at 0.5, based on the trend lines and Damen vessel information. This value can considered being high for a catamaran, however almost all catamarans are semi-displacement vessels and the FIRM catamaran is a displacement vessel with higher deadweight requirements than the comparison vessels.

Initial deck layout

The initial deck layout is similar to the mono-hull design. The demi-hulls consist of a tanktop, tween deck and a main-deck. The superstructure has three decks A- B- and C-deck, mainly used for accommodation. The ROV system and “moonpool” are considered to occupy 20 meters of the vessel’s length, similar to the mono-hull. The moonpool is modeled as a hole in the deck with the same dimensions as the moonpool for the mono-hull design. A sketch of the main-deck layout is made to estimate the main particulars. This sets the overall length and breadth of the catamaran at 85m and 24.3m.

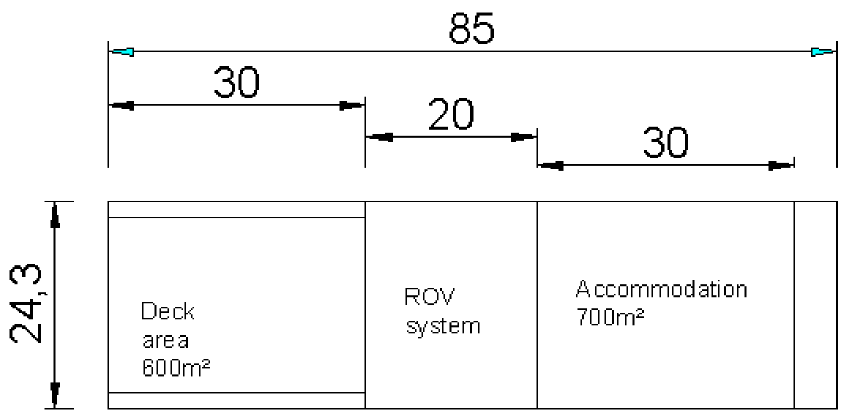


Figure 27, Basic main deck layout catamaran

Main particulars

In accordance with the ratios the preliminary main particulars for the catamaran would be:

Main particulars	
L	85 m
B	24.3 m
T	3.7 m
D	7.2 m
B demi	7.4 m
C_B	0.5
Displacement	2380 t

Table 24, Initial main dimensions catamaran

This results in a design with a total predicted resistance of 830kN at 25 knots, which is favorable over the mono-hull design, see figure 28.

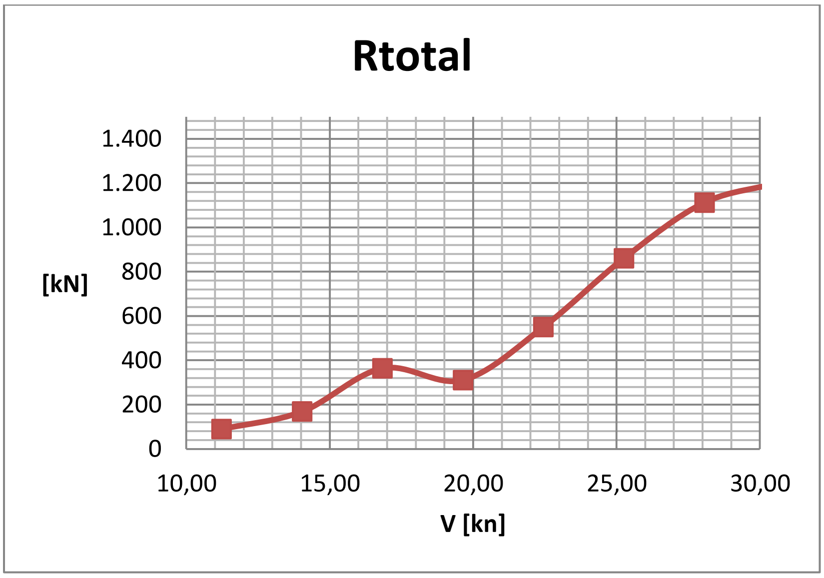


Figure 28, Resistance catamaran

However the problem arose that the vessel has far to less displacement for its purpose, see Chapter 3.6 for the hydrostatics calculation. This is because all known catamarans of this size, which were used to determine the main particulars, have a completely different purpose than the FIRM catamaran. They are mainly light weight high speed ferries, with low deadweight requirements built out of aluminum.

The FIRM catamaran is an offshore vessel constructed out of steel, because it has to perform heavy duty offshore operations alongside platforms. The approximated deadweight requirement is 1450 ton, according to the initial requirements. The lightship weight of the FIRM is far higher than the other catamarans, making the required displacement higher and making this concept vessel a unique case. Therefore the main particulars have to deviate from the ones in table 24, changing some of the ratios given earlier.

In accordance with the basic layout of the main deck the overall length and breadth of the vessel remain the same. Increasing these parameters would lead to a vessel too large vessel. It was therefore chosen to increase the draft and C_B of the demi-hulls to gain displacement. Another option was to increase the breadth of the demi-hulls without increasing the overall breadth of the catamaran. This would bring the demi-hulls closer together which is destructive for the resistance of the vessel due to hull interference.

3.3 Hull design and lines

The final linesplan and the main particulars of the catamaran are given in table 25 and figure 29. Striking characteristics of this vessel, compared to other catamarans, are the low B/T ratio and high C_B.

Main particulars		
L_{oa}	85	[m]
L_{wl}	85	[m]
L_{pp}	82	[m]
B demi-hull	7.4	[m]
B_{oa}	24.3	[m]
T_{design}	6.0	[m]
D	9.5	[m]
Displacement, at T_{design}	5270	[t]
$C_{B,\ Demi\text{-}hull}$	0.68	[-]
$L/B_{overall}$	3.5	[-]
$L/B_{Demi\text{-}hull}$	11.5	[-]
$B/T_{Demi\text{-}hull}$	1.23	[-]
Wetted area	2547	[m²]
Waterplane area	1090	[m²]
LCB	-1.14	%

Table 25, Main particulars catamaran

The complete list of the hull properties can be found in Appendices XII.

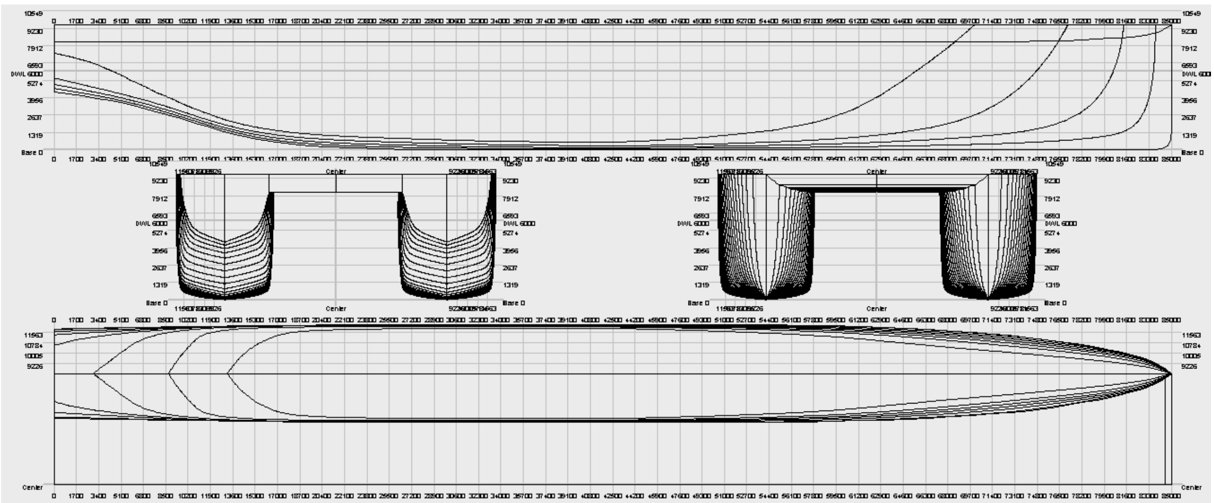


Figure 29, Linesplan catamaran

3.4 Resistance calculation

Compared to a mono-hull vessel there are far less methods available to predict the resistance of a catamaran. Within Damen a resistance prediction tool is used, which is based on model test results of Damen catamarans and data of systematic catamaran series. A result of this tool is given in figure 28, where it was used to determine the resistance of a catamaran based on the initial parameters given in Chapter 3.2. Another method which can be used is described by Molland (1994). He tested a series of systematic catamaran models and compared the resistance of the catamaran with the resistance of only 1 demi-hull. This way it is possible to use a program like Holtrop and Mennen to calculate the single hull resistance, multiply is by 2, and use the research of Molland to predict the extra resistance generated by hull interference.

Molland

Resistance prediction with the method of Molland (1994) for high speed displacement catamarans. In this research a number of systematic models were tested. All 10 models have the same prismatic coefficient of C_P = 0.693, and are varied by length/displacement ($L/\nabla^{1/3}$) and breadth/draft (B/T) ratio. The three models that come closest to the FIRM catamaran are given in table 26, where the parameters are compared to the parameters of the FIRM.

Parameter	FIRM catamaran	Model 3b	Model 4a	Model 4b
$L/\nabla^{1/3}$	4.88	6.27	7.4	7.41
B/T	1.23	2	1.5	1.5
C_P	0.757	0.693	0.693	0.693
C_B	0.68	0.397	0.397	0.397

Table 26, Comparison model catamaran and FIRM catamaran

Table 26 shows that the parameters of the models do not match with the FIRM catamaran and interpolation between the models is impossible because the FIRM falls outside the range of tested models. Therefore the results of the model tests are used to make an educated guess of the increased resistance due to hull interference, by examining the dimensionless friction coefficient (C_T) of the tested models. Table 26 gives the C_T coefficients for the three models, for both the mono-hull test and the catamaran test. The coefficients are for a speed of 25 knots, which corresponds to a Froude number of F_N = 0.45, and a separation/length (S/L) ratio of 0.2. See Appendices XIV for the complete results of the model tests.

Model	C_T demi-hull x1000 [-]	C_T catamaran x1000 [-]	Difference [%]
3b	12	16.5	37.5
4a	9.25	12	29.7
4b	9.25	11.7	26.5

Table 27, Resistance coefficients catamaran models

The results show an average increase of 31% of the total resistance coefficient for the catamaran. The C_T values of the model tests are compared to the C_T values of the resistance prediction according to the method of Holtrop & Mennen and the Damen catamaran resistance prediction tool, which are presented in table 28.

Method	C_T x1000
Damen catamaran prediction tool	12.2
Holtrop and Mennen, 1 demi-hull	7.8

Table 28, Total resistance coefficient H&M and Damen resistance prediction tool

Results

The resistance predictions for the FIRM catamaran according to the three methods are plotted in figure 30. The red line shows the results of the Damen resistance prediction tool. The blue line is the total resistance according to Holtrop and Mennen for 1 demi hull, multiplied by 2. The green line shows the results of the method of Molland, which is the total resistance according to Holtrop and Mennen multiplied with a correction factor for hull interference.

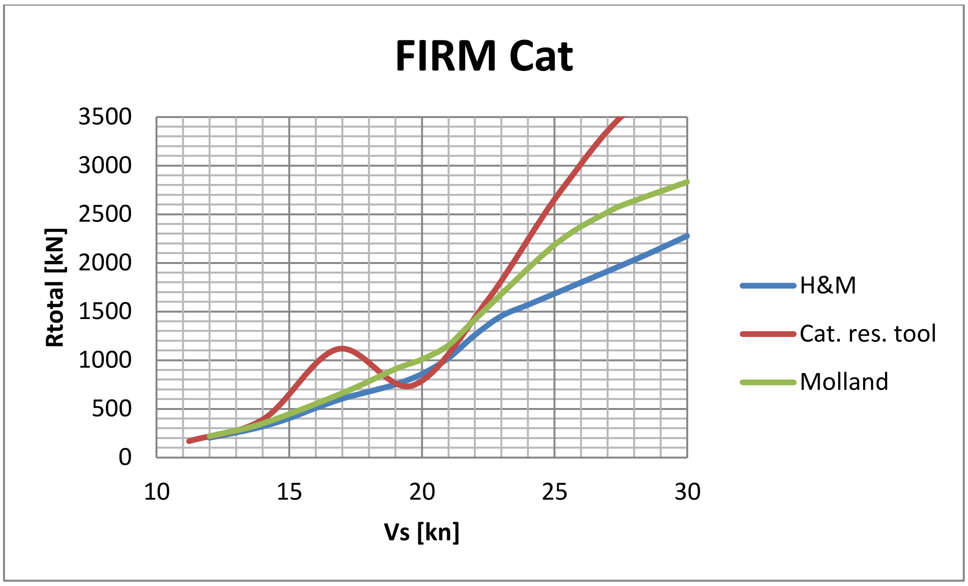


Figure 30, Total resistance catamaran

Method	Resistance at 25 knots [kN]
Holtrop & Mennen	1684
Molland	2184
Damen catamaran resistance prediction tool	2645

Table 29, Total resistance catamaran

Evaluation of resistance results

The FIRM catamaran falls outside the applicability area for Holtrop and Mennen and the Damen catamaran resistance prediction tool, therefore the results in figure 30 should be regarded as estimations. The only correct way to predict the resistance would be by doing model tests. Unfortunately this is not possible, making the estimations above the only reference for the resistance of the catamaran design. The blue line is considered to be the lower boundary and the red line the upper boundary. The total resistance of the FIRM catamaran should lie between these two boundaries.

After studying the research done by Molland it became clear that $L/\nabla^{1/3}$ is the predominant hull parameter. If this is increased, the resistance decreases rapidly. This corresponds to the results in figure 28. Unfortunately the FIRM catamaran has a high $L/\nabla^{1/3}$ ratio due to its deadweight requirements and respectively high lightship weight. This could be decreased by increasing the length of the vessel. Increasing the length also lowers the Froude number, which is positive for the total resistance coefficient, as is goes down for lower Froude numbers. However an increase of the length would lead to a vessel that is too big for its purpose.

Due to the high uncertainty of the resistance a power speed analyses becomes meaningless. It is recommended that model tests are performed first before proceeding with this design.

3.5 Weight calculation

The hull and superstructure weight (weight group 100) are calculated by means of weight factors, like the mono-hull design. The weight factor for the steel weight of the hull is kept equal to the weight factor for the mono-hull and the superstructure is constructed out of aluminum. Weight group 700, Joinery and arrangement of accommodation is also calculated by Damen standard weight factors and based on the floor area of the accommodation. The other weight groups are based on the mono-hull design. Weight groups 200, 500 and 800 are similar to the mono-hull design, because there is no accurate power speed analyses the total machinery weight of the mono-hull was taken as an estimate for the catamaran. The deck equipment (500) is also considered to be equal to the mono-hull, because the vessel is due to perform the same tasks. The weight of weight groups 300, 400 and 600 is based on the mono-hull design and scaled with a factor of 0.7, which is the ratio between the hull weight of the mono-hull and the catamaran.

The structure between the demi-hulls is modeled by H-beams, spread 1 meter apart and a plate on top of it, the calculation can be found in Appendices XIV.A. The weight calculation for the bare hull weight, weight group 100, can be found in Appendices XIV.B.

Total light ship weight

Weight group	Weight [t]	VCG [m]	LCG [m]	TCG [m]
100 Shipbuilding	1,758	7.23	45.53	0.00
200 Main machinery	710	3.50	33.00	0.00
300 Primary ship systems	199	7.70	46.00	0.00
400 Electrical system	166	7.10	47.00	0.00
500 Deck equipment	402	16.50	20.00	0.00
600 Secondary ship systems	36	8.50	36.00	0.00
700 Joinery and arrangement of accommodation	333	14.00	65.00	0.00
800 Nautical, navigation and communication equipment	3	13.20	65.00	0.00
Margins lightship weight	*180 (5%)*	*0.30*	*0.00*	*0.00*
Light ship weight (inclusive 5% margin)	3,787	8,49	42,03	0.00

Table 30, Summary weight calculation

3.6 Hydrostatics

This is a summary of the hydrostatics at the design draft, an extensive hydrostatics report can be found in Appendices XV. The deadweight is based on the initial requirements of Chapter 1.2.

HYDROSTATICS				LCG	VCG	
Light ship weight (incl margin)		3787	t	42.03	8.49	
Deadweight (approx)		1450	t	42.00	7.75	
Displacement (wanted)		5237	t			
				LCB	**VCB**	
Available displacement (T = 6 m)		5270	t	41.53	3.42	
Margin		33	t			

Table 31, Hydrostatics catamaran

3.7 Stability

One of the reasons to design a catamaran concept for the FIRM was the good transverse stability characteristics of a catamaran. Catamarans are known to be very stable due to the two demi-hulls which are apart from each other, resulting in high GM values. In Appendices XVI a stability calculation is made for a crane operation with the catamaran design, without heel compensation. This loading condition is compared to the crane operation condition (100t @ 15m) of the mono-hull without heel compensation. The results are given in table 32.

Vessel	Heeling angle	G'M	T_{mean}	Trim
Mono-hull	7.53	2.613	5.819	-0.326
Catamaran	2.84	12.055	5.83	-0.011

Table 32, Crane operation heel comparison

Looking at the results it can be concluded that the catamaran is much more stable than the mono-hull and therefore better suitable to perform crane operations. The catamaran doesn't need heel compensation and the mono-hull without heel compensation won't even comply with the stability requirements.

4. Selection

In the two preceding chapters the two concept designs of the mono-hull and the catamaran FIRM have been evaluated. Both vessels have positive and negative aspects. In this chapter these aspects are discussed which leads to a choice of concept. The final concept is than evaluated and improved in Chapter 5.

With the start of this project the reason to design a catamaran concept was the high transverse stability and high speed of this type of vessel. Looking at the stability this was correct, a catamaran does have a higher GM than a mono-hull and is more stable for crane operations. On the other hand the speed of a catamaran is mostly due to dynamic lift, making it a semi-displacement vessel. Most catamarans are lightweight vessels with a low deadweight requirement. The FIRM catamaran is an offshore vessel with high deadweight requirements and the “high” speed of 25 knots turned out to be a lot slower than most catamarans can go, making it sail at a lower Froude number. Due to the size, weight and speed, making it a displacement catamaran the vessel turned out to have a very high resistance. In Chapter 3.4 the resistance of the catamaran is calculated with three different methods and even with the method that resulted in the lowest resistance (Holtrop and Mennen, without taking hull interference into account) the resistance of the catamaran turned out to be almost 50% higher than the mono-hull at 25 knots. This leads to only one conclusion, a catamaran is an infeasible solution for this particular vessel and therefore the mono-hull concept is chosen.

5. Mono-hull concept optimization and final design

This chapter continues with the design of the FIRM mono-hull concept. The new goal is to optimize the current design by improving the negative aspects, like the high resistance; roll motions at DP; high GM at transfer and taking over of green water. At first a possible resistance reduction and improved stability at DP is investigated, Chapter 5.1 and 5.3. This eventually leads to a new design of the FIRM mono-hull concept in Chapter 5.3.

5.1 Resistance reduction

During the design phase it was observed that the required power is high and the load on the propellers forced the design to have four propellers for propulsion. This condition only occurs for maximum draft and maximum speed, in other words with full load and 25 knots. Given the purpose of the vessel one can wonder how often this particular situation will occur. For quick response the vessel will travel at maximum speed, but this is only 5% of the total operational profile and it is very unlikely that the vessel will carry 600 ton of deck load in this condition. Quick response means a repair or replacement of a certain critical part of an offshore oil and gas operation; these are never 600 tons in weight.

Besides the deck load requirement the endurance also adds in the total deadweight requirement. In case of quick response it is not necessary to take in 100% consumables, the most likely minimum amount of consumables is calculated and will, together with the deck load requirement, form the new deadweight requirement. Taken this in mind an alteration is made in the requirements in order to investigate the possible reduction of resistance and installed power.

New requirements:

- 25 knots with 100t deck load and minimal amount of consumables
- 15 knots with max deck load (600t) and max consumables

Displacement calculation

To get an impression of the range a map of the North- and Norwegian Sea is given with a radius of 600 nautical miles from Bergen, Norway. This is the most likely operating area and also forms the base of the wave scatter diagram used for the sea keeping calculations.

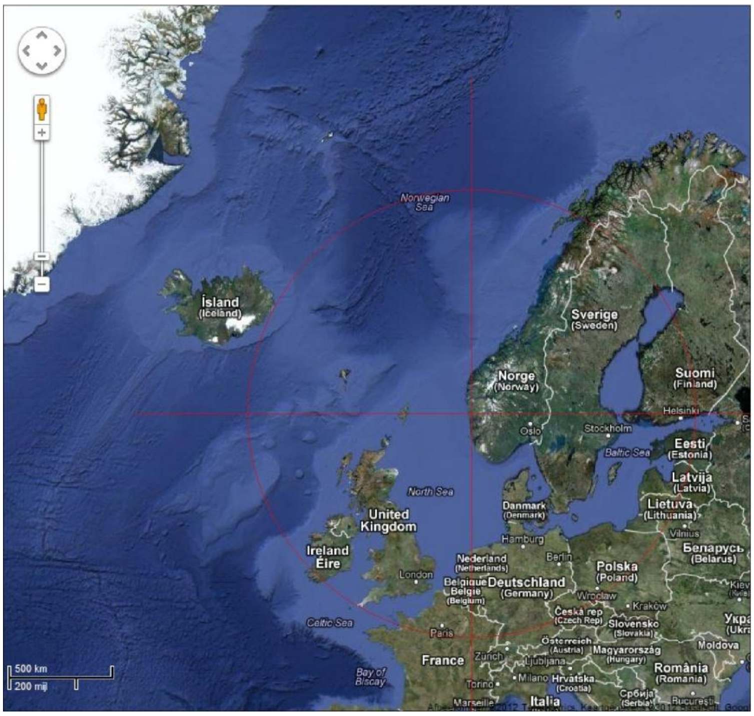


Figure 31, Map op North-West Europe

The required deadweight and displacement for this new situation:

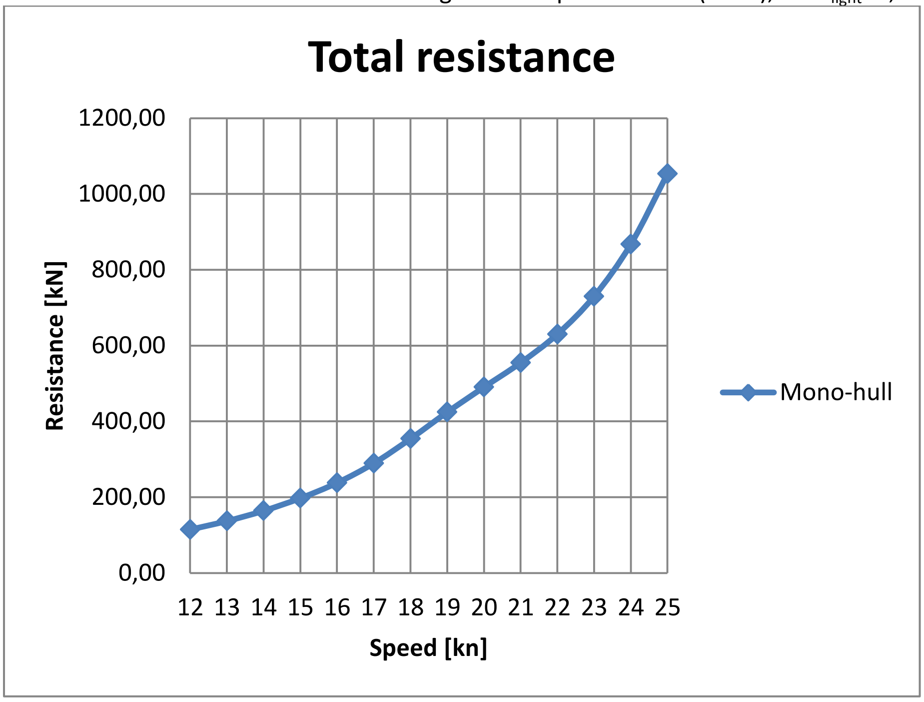
Fuel capacity for 1200 miles full speed and 2 days DP	=	265	ton
Fresh water	=	50	ton
Sewage	=	50	ton
Deck load	=	100	ton
Crew and stores	=	17	ton +
Total	=	482	ton

Light ship weight	=	4646	ton
Deadweight	=	482	ton +
Displacement needed	=	5128	ton

The design is kept similar and the above summation allows a draft reduction of the vessel which results in a resistance reduction. The new draft for this light service condition is set at 5.5 meters.

Resistance

New resistance calculation according to Holtrop & Mennen (1984), for T_{light}=5,5m.



V	R_{total}
[kn]	[kN]
12	114.54
13	137.02
14	164.05
15	197.36
16	237.83
17	289.36
18	354.09
19	424.16
20	490.19
21	554.71
22	629.92
23	729.77
24	867.16
25	1053.24

Figure 32, Resistance mono-hull T=5.50m

Resistance reduction	=	86	kN
P_B reduction, approximately	=	1850	kW

On a total required break power 24280 kW this is a decrease of +/- 7.5%. This results in a reduction of fuel consumption of 324 kg every hour while sailing at full speed. Besides the fuel saving it allows the designer to fit smaller engines into the design.

5.2 Increase stability for DP

One of the weak points of the mono-hull compared to the catamaran was transverse stability; this was for instance expressed in the seaway calculations for DP condition. The criterion for roll is 4 degrees RMS and the calculation showed an operability at DP of only 57%. This calculation already included a passive anti-roll tank and bilge keels. Looking at the differential equation for the roll motion of a vessel it becomes clear what could be done to improve this.

Roll motion:

$$(I_4 + A_{44})\ddot{\phi} + B_{44}\dot{\phi} + C_{44}\phi = F_4 e^{i\omega_e t}$$

$$\phi = \frac{F_4}{\sqrt{(C_{44} - (I_4 + A_{44})\omega_e^{\,2})^2 + B_{44}^{\,2}\omega_e^{\,2}}}\cos(\omega_e t + \varepsilon)$$

$$C_{44} = GM_t \nabla \rho g$$

$$I_4 = k_{xx}^{\,2} \nabla \rho$$

I_4 = Moment of inertia for roll

A_{44} = Added inertia coëfficient for roll

B_{44} = Non-dimensional damping coëfficient for roll

C_{44} = Hydrostatic restoring coëfficient for roll

F_4 = Roll exciting moment at the encounter frequency ω_e

ϕ = Instantaneous roll displacement

$\dot{\phi}$ = Instantaneous roll velocity

$\ddot{\phi}$ = Instantaneous roll acceleration

The damping and/or the restoring coefficient have to be increased to decrease the roll motions. To increase the restoring coefficient the GM of the vessel has to be increased. However we always have to keep in mind that a too large GM results in high transverse accelerations which are unpleasant for the people onboard and will also affect the operability. The damping coefficient can be increased by adding for instance a keel, active fin stabilizers, or a larger passive anti rolling tank.

Increase of hydrostatic restoring coefficient.

$$GM = KB + BM - KG$$

There are two ways to increase the GM and both require a change in the vessels geometry. First possibility is to lower the CoG, for instance by using lightweight materials in the upper decks or placing heavy equipment lower in the vessel. Second option is to alter the design in such a way that the metacentric height increases, this can be done by increasing the displacement. The negative side of this option is that it will increase the vessels resistance as well.

The best solution is to design a hull form that has the same resistance, or maybe even lower than the current design in transit and has a higher displacement at DP. The next chapter covers a new loop through the design spiral in which the mono-hull design is optimized.

5.3 New design

The new approach of the design requirements, the selection procedure and other knowledge attained in the previous chapters results in a new, final, concept design of the FIRM. This design is based on the previous mono-hull and has the following improvements and alterations:

- Reduction of roll motions
  The new design has a keel and integrated sponsoons. The keel increases the damping coefficient of the vessel and reduces the roll motions. The sponsoons are integrated in the hull over the length of the cargo deck. When the vessel is stationary it can increase the draft by pumping ballast water into the vessel, the waterplane area and displacement are than increased due to the geometry of the vessel. This results in an increase of the transverse stability (higher GM) and reduction of roll motions.

- Reduce green water overtaking and decrease GM at transit, higher freeboard
  The sea keeping calculations also showed a low percentage of operability due to green water overtaking at the cargo deck. Given this information and the idea to increase the draft at DP for increased stability led to an increase of the depth of 1 meter. By increasing the depth the VCG will increase resulting in a lower GM. This decreases the transverse accelerations which is pleasant for crew and passengers during transit.

- Definition of a light service draft for high speed
  In an attempt to reduce the resistance of the vessel the requirements are altered. The maximum speed of 25 knots has to be reached in a loading condition with only 100 tons of deadweight. The maximum deadweight requirement and corresponding 600t deck load will be reached at another draft.

- Vertical bow
  The new design has a vertical bow, this has two reasons. First esthetically, the new line of Damen vessels all have a vertical bow. This is a result of the Axe-Bow concept, applied to small high speed crafts. These vessels have a deeper fore foot (below the baseline) to prevent the bow from emerging out of the water in seaway and prevent corresponding slamming, which results in lower vertical accelerations. The deeper forefoot is unnecessary for larger vessels, because the bow emerges far less out of the water. The second reason is to increase the waterline, which results in a higher hull speed and less resistance. On the other hand the vertical bow raises the wet surface area which is detrimental for the frictional resistance.

- *The use of high tensile steel (recommendation)*
  The alterations to the hull, sponsoons, keel and increased Depth, have a negative effect on the light ship weight. As a result the displacement increases together with the resistance, to counter this effect a recommendation in done to investigate to use of high tensile steel in the hull construction to save weight. For this thesis this option is left out of the scope.

5.3.1 Hull design and lines

The new hull form has integrated sponsoons over the length of the cargo deck and a higher depth of 9 meter instead of 8 to decrease green water overtaking. Due to the sponsoons the total breadth of the vessel in increased with 2 meters, the breadth on the waterline remains same. Due to space requirements in the engine room and at the bow it was necessary to increase the block coefficient, which resulted in a higher displacement and corresponding higher resistance. As a result of the new displacement and light ship weight the design draft is lowered to 5.8 meters.

Main particulars		
L_{oa}	**120**	**[m]**
L_{pp}	117	[m]
L_{wl}	120	[m]
B_{max}	21	[m]
T_{design}	5.8	[m]
D	9.0	[m]
Displacement, at T_{design}	6785	[t]
C_b	0.501	[-]
C_p	0.677	[-]
Wetted area	2498	[m²]
Waterplane area	1782	[m²]
LCB	-3.0	%

Table 33, Main particulars final design

The complete list of the hull properties can be found in Appendices XVII.

Linesplan

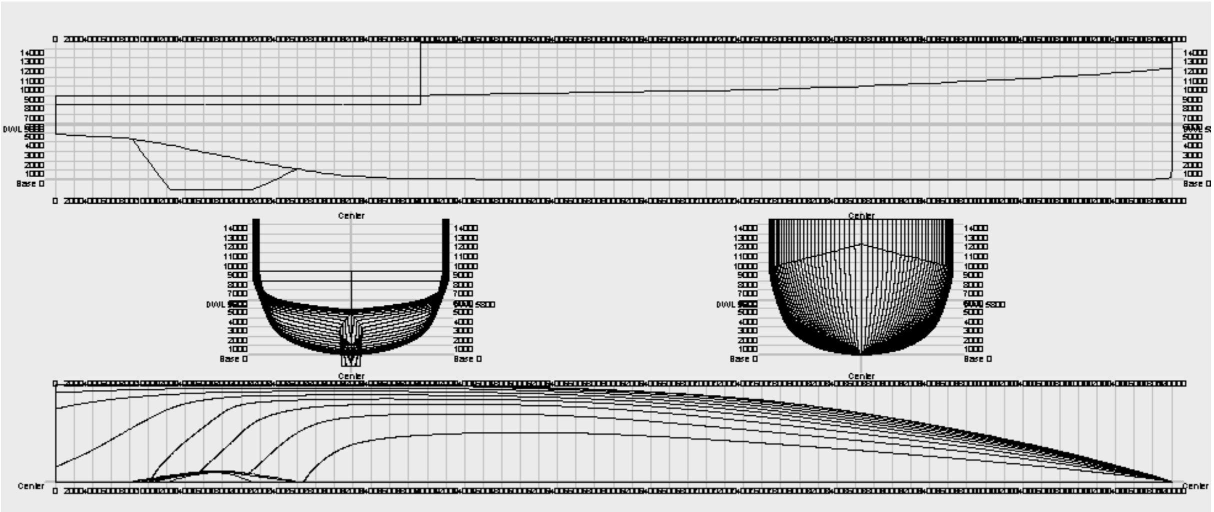
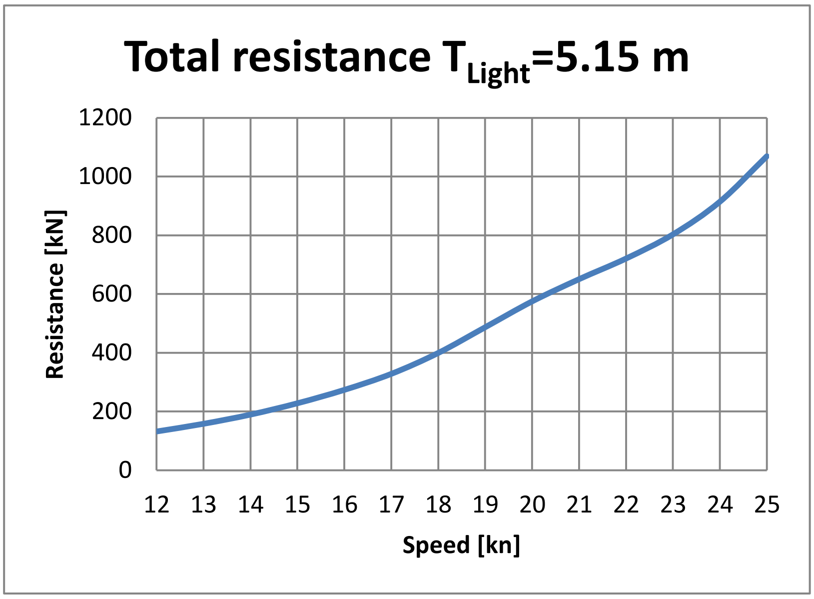


Figure 33, Linesplan final design

5.3.2 Resistance

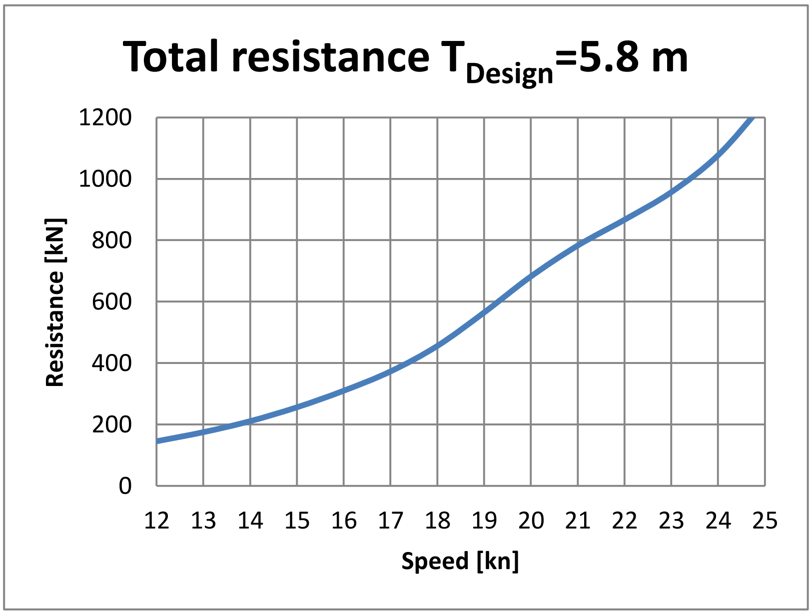
One of the new design considerations was the introduction of a light service draft for quick response operations. This concept was mentioned in Chapter 5.1 for the old mono-hull design. The idea behind this concept is that the vessel only has the ability to sail at 25 knots at this draft, with a restricted amount of deck load and fuel oil onboard. This way the resistance at full speed is lowered and the needed propulsion power is also lowered.

Below the resistance curves of the vessel for this light service draft (T=5.15 m) and the design draft are given, both calculated according to the method of Holtrop & Mennen (1984). In the light service draft condition the vessel has 100 ton of deck load and fuel oil for 1200 nautical miles and 2 days at DP. For the design draft the deadweight requirement is as mentioned in Chapter 1.4, 600 ton of deck load and enough fuel for an endurance of 30 days according to the operational profile. An overview of the hydrostatics for these conditions is given in Chapter 5.3.6.



V	Rtotal
[kn]	[kN]
12	132
13	158
14	190
15	228
16	274
17	328
18	399
19	487
20	575
21	651
22	721
23	803
24	914
25	**1069**

Figure 34, Resistance light service draft final design



V	Rtotal
[kn]	[kN]
12	145
13	175
14	211
15	**256**
16	310
17	373
18	456
19	565
20	682
21	783
22	867
23	956
24	1077
25	1248

Figure 35, Resistance design draft final design

The results of the resistance calculation show an increase of total resistance for the design draft, compared with the first mono-hull design. This is a result of the new geometry of the vessel with the sponsoons. Due to the new requirements this doesn't matter, for lower speeds like the economical speed of 15 knots the vessel has a low resistance. The light service draft has an almost identical resistance at 25 knots as the first mono-hull had at a light service draft, see Chapter 5.1. This is also a result of the new geometry, the new design has more displacement allowing a draft decrease.

5.3.3 Power speed analyses and propulsion system

The power calculation is focused on the maximum speed for the light service draft and the propulsion system is layed out to reach this speed for this condition. This amount of power is sufficient to reach economical speed at the design draft.

Power calculation main engines

The total break power is:

$$P_E = 13750kW$$

$$\eta_D = 0.65$$

$$\eta_S = 0.98$$

$$\eta_{GB} = 0.97$$

$$P_P = \frac{14893}{\eta_D} = 21152kW$$

$$P_S = \frac{P_P}{0.98} = 21583kW$$

$$P_B = \frac{P_S}{0.97} = 22251kW$$

Propulsion system

Previously the propulsions system consisted of four propellers in a diesel direct lay-out. This turned out to be unpractical and other options had to be considered for the propulsion system. Three possible solutions are:

- Use contra rotating pods, this way it is possible to fit two propellers on one pod.
- Increase the propeller diameter.
- Increase the propeller load

The second option had preference over the first because it is easier to apply in the current design and the third option requires an advanced propeller design. The minimum diameter for a double propeller configuration is:

$$\frac{P_S}{2} = 10791.5kW$$

Maximum propeller load = $400kW / D^2$

$$\sqrt{\frac{10791.5}{400}} = 5.20m$$

Minimum tip clearance (C) with the hull according to DNV for twin propeller vessels: 0.26D

$$C = 0.26 \cdot 5.20 = 1.35m$$

The design of the vessel hull had to be adapted due to this alteration, unfortunately this wasn't enough and the decision was made to rotate the propulsion train and set it under an angle of 4 degrees. Together with the fact that there is no draft restriction on the vessel lead to the decision to let the propellers protrude under the baseline of the vessel. Now it is possible to fit two propellers with a diameter of 5.20 meters, instead of only 4 meters.

Propulsion concept:

Four main engines: Wärtsila 8L38

Make	Wärtsila
Type	8L38
Output	5800kW
Speed	600 rpm
Specific fuel consumption	176 g/kWh
Weight	63 ton

Table 34, Main engines final design

Reduction gear : Wärtsila TCH310 twin in single out

Propellers : CPS145/C CPP

Schematic

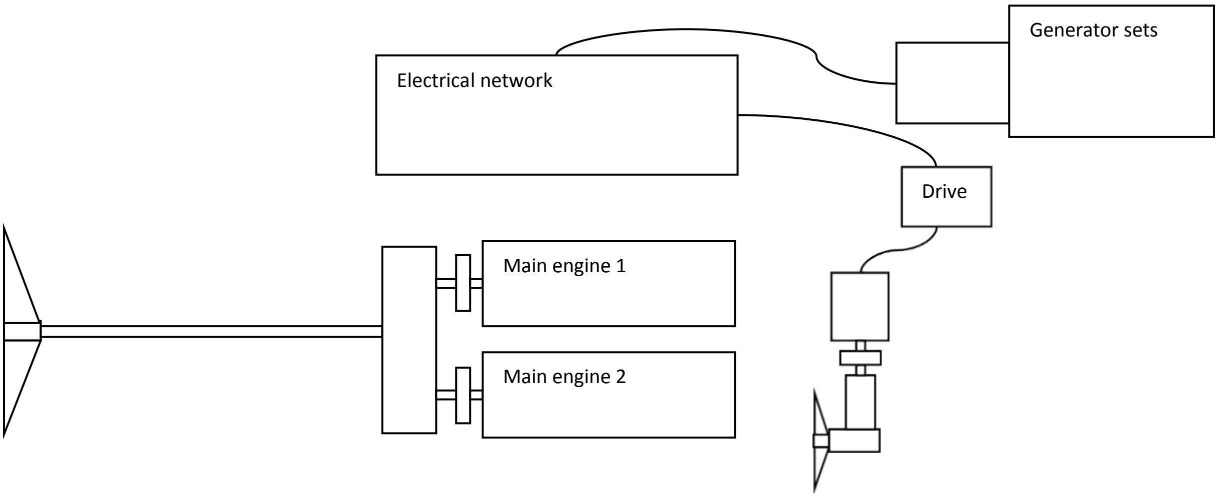


Figure 36, Schematic overview propulsion system final design

Artist impression

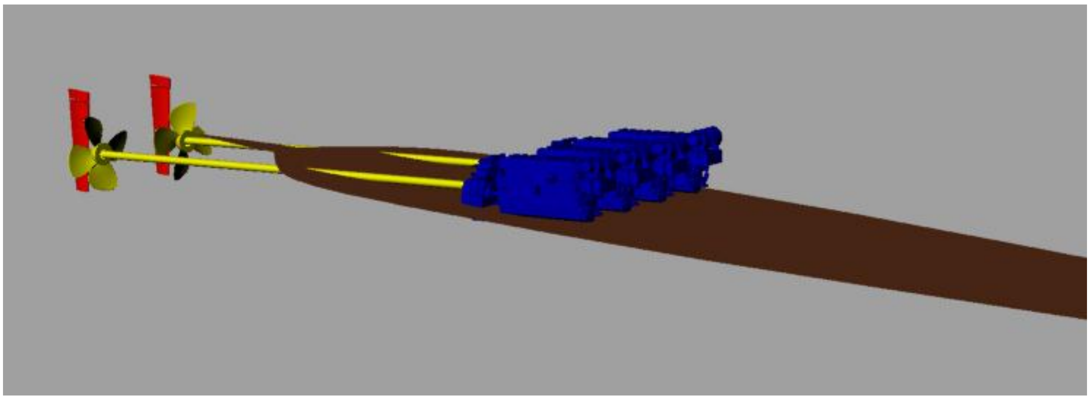


Figure 37, Artists impression propulsion system final design

5.3.4 Auxiliary systems and electric load balance

The auxiliary system is almost similar to the previous mono-hull system. The difference lies in the tunnel thruster power, which is slightly higher for the new design, see Chapter 5.3.8.

Load balance

Consumer	**Power**
Hotel load	500 kW
Crane	1350 kW
Tunnel thrusters	6000 kW
Total (with 5% margin)	8283 kW

Table 35, Main consumers final design

Generators

Make	Wärtsila
Type	8L20
Output	1405 ekW
Speed	900-1000 rpm
Specific fuel consumption	185g/kWh
Weight	20.7 t

Table 36, Auxiliary generator sets mono-hull 1 (2x)

Make	Wärtsila
Type	9L26
Output	2810 ekW
Speed	900-1000 rpm
Specific fuel consumption	184g/kWh
Weight	50 t

Table 37, Auxiliary generator sets mono-hull 2 (2x)

Make	Caterpillar
Type	C18
Output	547 ekW
Speed	1800 rpm
Specific fuel consumption	133.2 l/h
Weight	1.9 t

Table 38, Emergency generator set mono-hull

5.3.5 Weight calculation

Due to modifications the weight calculation had to be revised. The alterations can be divided into weight increase and weight reduction measures:

Weight increase:

- Keel
  The weight of the keel is estimated roughly by multiplying the total area of the keel with the specific weight of steel and a plate thickness of 9 mm.
- Higher depth
- Larger beam due to sponsoons
- Counter ballast for knuckle boom crane
  This was initially left out of the weight calculation. It is however necessary to counter ballast the vessel for the crane, which is place 5.5 meters out of heart ship, to avoid an initial heeling angle.

Weight reduction:

- Lighter main engines
- Two instead of four shaft lines and propellers
- Two instead of four gearboxes

Potential weight reduction, recommendation, not implemented into the design:

- *Use of high tensile steel*
  The specific weight of high tensile steel is similar to that of mild steel. The weight gain lies within the higher strength of the material which allows us to reduce the thickness of the plates. The tensile strength of normal steel is 400MPa, high tensile steel has a tensile strength of 760MPa, an increase of 90%.

Besides the alteration in the weight of the vessel there will also be a shift in the CoG, mainly due to the larger depth.

New light ship weight and CoG

The new light ship weight and CoG is given in table 39, the complete weight calculation can be found in Appendices XIX.

Weight group	Weight [t]	VCG [m]	LCG [m]	TCG [m]
100 Shipbuilding	2,838	7.54	59.29	0.00
200 Main machinery	552	3.18	31.85	0.00
300 Primary ship systems	284	7.66	56.36	0.00
400 Electrical system	237	6.55	57.27	0.00
500 Deck equipment	592	12.84	30.16	0.00
600 Secondary ship systems	51	8.03	46.09	0.00
700 Joinery and arrangement of accommodation	333	13.61	73.75	0.00
800 Nautical, navigation and communication equipment	3	22.50	60.00	0.00
Margins lightship weight	*246 (5%)*	*0.30*	*0.00*	*0.00*
Light ship weight (inclusive 5% margin)	5,135	8.37	53.24	0.00

Table 39, Total light ship weight and CoG final design

5.3.6 Hydrostatics

The hydrostatic calculations for this design are more extensive than the previous mono-hull concept. For each draft a summary of the hydrostatics is made which can be seen in tables 40 until 42.

HYDROSTATICS T=5.15m				LCG	VCG	
Light ship weight (incl margin)		5,135	t	53.24	8.37	
Deadweight						
Deck cargo		100	t	23.00	10.00	
Fuel oil		265	t	79.07	4.09	
Fresh water		50	t	97.30	3.25	
Sewage		50	t	55.00	1.75	
Crew and stores		17	t	75.00	13.50	
Total		482	t	66.69	5.32	
Displacement (wanted)		5,617	t			
				LCB	VCB	
Available displacement (T = 5.15 m)		5,643	t	54.70	3.09	
Margin		26	t			

Table 40, Design hydrostatics final design T=5.15 m

HYDROSTATICS T=5.80m				LCG	VCG	
Light ship weight (incl margin)		5,135	t	53.24	8.37	
Deadweight						
Deck cargo		600	t	23.00	10.00	
Fuel oil		770	t	62.28	4.75	
Fresh water		100	t	97.29	3.85	
Sewage		50	t	55.00	1.75	
Crew and stores		17	t	75.00	13.50	
Total		1537	t	49.13	6.74	
Displacement (wanted)		6,672	t			
				LCB	VCB	
Available displacement (T = 5.80 m)		6,794	t	53.51	3.50	
Margin		122	t			

Table 41, Design hydrostatics final design T=5.80 m

Summary of hydrostatics for crane operation and DP draft, T=6.6m

The philosophy behind the new design with the sponsoons and keel is a reduction of the roll motions at DP. Increasing the draft of the vessel results in a larger waterplane area and rapid increase of displacement which leads to more stability, see Chapter 5.2. Therefore a third draft for the vessel is defined, the crane operation and DP draft. To reach this draft ballast water is pumped into the vessel. Table 42 gives an overview of the hydrostatics for this condition.

HYDROSTATICS T=6.60m				**LCG**	**VCG**	
Light ship weight (incl margin)		5,135	t	53.24	8.37	
Deadweight						
Deck cargo		600	t	23.00	10.00	
Fuel oil		770	t	62.28	4.75	
Fresh water		100	t	97.29	3.85	
Sewage		50	t	55.00	1.75	
Crew and stores		17	t	75.00	13.50	
Ballast water		1606	t	55.41	2.30	
Total		3143	t	52.34	3.30	
Displacement (wanted)		8278	t			
				LCB	**VCB**	
Available displacement (T = 6.60 m)		8283	t	52.30	3.98	
Margin		5	t			

Table 42, Design hydrostatics final design T=6.6 m

5.3.7 Stability

A new design requires a new look at the stability of the vessel. The criteria for the mono-hull given in Chapter 2.8 are also valid for this vessel. The chapter covers intact stability calculations, loss of load calculations for crane operations and a prediction concerning the outcome of future damage stability calculations.

Intact stability calculations

The initial mono-hull design complied with all the stability requirements. The thing that struck was the high G'M for all loading conditions, this is good for the stability, but also leads to high transverse accelerations that are unpleasant for the crew. The new design has a higher VCG due to the higher freeboard, resulting in lower G'M values for the light service draft and design draft. Only the deepest, DP, draft still has a high G'M because the CoG is lowered due to the large amount of ballast water taken into the double bottom of the vessel.

The loading conditions are in accordance with the conditions given in the previous chapter:

Light service draft, maximum mean draft (Lpp/2) = 5,15 meters

- 1.1 Departure, 100t deck load
- 2.2 Arrival, 100t deck load

Design draft, maximum mean draft (Lpp/2) =5.80 meters

- 2.1 Departure, 600t deck load
- 2.2 Arrival, 600t deck load

DP operation draft, maximum mean draft (Lpp/2) = 6.6meters

- 3.1 Departure, 600t deck load
- 3.2 Arrival, 600t deck load

Crane operation

- 4.1 Crane operation 100t@15m, 100% consumables, 550t deck load
- 4.2 Crane operation 100t@15m, 10% consumables, 550t deck load

All loading conditions comply with the stability criteria and the extensive results can be found in Appendices XX.

Condition	Tmean [m]	Min G'M [m]	Max GZ [m]	Top GZ [degrees]	Area under GZ up to 30^0 [mrad]	Area under GZ between 30^0 and 40^0 [mrad]	Max angle of inclination [degrees]	Max. stat. angle [degrees]
1.1	5.093	1.684	0.746	59.387	0.215	0.124	27.472	5.15
1.2	4.981	1.660	0.686	60.000	0.209	0.118	28.639	5.459
2.1	5.796	2.151	0.922	51.727	0.262	0.149	24.291	3.144
2.2	5.466	1.754	0.669	30.38	0.212	0.115	26.183	4.371
3.1	6.596	3.078	1.554	52.449	0.375	0.229	23.484	1.684
3.2	6.131	3.111	1.591	54.007	0.383	0.233	22.915	1.933
4.1	6.600	2.770	1.271	50.310	0.329	0.193	24.236	1.870
4.2	6.263	2.865	1.295	51.573	0.340	0.196	24.173	2.009

Table 43, Intact stability calculation final design results

The loading conditions for free sailing conditions have lower G'M values than the original mono-hull design, resulting in a less cruel vessel. For the DP and crane operations the G'M is high for good stability. This is an improvement compared with the original design.

Loss of load calculation

The loss of load calculation is performed for loading condition
Loss of load calculation, maximum mean draft (Lpp/2) = 6.5meters

- 5.1 Loss of load calculation for loading condition 4.1
- 5.2 Loss of load calculation for loading condition 4.2

A summary of the results is presented in table 44, detailed results can be found in Appendices XXI.

The moment on the vessel:
100 tons load at 20.5 meters out of heart ship results in a moment of 2,050tm, or 20,111kNm

Loading condition	Statical angle of inclination (QL)	Statical angle of equilibrium Qe	Area A2>A1
4.1	1.51	4.086	Yes
4.2	1.73	4.689	Yes

Table 44, Results loss of load calculation mono-hull

The vessel complies with the regulations for loss of load and has a smaller statical angle of inclination and equilibrium than the initial design. The new design heels less due to the sponsoons and performs better than the initial mono-hull design.

Damage stability calculations

The same method as for the original design is used to predict if the vessel will comply with the SPS code (2008).

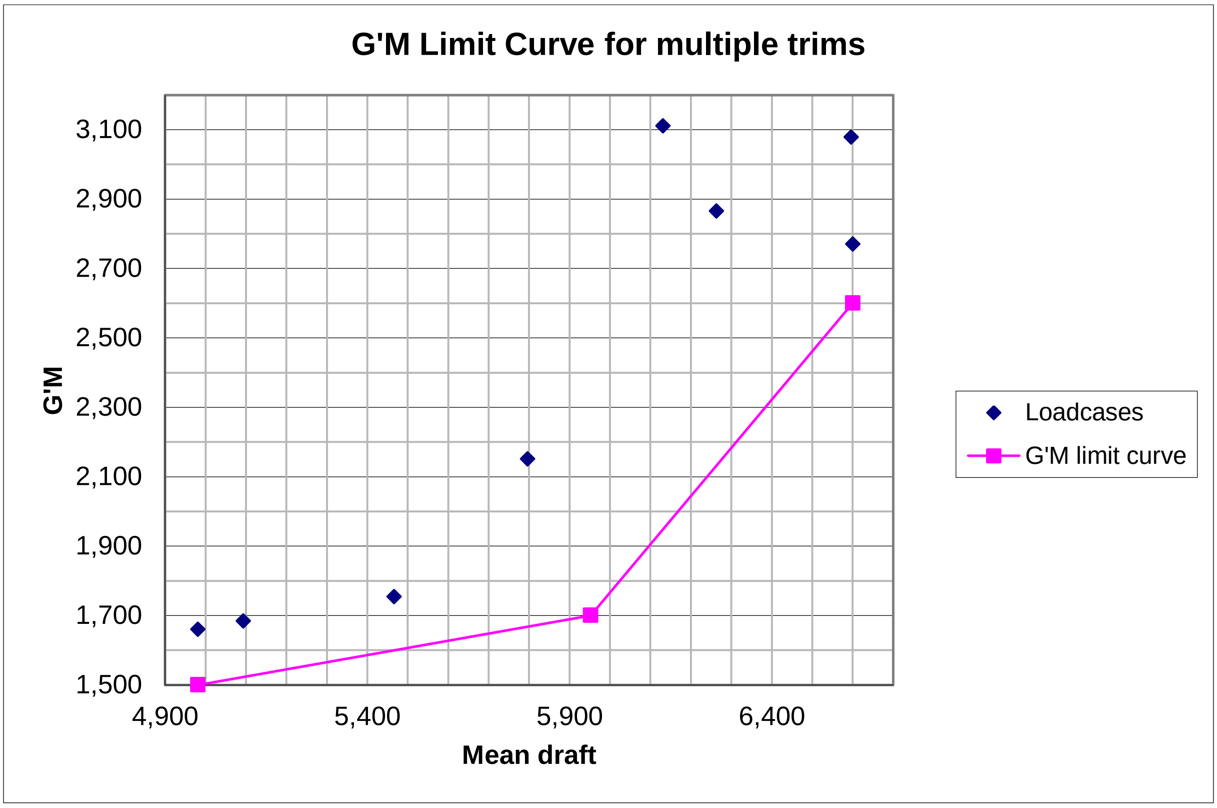


Figure 38, G'M limit curve final design

Condition	Tmean	G'M
Lightest service draft (dl)	4.981	1.500
Partial subdivision draft (dp)	5.952	1.700
Deepest subdivion draft (ds)	6.600	2.600

Table 45, Drafts and G'M values for probabilistic damage stability calculation

The G’M limit curve visualizes the difference between the free sailing conditions and the crane operation condition. A lower G’M for free sailing results in lower transverse accelerations, which is pleasant for crew and passengers. The higher G’M for the higher drafts gives more stability which is needed for crane operations. All the G’M values for the three drafts are higher than 1.5, this makes it very likely that the vessel will comply with the regulations.

5.3.8 Dynamic positioning

The calculations concerning dynamic positioning are similar to the mono-hull calculations earlier in this report, the big difference lies in the addition of a keel to the model, which results in higher current forces on the aft of the vessel.

Results

The environmental forces and moments on the vessel are given in figures 39 and 40, as a comparison the forces and moments on the original mono-hull design without a keel are also given in the same graph. The contour of the vessel is similar to the original design, resulting in the same wind forces. The complete table with calculations of the forces and moments is given in Appendices XXII.

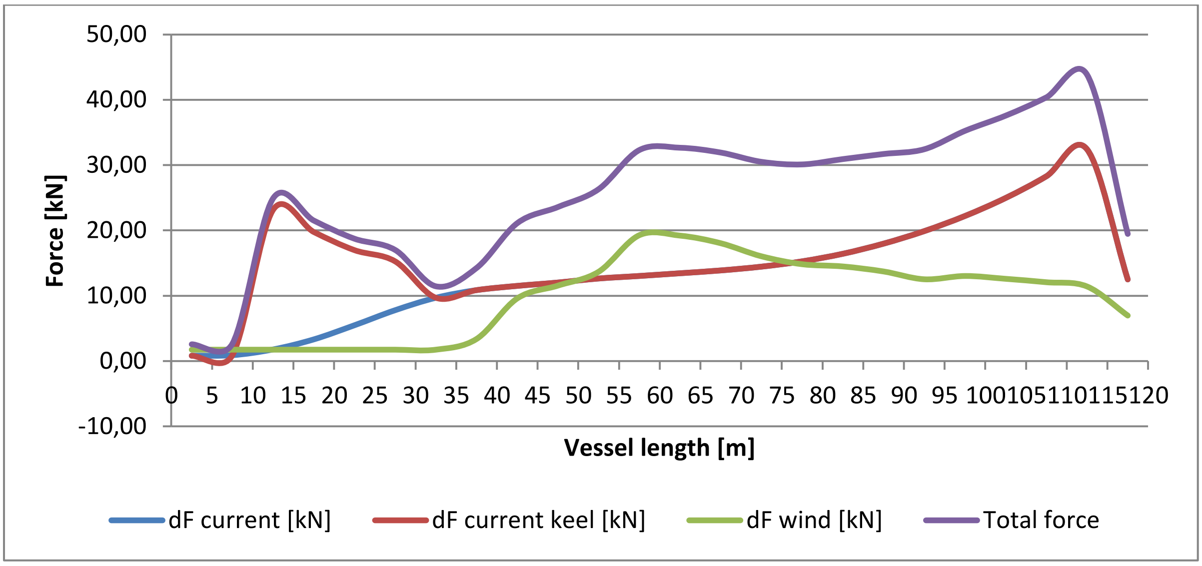


Figure 39, Forces on final design

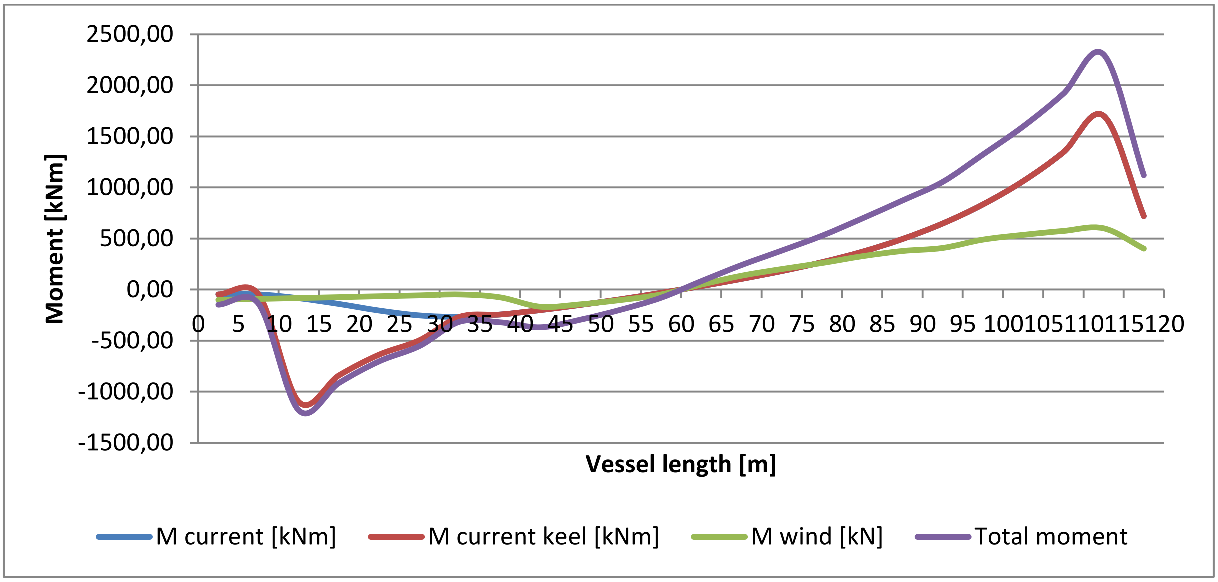


Figure 40, Moments on final design

Thruster forces and static equilibrium

Forces wrt COG					
	waves	current	wind	total	
Fx	0	0	0	0	kN
Fy	0	378	235	613	kN
Mz	0	3597	3292	6888	kNm

Table 46, Environmental forces and moment on final design

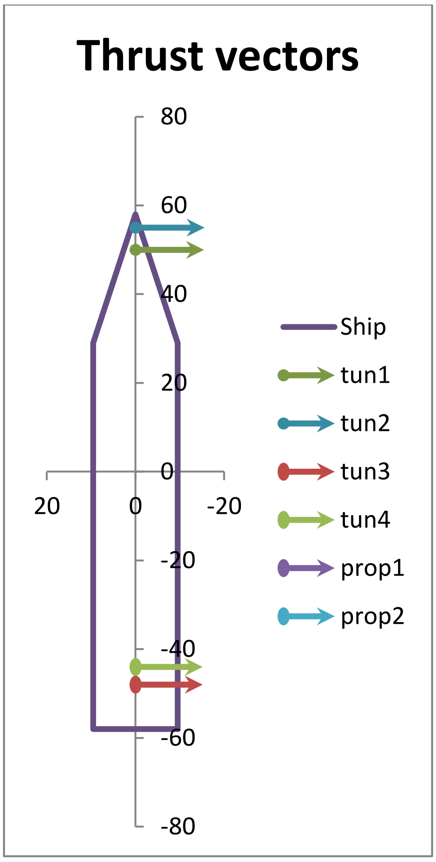


Figure 41, Thrust vectors final design

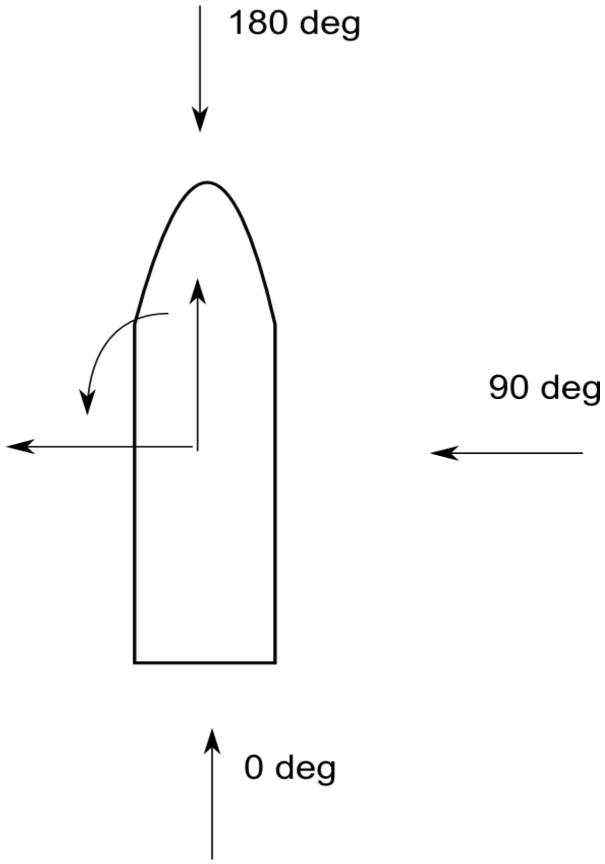


Figure 42, Orientation forces, moments and heading

Thruster forces:

	actual	min	max		
Thrust tunnel 1	-155.9	-191.3	191.3	kN	-82%
Thrust tunnel 2	-157.1	-191.3	191.3	kN	-82%
Thrust tunnel 3	-150.0	-191	191	kN	-78%
Thrust tunnel 4	-150.0	-191	191	kN	-78%
Total applied power	4848	0	31200	kW	16%

Table 47, Thruster forces final design

The propulsion configuration will be:

2x Propellers with rudders for forward and backward thrust	11600kW each
2x Bow thruster	1500kW each
2x Stern thruster	1500kW each

Due to the keel the current forces on the vessel are higher resulting in larger stern thrusters. The moment on the vessel due to these forces is lower, also because of the keel. The applied force is divided more equal over the length of the vessel.

5.3.9 General arrangement plan and tank arrangement

For this final design a general arrangement plan has been made, figure 43 until 45. This gives a 2D overview of the arrangement of the decks. Figure 43 shows the tanktop, tween deck and main deck of the vessel. Main areas below the main deck are the engine room, bowthruster room and switchboard room. The top view of the main deck gives an overview of the deck layout with the crane, some accommodations space and the ROV launch and recovery system. Figure 44 shows the decks of the superstructure, which are mainly used for accommodation space, and the bridge. The last figure is the side view of the vessel in which the contour of the new design becomes visible.

The tank arrangement is given in figure 46. The tanks below the tanktop and the wingtanks are mainly ballast water tanks which are used for trimming and draft increase for the crane operations. All the fuel oil tanks are placed before the engine room between tanktop and tween deck and separated from the hull by ballast water tanks or voids according to class. Fresh water tanks are placed at the front of the vessel as a wingtank and separated from the fuel oil tanks by a cofferdam.

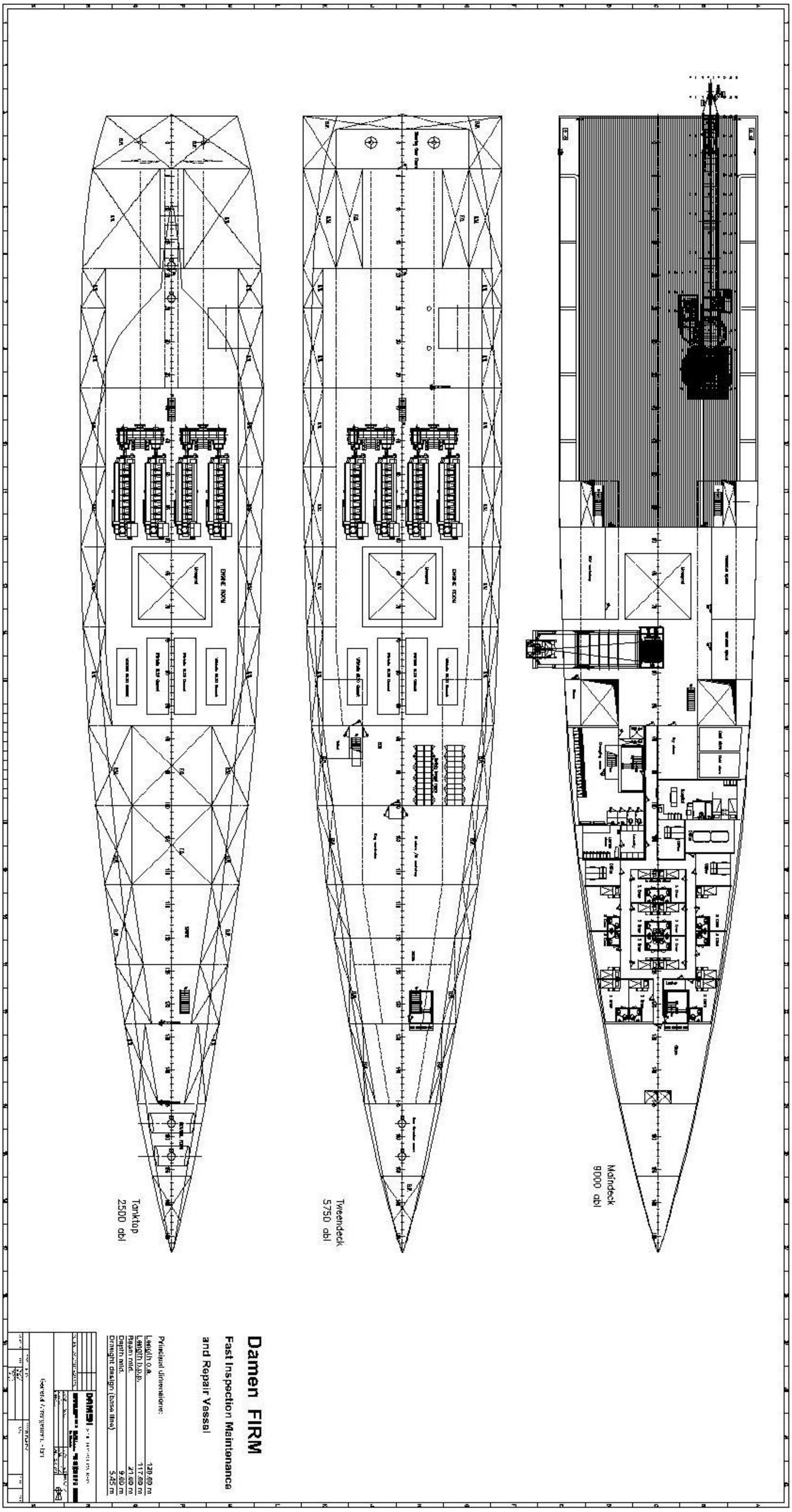


Figure 43, GA plan final design 1

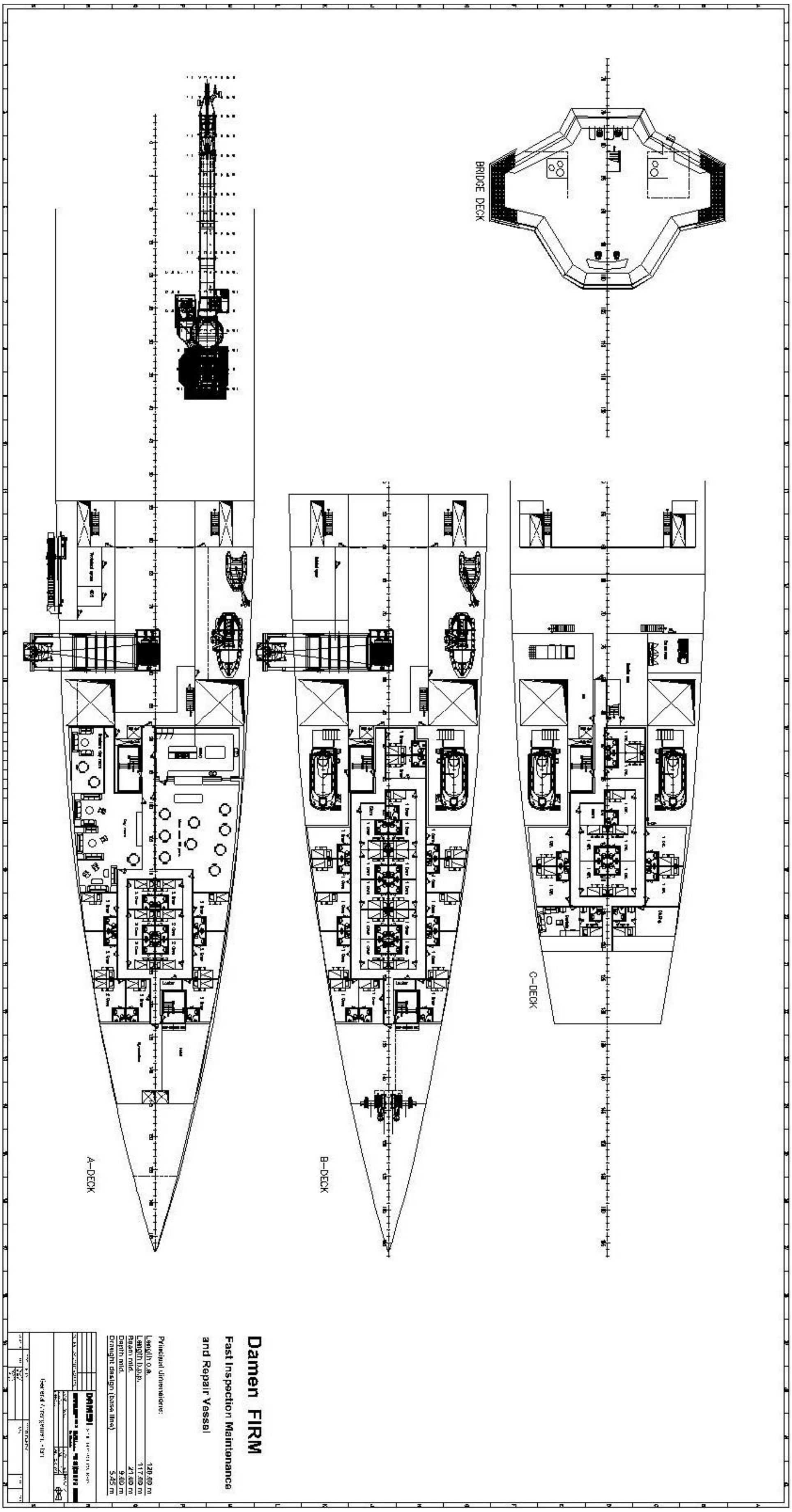


Figure 44, GA plan final design 2

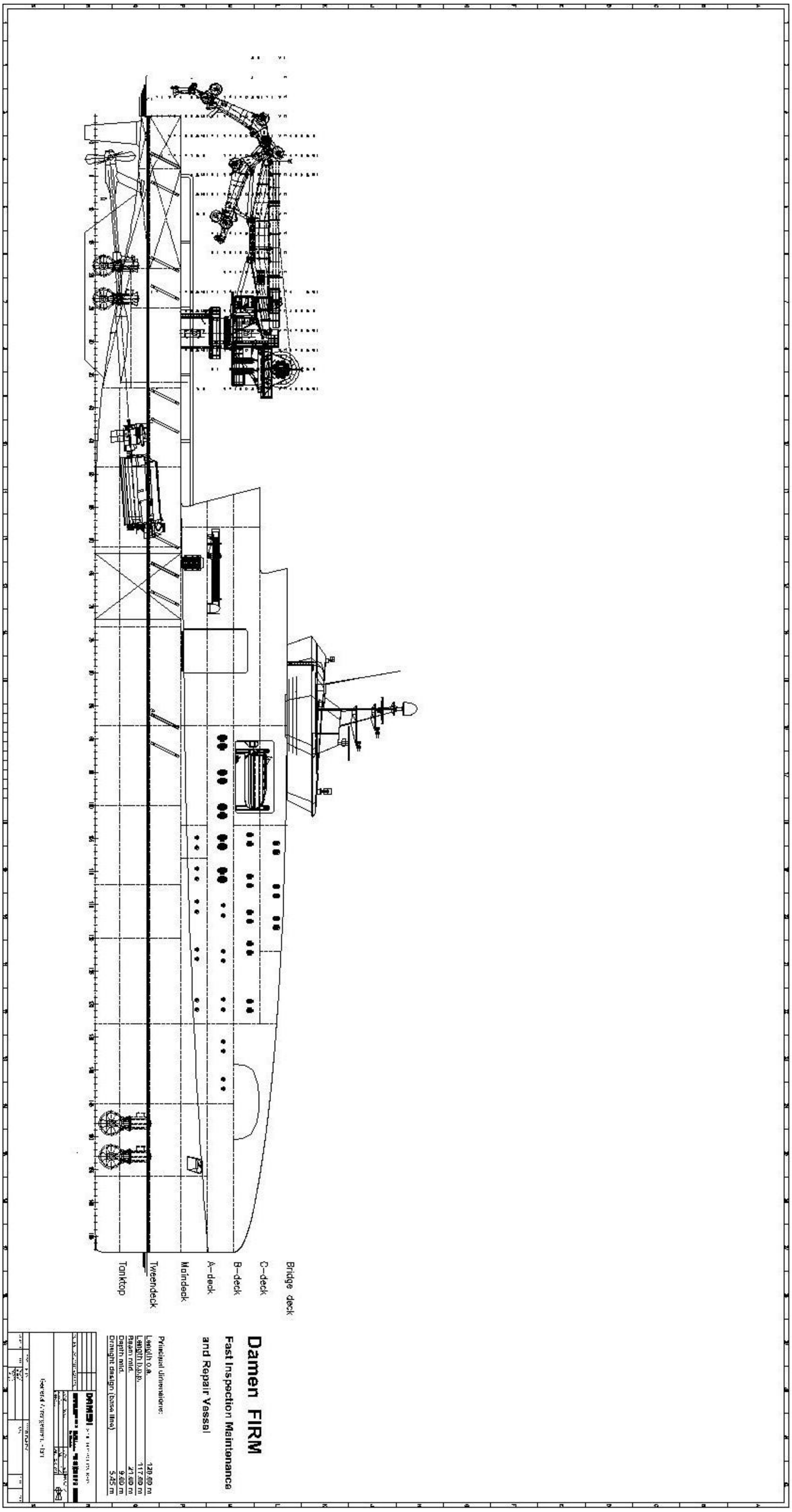


Figure 45, GA plan final design 3

Tank arrangement plan

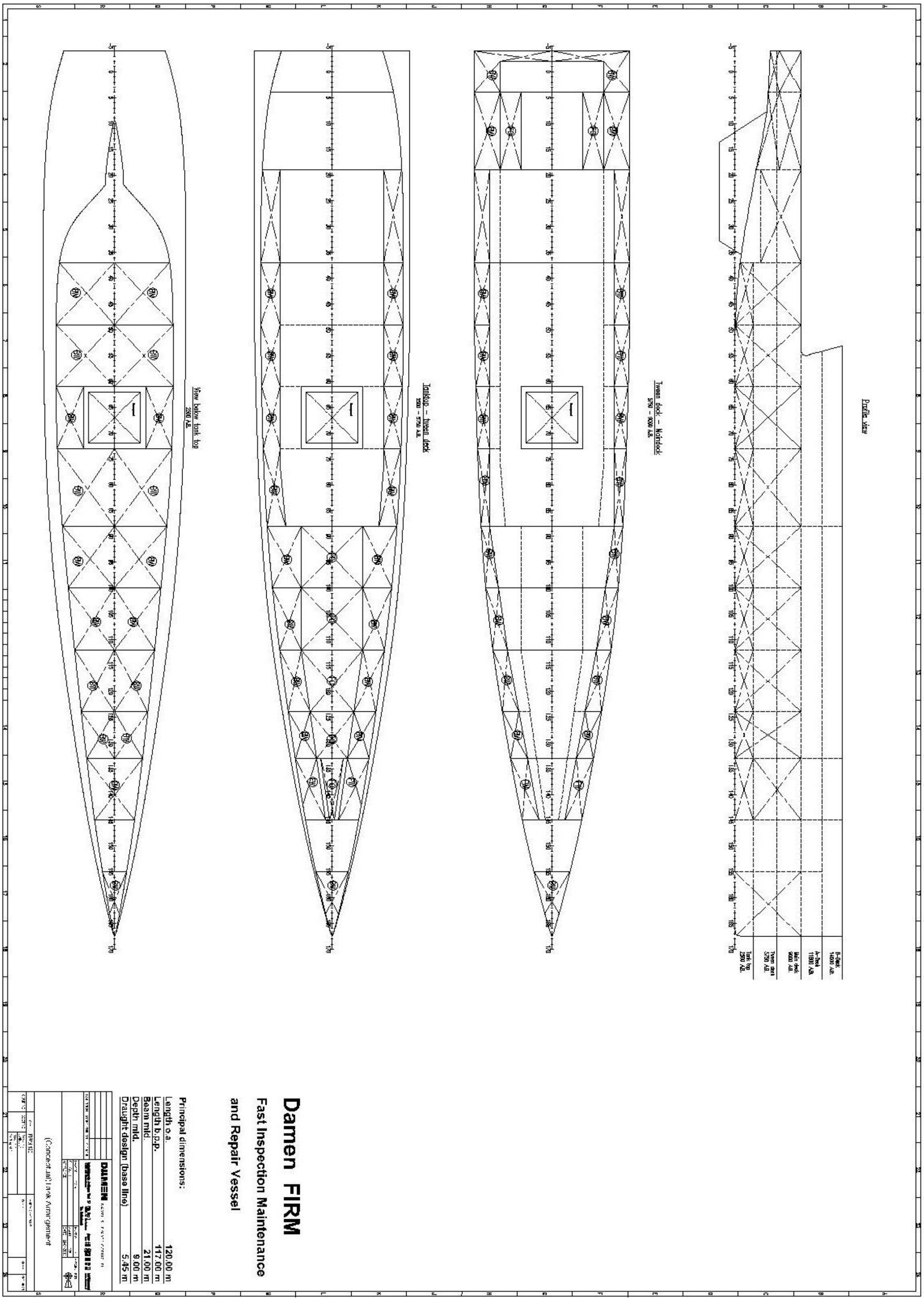


Figure 46, Tank arrangement final design

5.3.10 Artists impressions

The structural design of the vessel is shown above in 2D. Besides the 2D general arrangement plan, a 3D model has been made to give a better impression of the structural design of the vessel. The 3D model is basic, without any details and only meant to give an idea of the appearance of the final concept as a complement to the general arrangement plan.

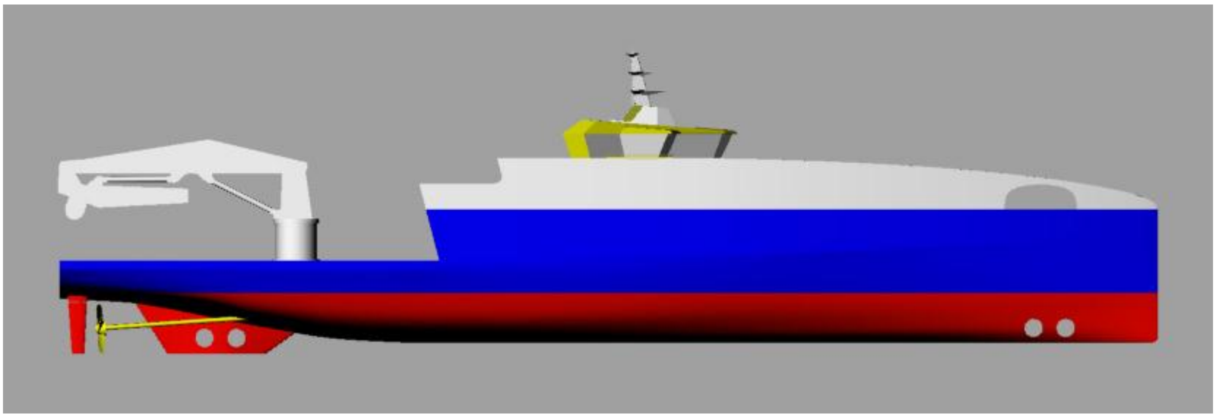


Figure 47, Artists impression final design 1

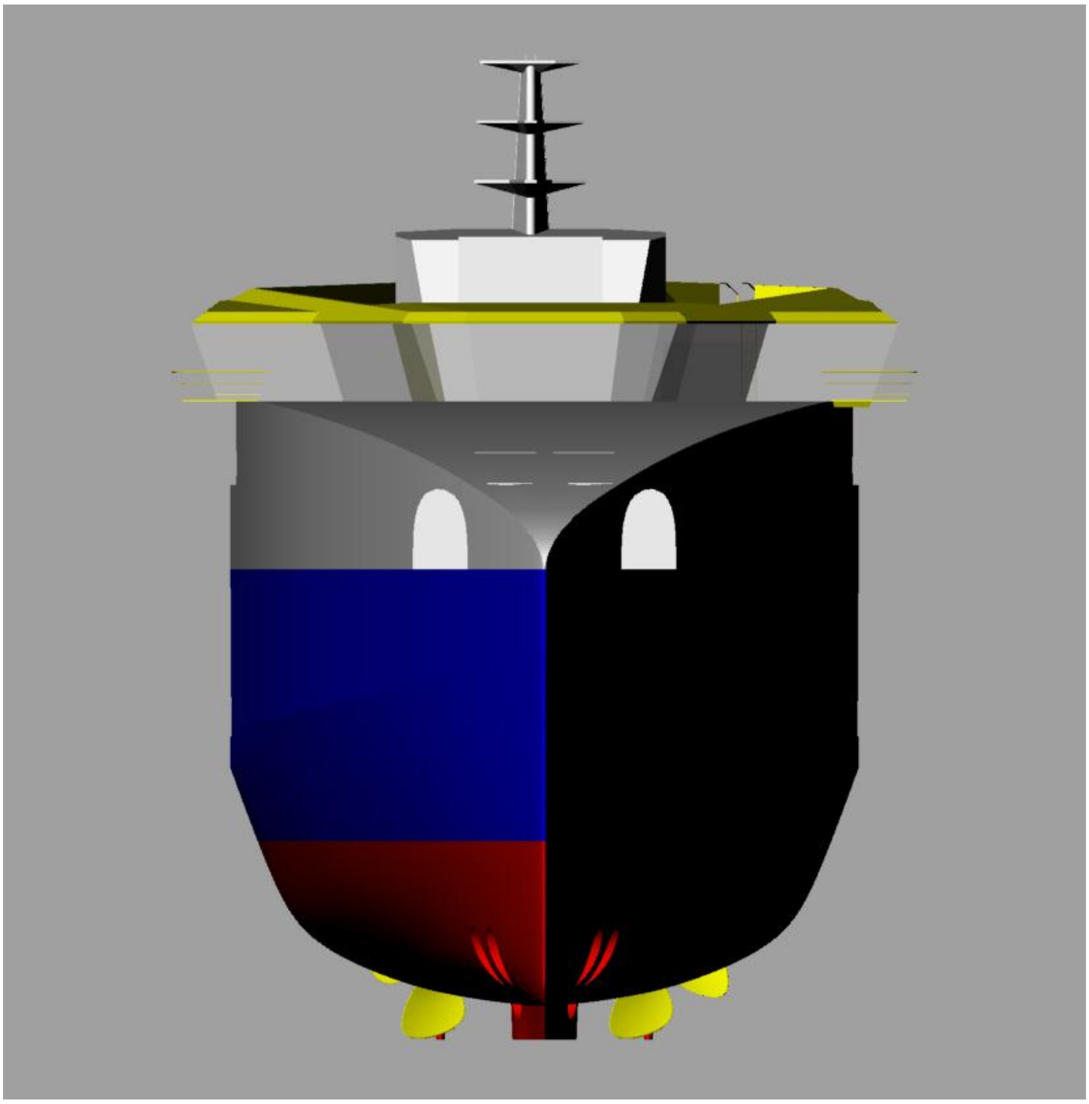


Figure 48, Artists impression final design 2

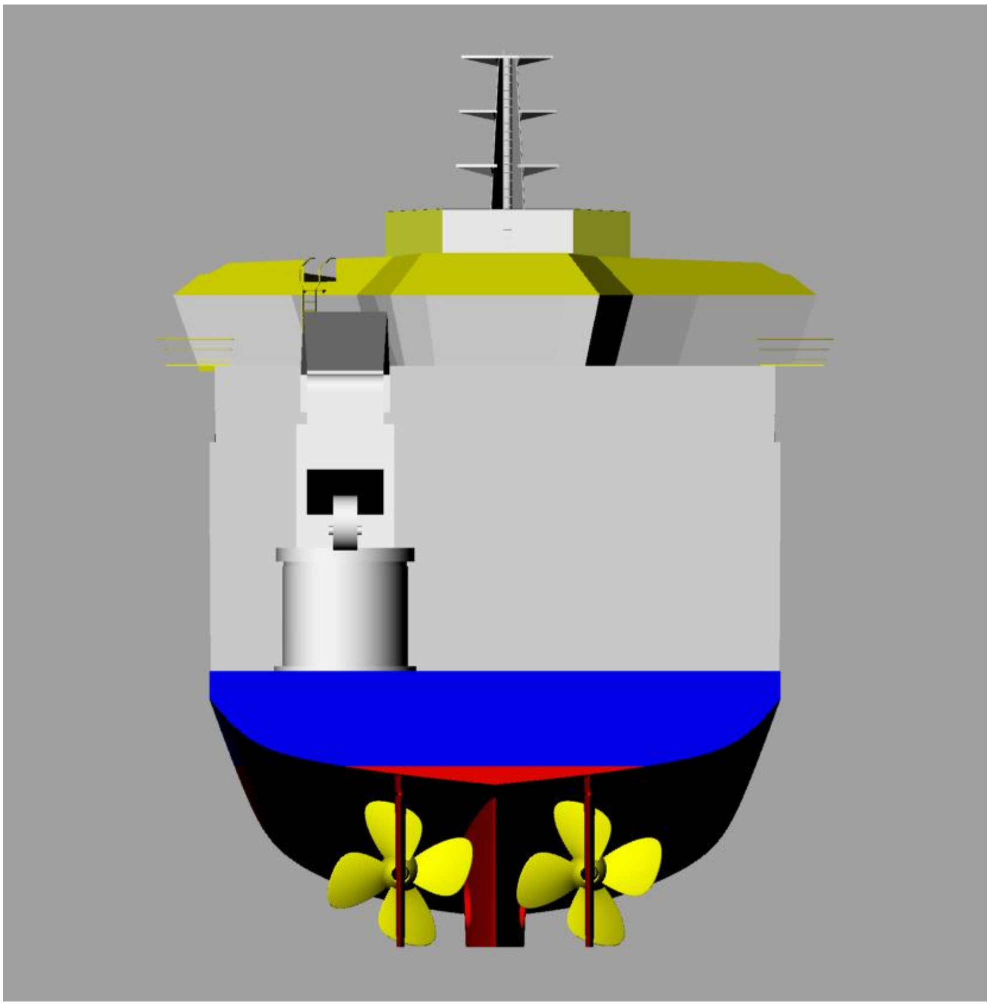


Figure 49, Artists impression final design 3

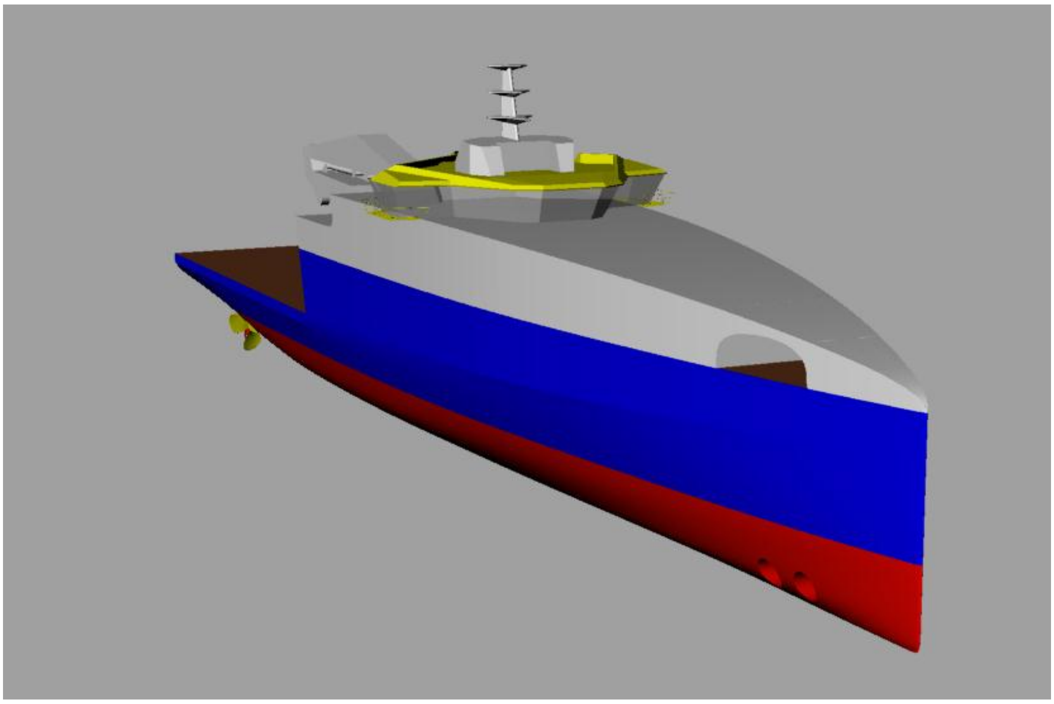


Figure 50, Artists impression final design 4

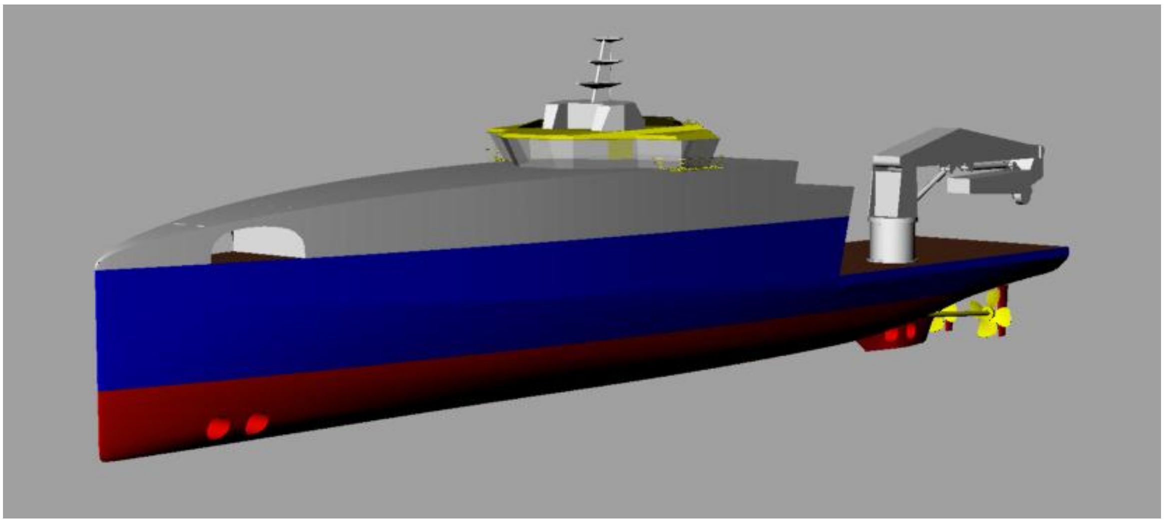


Figure 51, Artists impression final design 5

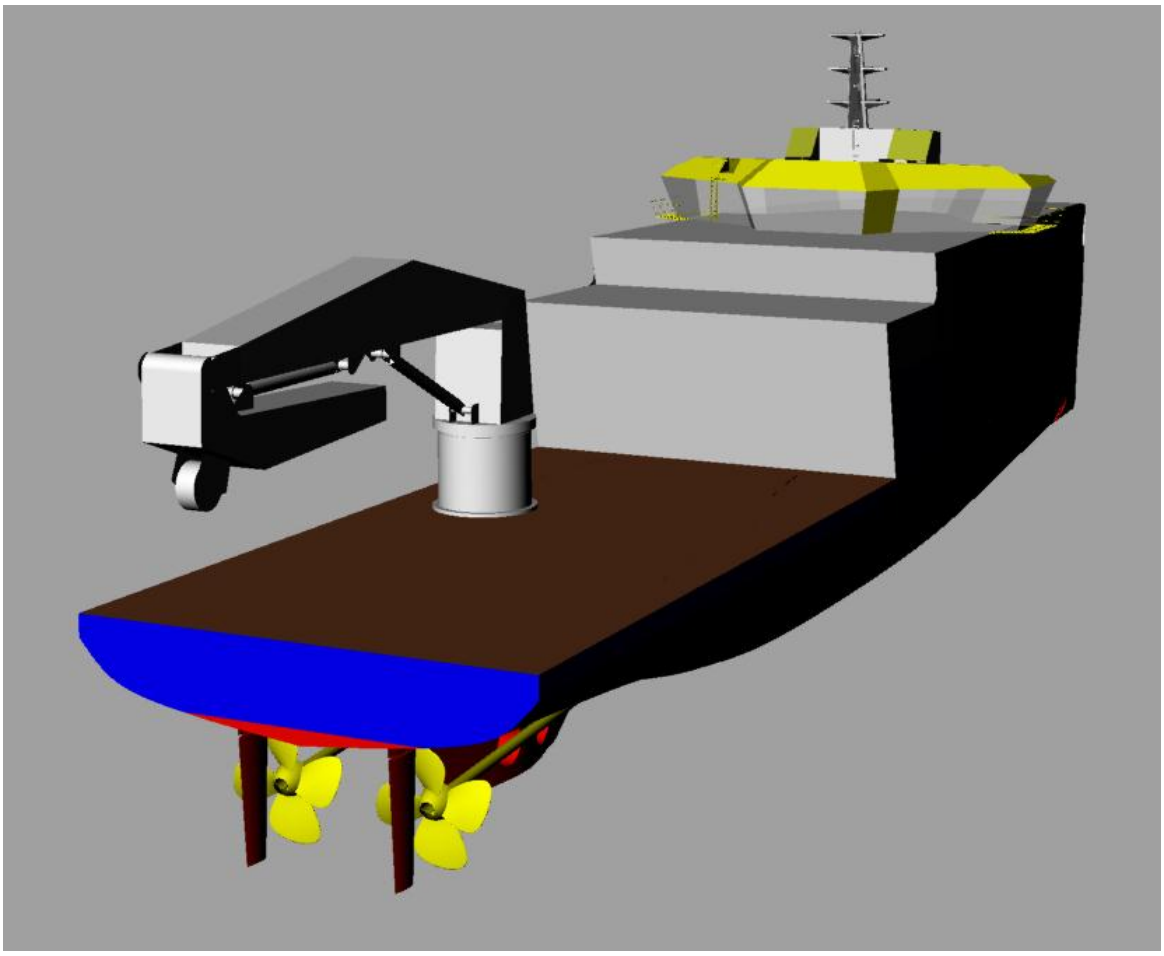


Figure 52, Artists impression final design 6

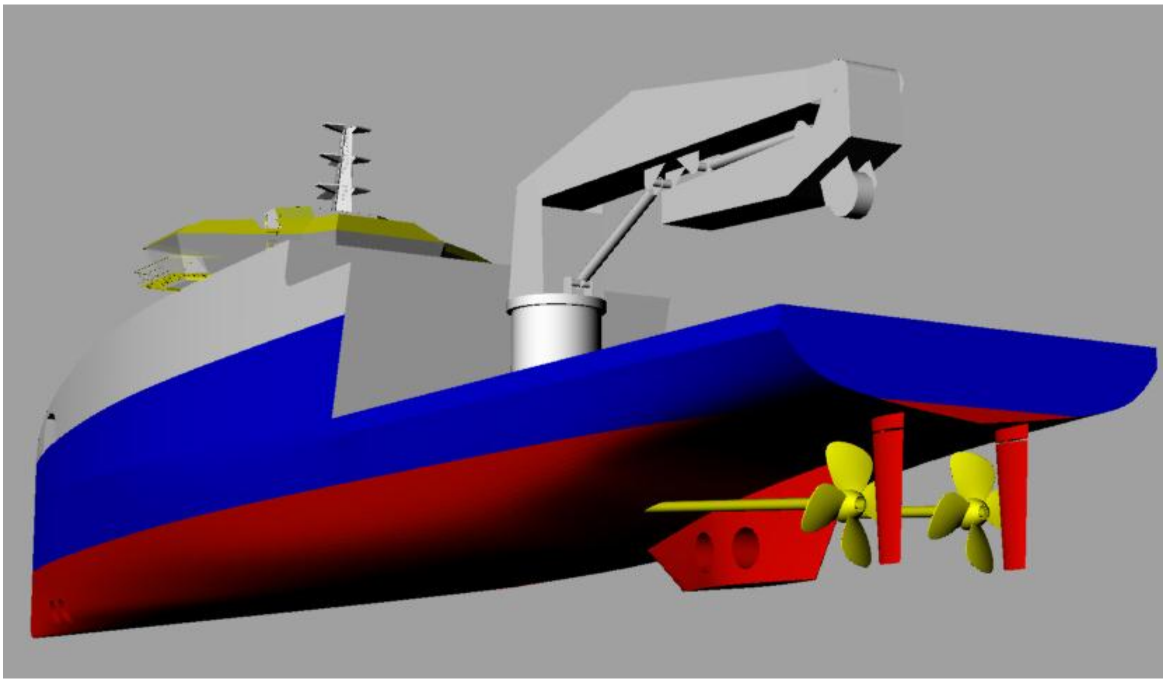


Figure 53, Artists impression final design 7

6 Conclusion

The outcome of this report shows that it is technically possible to design an Inspection Repair and Maintenance vessel with a maximum speed requirement of 25 knots. At first two design were made which were compared to each other, the outcome of this comparison was that a mono-hull design is preferable over a catamaran due to the significantly lower resistance. The high resistance makes the catamaran an infeasible solution for this design.

The design is based on a fast displacement Marwood and Bailey hull form, which is suitable for the high speed requirement. Integrated sponsoons were implemented, this results in better performance for both stationary operations as well as free sailing conditions. By taking in ballast water the draft of the vessel can be adjusted for the right condition. A lower draft results in a lower G'M which reduces the lateral accelerations at free sailing, optimizing the seaway characteristics. It also reduces the resistance making it possible to reach the maximum speed of 25 knots. A higher draft lowers the vertical center of gravity of the vessel and increases the G'M which is favorable for stationary operations because the vessel becomes more stable. This is especially interesting for crane operations over the side, because the static heeling angle is reduced significantly.

The final design of the FIRM is still a concept vessel, which was the goal for this project. This means that all main characteristics of the vessel are set and checked by means of various calculations. If any interest in this vessel is shown in the future it should be worked out further in detail. If this is the case a few future recommendations are made which might improve the design and also might require an alteration of the initial design criteria.

Future recommendations

The amount of power needed to reach 25 knots is extremely high and according to the operational profile the vessel will only sail at this speed for 5% of the time. With a small reduction of the maximum speed by only a few knots it is possible to install a propulsion system with approximately 20 to 25% less power. The vessel will still be fast in comparison to its competitors.

The propulsion system that was implemented for this design is very basic with a separate power generation system for the electrical system. The main propulsion engines could also be used to generate electrical power by for instance shaft generators. Another possibility is to design a diesel electric system, this can be combined with the use of POD propellers which makes the aft tunnel thrusters redundant.

It can be interesting to investigate the possibility to use high tensile steel for the hull construction. This might lower the light ship weight and results in lower draft and resistance.

Latest developments

Outside the scope of this thesis the FIRM concept has evolved the last few months, this new FIRM design won't be discussed in detail, but it's nice to mention it shortly. The requirements for the vessel were adjusted to the demands of a new Norwegian customer. The major changes in the requirements were:

- Maximum speed reduces to 22 knots instead of 25 knots;
- Two ROV LARS systems over the side (PS and SB), fully enclosed in a hangar;
- Addition of a heli-deck, amidships;
- A second 5x5 m moonpool for ROV LARS operations;
- 800 m^2 deck space instead of 600 m^2;
- Addition of a module handling tower over the 7.2x7.2 m moonpool.

This resulted in major changes in the design, like the addition of an extra deck layer in the superstructure and relocation of the bridge. The vessel is also has a diesel electric propulsion system with POD (pulling) propulsors. The result was a concept vessel which was presented at the Europort 2013 in Rotterdam. The specification sheet, some artists impressions and a photo of the scale model are given below to get an impression.

DAMEN FIRM 120
CONCEPT DESIGN

GENERAL

Basic functions	Inspection Repair and Maintenance Transport of supplies and crew ROV support Module handling Emergency response & Rescue Dynamic Positioning
Classification	DnV 1A1 with the following class notations: SF, E0, DYNPOS-AUTR, CLEAN DESIGN, COMF-V(3), ICE-C, LFL*

DIMENSIONS

Length o.a.	120.00	m
Length b.p.p.	117.00	m
Beam mld.	21.00	m
Depth mld.	9.50	m
Design draught (base)	5.00	m
Full load draught (base)	7.00	m
Deadweight (design)	1450	t
Deadweight (full load)	5500	t
Deck load (at 1 m above deck)	3000	t
Freeboard at max draught	2.5	m
Freeboard at operational draught	4.5	m

TANK CAPACITIES

Fuel oil (service)	1130	m^3
Potable water (service)	160	m^3
Sewage	50	m^3
Special products	300	m^3
Roll reduction	200	m^3

PERFORMANCES (APPROX.)

Speed (at design draught)	22	kn
Speed (economical)	14	kn

PROPULSION SYSTEM

Main propulsion	Diesel-Electric, 3300 V, 60 Hz
Propulsion power	2x 7000 ekW
Propellers	2x 4000 mm, FP, POD
Bow thruster	2x 1800 ekW, 2300 mm, FP
Retractable thruster	1x 1800 ekW, 2500 mm, FP

AUXILIARY EQUIPMENT

Networks	3300 V / 440 V / 230 V - 60 Hz
Main generator sets	5x 3000 ekW
Harbour generator set	1x 340 ekW
Emergency generator set	1x 175 ekW

DECK LAY-OUT

Deck crane	1x Knuckle boom, 100 t at 15 m, AHC
Module Handling System	Capacity to handle modules up to 30 t and 8m height AHC, to 2000 m, in conditions up to 4,5Hs
Tugger winches	2x each 10t pull
Fast rescue craft	1x 6.5 m, 212 hp inboard with waterjet
Live boats	2x 50 persons each

WORKING DECK

Deck area	800 m^2
Deck strength	10 t/m^2

ROLL REDUCTION

Active	Active stabilizing fins
Passive	Roll reduction tank

HELICOPTER FACILITIES

Helicopter deck capacity	D-factor 19.5 m , take-off weight 8.6t

ACCOMMODATION

Crew/ special personnel	100 persons

NAUTICAL AND COMMUNICATION EQUIPMENT

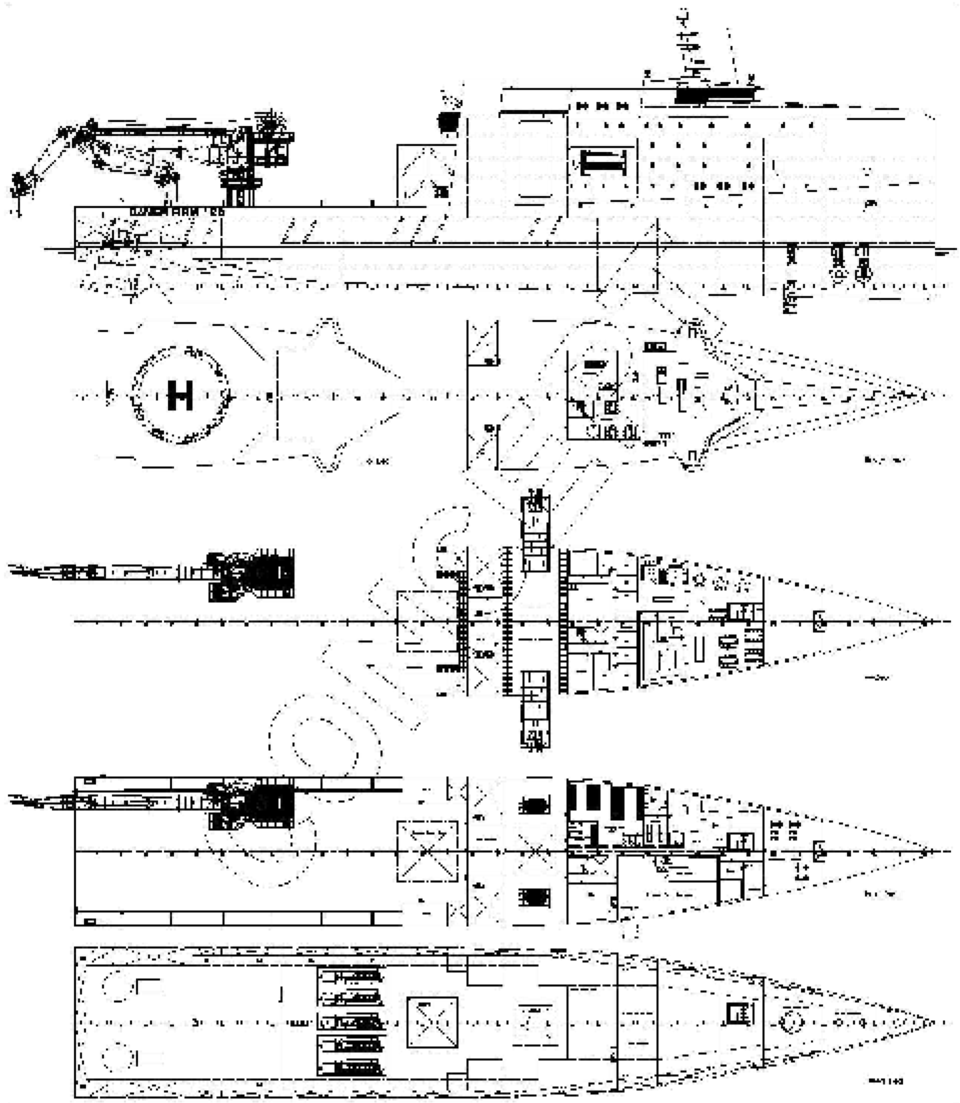
Radar systems	1x X-band + S-band
DP – system	DP2
Communication	GMDSS A3

HYDROLOGICAL AND OCEANOGRAPHIC EQUIPMENT

Spaces	Several working spaces ROV control room
Equipment	2x ROV LARS
Moonpool	1x 7.2x7.2 m 1x 5x5 m

OPTIONAL

Fire fighting equipment
Oil recovery equipment



DAMEN FIRM 120
CONCEPT DESIGN

DAMEN

DAMEN SHIPYARDS GORINCHEM

Member of the DAMEN SHIPYARDS GROUP

Industrieterrein Avelingen West 20
4202 MS Gorinchem

P.O. Box 1
4200 AA Gorinchem
The Netherlands

phone +31 (0)183 63 99 11
fax +31 (0)183 63 21 89

info@damen.nl
www.damen.nl

DSGo-P0.0-mmyy

Artists impressions and photo Damen FIRM 120

Figure 54, Artists impression 1 Damen FIRM 120 concept

Figure 55, Artists impression 2 Damen FIRM 120 concept

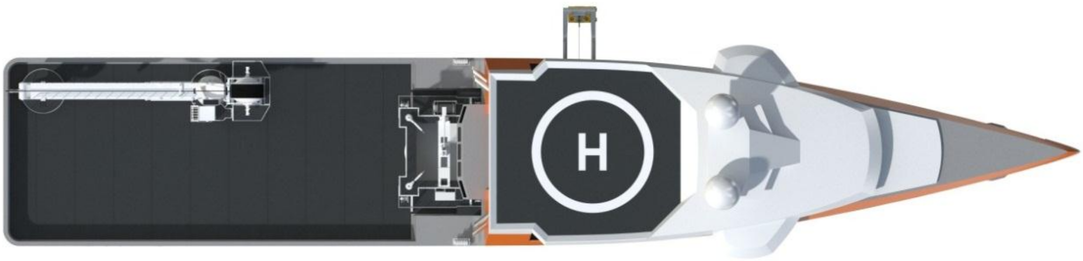


Figure 56, Artists impression 3 Damen FIRM 120 concept

Figure 57, Artists impression 4 Damen FIRM 120 concept

Figure 58, Artists impression 5 Damen FIRM 120 concept

Figure 59, Artists impression 6 Damen FIRM 120 concept

Figure 60, Artists impression 7 Damen FIRM 120 concept

Figure 61, Scale model Damen FIRM 120 concept

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Appendices

I Design hydrostatics report mono-hull.

Design length	120.00	*(m)*	Midship location	60.000	*(m)*
Length over all	120.00	*(m)*	Relative water density	1.025	
Design beam	19.000	*(m)*	Mean shell thickness	0.0000	*(m)*
Maximum beam	19.000	*(m)*	Appendage coefficient	1.0000	
Design draft	6.000	*(m)*			

Volume properties			Waterplane properties		
Moulded volume	6103.6	*(m^3)*	Length on waterline	115.34	*(m)*
Total displaced volume	6103.6	*(m^3)*	Beam on waterline	18.515	*(m)*
Displacement	6256.2	*(tonnes)*	Entrance angle	51.693	*(Degr.)*
Block coefficient	0.4462		Waterplane area	1715.3	*(m^2)*
Prismatic coefficient	0.6419		Waterplane coefficient	0.7523	
Vert. prismatic coefficient	0.5931		Waterplane center of floatation	47.962	*(m)*
Wetted surface area	2288.2	*(m^2)*	Transverse moment of inertia	41174	*(m^4)*
Longitudinal center of buoyancy	54.986	*(m)*	Longitudinal moment of inertia	1435649	*(m^4)*
Longitudinal center of buoyancy	-4.347	*%*			
Vertical center of buoyancy	3.807	*(m)*			

Midship properties			**Initial stability**		
Midship section area	79.241	*(m^2)*	Transverse metacentric height	10.553	*(m)*
Midship coefficient	0.6951		Longitudinal metacentric height	239.02	*(m)*

Lateral plane

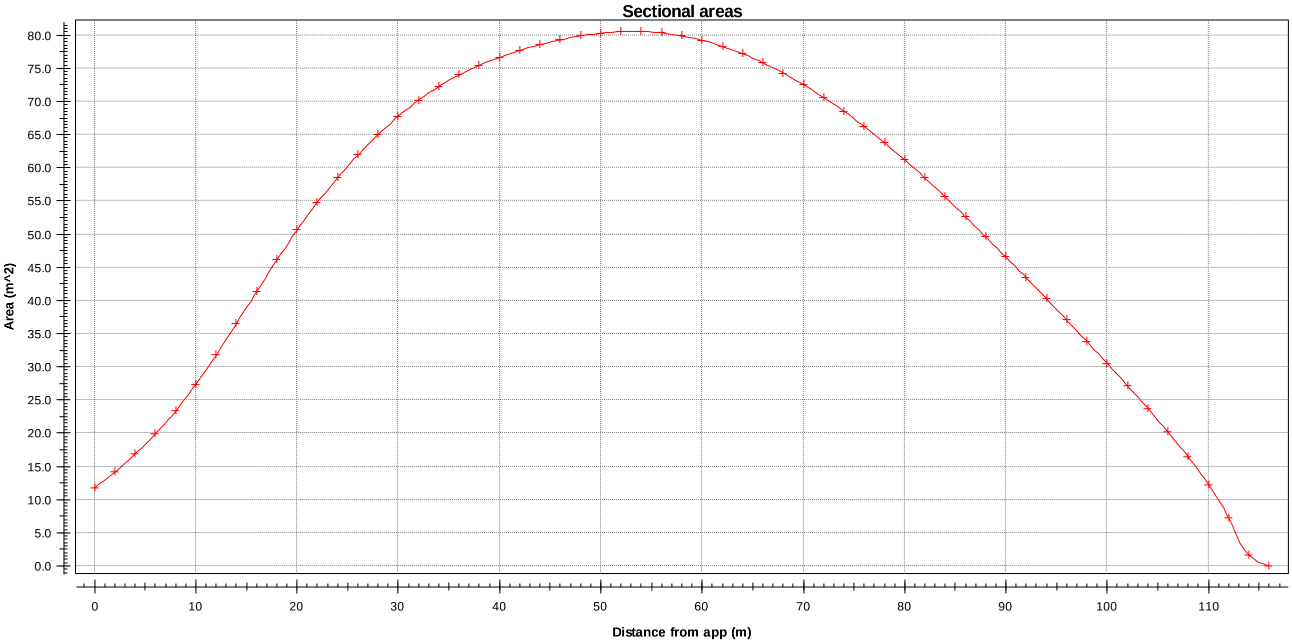
Lateral area	583.10	*(m^2)*
Longitudinal center of effort	64.268	*(m)*
Vertical center of effort	3.244	*(m)*

The following layer properties are calculated for both sides of the ship

Location	**Area**	**Thickness**	**Weight**	**VCG**	**LCG**	**TCG**
	(m^2)		*(tonnes)*	*(m)*	*(m)*	*(m)*
Layer 0	3950.1	0.000	0.000	5.881	61.018	0.000 (CL)

Sectional areas

Location	**Area**	**Location**	**Area**	**Location**	**Area**	**Location**	**Area**	**Location**	**Area**
(m)	*(m^2)*	*(m)*	*(m^2)*	*(m)*	*(m^2)*	*(m)*	*(m^2)*	*(m)*	*(m^2)*
0.000	11.726	24.000	58.530	48.000	79.884	72.000	70.616	96.000	37.048
2.000	14.190	26.000	61.939	50.000	80.294	74.000	68.516	98.000	33.808
4.000	16.852	28.000	65.014	52.000	80.523	76.000	66.241	100.000	30.519
6.000	19.866	30.000	67.773	54.000	80.554	78.000	63.803	102.000	27.172
8.000	23.367	32.000	70.201	56.000	80.362	80.000	61.203	104.000	23.738
10.000	27.358	34.000	72.277	58.000	79.923	82.000	58.467	106.000	20.172
12.000	31.771	36.000	74.006	60.000	79.241	84.000	55.614	108.000	16.401
14.000	36.503	38.000	75.445	62.000	78.325	86.000	52.660	110.000	12.241
16.000	41.342	40.000	76.654	64.000	77.185	88.000	49.633	112.000	7.234
18.000	46.097	42.000	77.694	66.000	75.833	90.000	46.551	114.000	1.597
20.000	50.612	44.000	78.578	68.000	74.280	92.000	43.422	116.000	0.000
22.000	54.766	46.000	79.309	70.000	72.537	94.000	40.252		



NOTE 1: Draft (and all other vertical heights) is measured above base Z=0.00!
NOTE 2: All calculated coefficients based on project length, draft and beam.

II Tank volumes mono-hull concept

SUMMARY OF MAXIMUM TANKVOLUMES

Compartment		Volume	Weight	VCG	LCG	TCG	Mom.In.T	S.W.
Void DB	19-37	162.074	162.074	2.798	21.198	0.000	1168.768	1.000
Void SB	19-37	93.067	93.067	5.826	19.869	8.045	17.397	1.000
Void PS	19-37	93.067	93.067	5.826	19.869	-8.045	17.397	1.000
Void DB	4-19	167.450	167.450	4.618	9.230	0.000	3281.731	1.000
Engine room	37-88	2693.516	2693.516	5.388	43.752	0.000	10648.267	1.000
MD acco	51-152	2975.052	2975.052	9.409	66.243	0.000	25864.115	1.000
A-deck acco	51-167	3092.037	3092.037	12.201	67.637	0.000	26011.975	1.000
Subtotal		9276.262	9276.262	8.898	57.431	0.000		

Compartment		Volume	Weight	VCG	LCG	TCG	Mom.In.T	S.W.
BW FP	152-fwd	124.140	127.243	7.159	108.790	0.000	24.432	1.025
BW DB CT	133-142	44.169	45.273	1.509	95.456	0.000	51.167	1.025
BW DB SB	124-133	35.714	36.607	1.528	89.832	1.339	17.682	1.025
BW DB PS	124-133	35.714	36.607	1.528	89.832	-1.339	17.682	1.025
BW WT SB	124-133	51.151	52.429	5.251	89.930	3.944	6.096	1.025
BW WT PS	124-133	51.151	52.429	5.251	89.930	-3.944	6.096	1.025
BW DB SB	112-124	60.231	61.737	1.542	82.434	1.718	49.885	1.025
BW DB PS	112-124	60.231	61.737	1.542	82.434	-1.718	49.885	1.025
BW WT SB	112-124	69.591	71.331	5.208	82.615	5.112	11.131	1.025
BW WT PS	112-124	69.591	71.331	5.208	82.615	-5.112	11.131	1.025
BW DB SB	100-112	73.735	75.578	1.542	74.082	2.099	89.787	1.025
BW DB PS	100-112	73.735	75.578	1.542	74.082	-2.099	89.787	1.025
BW WT SB	100-112	83.503	85.591	5.055	73.964	6.065	18.480	1.025
BW WT PS	100-112	83.503	85.591	5.055	73.964	-6.065	18.480	1.025
BW DB SB	88-100	84.531	86.644	1.541	65.726	2.401	132.980	1.025
BW DB PS	88-100	84.531	86.644	1.541	65.726	-2.401	132.980	1.025
BW WT SB	88-100	102.940	105.514	4.826	65.727	6.475	39.307	1.025
BW WT PS	88-100	102.940	105.514	4.826	65.727	-6.475	39.307	1.025
BW DB SB	73-88	113.100	115.927	1.558	56.334	2.616	211.710	1.025
BW DB PS	73-88	113.100	115.927	1.558	56.334	-2.616	211.710	1.025
BW WT SB	73-88	87.549	89.737	5.290	56.126	7.765	11.262	1.025
BW WT PS	73-88	87.549	89.737	5.290	56.126	-7.765	11.262	1.025
BW DB SB	61-73	86.749	88.917	1.612	46.966	2.662	174.526	1.025
BW DB PS	61-73	86.749	88.917	1.612	46.966	-2.662	174.526	1.025
BW WT SB	61-73	79.738	81.731	5.256	46.871	7.863	12.368	1.025
BW WT PS	61-73	79.738	81.731	5.256	46.871	-7.863	12.368	1.025
BW DB SB	49-61	75.022	76.897	1.698	38.644	2.548	148.006	1.025
BW DB PS	49-61	75.022	76.897	1.698	38.644	-2.548	148.006	1.025
BW WT SB	49-61	80.185	82.189	5.298	38.518	7.892	13.250	1.025
BW WT PS	49-61	80.185	82.189	5.298	38.518	-7.892	13.250	1.025
BW DB SB	37-49	111.839	114.635	2.448	30.313	2.907	244.083	1.025
BW DB PS	37-49	111.839	114.635	2.448	30.313	-2.907	244.083	1.025
BW WT SB	37-49	69.378	71.112	5.639	30.122	8.022	13.177	1.025
BW WT PS	37-49	69.378	71.112	5.639	30.122	-8.022	13.177	1.025
BW SB	4-19	63.457	65.043	6.711	8.106	8.139	12.106	1.025
BW PS	4-19	63.457	65.043	6.711	8.106	-8.139	12.106	1.025
BW SB	-4-4	57.480	58.917	6.723	-0.951	5.899	170.114	1.025
BW PS	-4-4	57.480	58.917	6.723	-0.951	-5.899	170.114	1.025
Subtotal		2940.090	3013.592	3.841	56.031	0.000		

Compartment		Volume	Weight	VCG	LCG	TCG	Mom.In.T	S.W.

III Weight calculation mono-hull concept

Name	Type	Hull weight up to D [kg]	L [m]	B[m]	D[m]	Tdesign [m]	Weight factor [kg/m³]
SD Victoria	WSS 8316	754995	83	16	7.2	4.25	79
Seveiros Fragata	PSV 7216	768176	71.8	16	7.5	5	89
Pool Expres	PSV 7216	812799	71.8	16	7.5	5	94
Vos Tracker	SSV 4711	205620	47.98	11	5.5	4.25	71
Barend Biesheuvel	PV 6111	340009	61.25	11	5.8	4	87
World Diamond	PSV 3300	925223	80.2	16.2	7.5	6.15	95
Fairplayer	DP Heavy lift vessel	4374571	133.8	26.5	14.1	8.1	88
Pharuehatsabodi	HRV 6613	452595	66.33	13.2	6.5	3	80
Tran Dai Nghia	HSV 6613	453526	66.33	13.2	6.5	3	80
Hr. Ms. Pelikaan	LSV 6513	449203	65.33	13.2	6.5	3	80
Med Otto	AHTS 6114	489759	60.36	13.5	6	4.5	100
Brodospas Alfa	AHTS 130	677795	66.88	15	6.75	5	100
Average							**87**

Table 48, Weight factor comparison

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg/m3]	[kg]	[m]	[m]	[m]
			[m3]			AB	fr 0	SB = +
100	Shipbuilding							
110	Hull		18240 m3	87 kg/m3	1,586,880	5.00	55.30	
110	MD-AD		4203 m3	50 kg/m3	210,140	9.50	71.00	
110	AD-BD		4256 m3	50 kg/m3	212,800	12.30	71.00	
	Total hull	Total volume	26699 m3					
		Factor	2009820 kg					
			75 kg/m3					
120	BD-CD	Aluminium	2128 m3	30 kg/m3	63,840	15.10	71.00	
120	CD-Bridge deck	Aluminium	1702 m3	30 kg/m3	51,072	17.90	67.00	
120	Wheelhouse	Aluminium	798 m3	48 kg/m3	38,304	22.50	61.00	
	Total superstructure	Total volume	4628 m3					
		Factor	153216 kg					
			33 kg/m3					
130	Small steelwork		2163036	6.0%	129,782	7.07	59.21	
161	Paint		2292818	1.5%	34,392	7.07	59.21	
	Rolling margin & welding material		2292818	4.5%	103,177	7.07	59.21	
	Shipbuilding total				2,430,387	7.07	59.21	

Table 49, Weight calculation mono-hull 100

Description	Mass [t]	VCG	LCG
Basic hull	942.33	4.58	58
Double bottom	278.24	1.77	62.13
Shaft tunnel	9.00	2.5	23.2
Tween deck	99.96	5.25	53
Steel fenders	1.05	8.55	58.50
Transverse bulkheads	79.15	4.58	55.5
Wing tanks	49.1	5.25	49.00
Bridge	64.33	20.5	61.00
Superstructure	533.06	14.1	71.00
Natural Hold vent.	10.64	4.58	58.00
Aux. Foundations	101.55	4.38	39.9
Hull finishing	36.40	4.58	58.00
Engine room finishing	15.20	3.00	39.9
Stem/Stern/Rudder	43.50	3.00	55.68
Shaft brackets	74.55	1.50	4.64
Total	**2337.98**	**6.74**	**58.35**

Table 50, Steel weight calculation mono-hull Westers

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
200	**Main machinery**							
211	Main engines	Wartsila 9L38	4	72000	288,000	4.00	38.00	
212	Gearboxes	Single in single out	4	14500	58,000	3.50	30.00	
213	Propellers	4000 mm CPP	4	8000	32,000	2.00	2.00	
213	Shafts & stern tubes		4	40000	160,000	2.00	12.00	
213	Seals & bearings		4	2500	10,000	2.00	12.00	
221	Rudders		4	15000	60,000	2.00	0.00	
222	Steering gear		4	5000	20,000	6.00	0.00	
223	Bow thruster - 1	1500 kW	1	10600	10,600	1.50	103.00	
223	Bow thruster - 2	1500 kW	1	10600	10,600	1.50	98.50	
223	Sternthruster - 1	1500 kW	1	10600	10,600	2.00	12.00	
223	Stern thruster - 2	1500 kW	1	10600	10,600	2.00	8.00	
223	E motor bow thruster - 1	1500 kW	1	8000	8,000	3.50	103.00	
223	E motor bow thruster - 2	1500 kW	1	8000	8,000	3.50	98.50	
223	E motor sternthruster - 1	1500 kW	1	8000	8,000	4.00	12.00	
223	E motor stern thruster - 2	1500 kW	1	8000	8,000	4.00	8.00	
223	Drive bow thruster - 1		1	2000	2,000	3.50	103.00	
223	Drive bow thruster - 2		1	2000	2,000	3.50	98.50	
223	Drive sternthruster - 1		1	2000	2,000	4.00	12.00	
223	Drive stern thruster - 2		1	2000	2,000	4.00	8.00	
	Main machinery total				**710,400**	**3.13**	**27.24**	

Table 51, Weight calculation mono-hull 200

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
300	**Primary ship systems**							
310	Bilge ballast piping		1	25000	25,000	3.75	55.00	
310	Fifi piping		1	7500	7,500	8.00	58.00	
320	Fuel oil piping		1	10000	10,000	3.75	45.00	
330	Cooling water piping		1	20000	20,000	3.00	48.00	
340	Fresh water piping		1	2000	2,000	11.00	75.00	
340	Sewage piping		1	8000	8,000	11.00	75.00	
340	Deck scupper piping		1	5000	5,000	10.50	58.00	
350	Tank sounding/filling piping		1	17500	17,500	6.00	58.00	
360	Lub oil piping		1	8000	8,000	3.50	47.00	
380	Exhaust piping ER		2	4000	8,000	10.50	50.00	
380	Exhaust piping PR		4	3500	14,000	13.50	57.00	
390	Miscellaneous piping		1	20000	20,000	5.00	58.00	
300	System fillings		145,000	20%	29,000	7.17	55.23	
300	Appendages		145,000	20%	29,000	7.17	55.23	
					0			
310	Bilge ballast equipment		1	2000	2,000	4.00	55.00	
310	Fifi equipment		1	1000	1,000	8.00	58.00	
320	Fuel oil equipment		1	3000	3,000	3.50	45.00	
330	Cooling water equipment		1	12000	12,000	3.00	48.00	
340	Fresh water equipment		1	3000	3,000	11.00	75.00	
340	Sewage plant		1	6000	6,000	3.50	75.00	
340	Other sewage equipment		1	1000	1,000	4.00	83.00	
350	Tank sounding/filling equipment		1	1000	1,000	6.50	58.00	
360	Lub oil equipment		1	2500	2,500	3.50	47.00	
370	HVAC piping (spiro)		1	10000	10,000	13.50	75.00	
370	HVAC unit		1	6500	6,500	13.50	55.00	
370	Other HVAC equipment		1	3000	3,000	13.50	95.00	
380	Exhaust equipment		6	2500	15,000	10.50	48.00	
390	Remaining primary ship systems		1	15000	15,000	5.00	58.00	
	Primary ship systems total				**284,000**	**6.93**	**56.36**	

Table 52, Weight calculation mono-hull 300

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
400	**Electrical system**							
410	Generator set	Wartsila 8L20	2	20700	41,400	4.00	56.00	
410	Generator set	Wartsila 8L26	2	45000	90,000	4.00	56.00	
410	Emergency set	Cat C18	1	1905	1,905	17.50	54.00	
420	Cables & cable trays below main deck		1	32000	32,000	5.00	55.00	
420	Cables & cable trays above maindeck		1	22000	22,000	12.50	55.00	
430	Main switchboard		4	5500	22,000	6.50	65.00	
430	Other switchboards		1	10000	10,000	6.50	65.00	
450	Lighting		1	3000	3,000	13.50	70.00	
490	Remaining items		1	15000	15,000	8.50	58.00	
	Electrical system total				**237,305**	**5.77**	**57.27**	

Table 53, Weight calculation mono-hull 400

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
500	**Deck equipment**							
510	Anchor winch		1	5000	5,000	12.50	108.00	
510	Anchors		2	3000	6,000	10.50	113.00	
510	Chain		1	25000	25,000	6.50	110.00	
510	Chain stoppers		2	650	1,300	11.50	111.00	
510	Mooring winches aft		2	6000	12,000	9.00	2.00	
520	Capstans aft		2	1200	2,400	9.00	2.00	
540	Deck crane (subsea execution)		1	275000	275,000	17.20	20.00	
540	Deck crane Pedestal	Incl	1		0			
540	Store crane		1	5000	5,000	14.50	94.50	
550	Tugger winches		2	4000	8,000	9.00	38.50	
560	ROV Davit		1	15000	15,000	11.50	56.00	
570	Fast rescue boat + davit		1	8000	8,000	12.50	49.70	
570	Life boat + davits		2	10000	20,000	15.50	66.50	
570	MOB boat + davit		1	2000	2,000	11.50	42.00	
570	life rafts		6	500	3,000	8.50	41.00	
590	Remaining items		1	15000	15,000	8.00	58.00	
	Deck equipment total				**402,700**	**15.04**	**34.93**	

Table 54, Weight calculation mono-hull 500

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
600	**Secondary ship systems**							
610	Hydraulic piping		1	5000	5,000	9.00	40.00	
620	Compressed air piping		6	2000	12,000	8.00	45.00	
660	Pre-wetting piping	Local protection	1	3000	3,000	4.00	45.00	
670	CO_2 piping		1	1000	1,000	9.00	45.00	
680	Cold & freeze piping		1	1000	1,000	9.50	64.50	
680	Remaining systems		1	10000	10,000	4.00	50.00	
600	System fillings		22,000	20%	4,400	8.45	44.75	
600	Appendages		22,000	20%	4,400	8.45	44.75	
					0			
610	Hydraulic equipment		1	5000	5,000	9.50	45.50	
620	Compressed air equipment		1	3000	3,000	6.50	40.00	
670	CO_2 equipment		1	1000	1,000	10.00	42.00	
680	Cold & freeze equipment		1	1500	1,500	9.50	64.50	
	Secondary ship systems total				**51,300**	**7.35**	**46.09**	

Table 55, Weight calculation mono-hull 600

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[m2]	[kg/m2]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
700	**Joinery and arrangement of accommodation**							
710	Joinery main deck		650 m2	150	97,500	9.00	77.00	
710	Joinery A - deck		650 m2	150	97,500	11.80	75.00	
710	Joinery B - deck		450 m2	120	54,000	14.60	75.00	
710	Joinery C - deck		450 m2	120	54,000	17.40	72.50	
710	Joinery bridge deck		190 m2	100	19,000	21.50	59.50	
730	Floor plates	Steel	250 m2	43	10,750	3.50	58.00	
	Joinery and arrangement of accommodation total				**332,750**	**12.63**	**73.75**	

Table 56, Weight calculation mono-hull 700

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
800	**Nautical, navigation and communication equipment**							
			1	3000	3,000	21.50	60.00	
	Nautical, navigation and communication equipment total				**3,000**	**21.50**	**60.00**	

Table 57, Weight calculation mono-hull 800

IV Extensive hydrostatics report mono-hull concept

HYDROSTATIC PARTICULARS
FIRM

Trim = 0.000 m

Draft from base	4.500	4.600	4.700	4.800	4.900
Waterplane area	1418.63	1443.16	1469.80	1497.27	1526.03
Centre of flotation	49.724	49.308	48.812	48.303	47.745
Mom. of inertia long.	946018	980167	1016863	1056758	1100417
Mom. of inertia tran.	27930	28873	29840	30821	31824
Ton/cm immersion	14.54	14.79	15.07	15.35	15.64
Volume	3705.62	3848.57	3994.10	4142.30	4293.30
Volume & appendages	3705.62	3848.57	3994.10	4142.30	4293.30
Displacement	3798.26	3944.79	4093.95	4245.86	4400.63
Vert. Centre Buoyancy	2.859	2.921	2.984	3.048	3.111
Long. Centre Buoyancy	55.840	55.605	55.368	55.125	54.877
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	10.396	10.424	10.455	10.488	10.523
KM longitudinal	258.151	257.604	257.576	258.161	259.421
Mom change trim 1 cm	84.32	87.36	90.63	94.19	98.08
Wetted surface	1748.3	1785.5	1824.9	1865.4	1907.5
Block coefficient	0.3769	0.3829	0.3889	0.3950	0.4010
Hor.prism.coef	0.5988	0.6026	0.6064	0.6103	0.6142
Vert.prism.coef	0.5805	0.5797	0.5782	0.5764	0.5742
Midship coefficient	0.6293	0.6354	0.6414	0.6472	0.6528
Waterplane coef.	0.6493	0.6605	0.6727	0.6852	0.6984
Waterplane coef. fore	0.5036	0.5074	0.5112	0.5149	0.5186

Draft from base	5.000	5.100	5.200	5.300	5.400
Waterplane area	1556.35	1585.94	1611.13	1632.08	1649.27
Centre of flotation	47.147	46.563	46.115	45.788	45.557
Mom. of inertia long.	1148431	1200393	1250259	1292200	1325936
Mom. of inertia tran.	32861	33921	34992	36035	37003
Ton/cm immersion	15.95	16.26	16.51	16.73	16.90
Volume	4447.25	4604.24	4764.00	4926.09	5090.11
Volume & appendages	4447.25	4604.24	4764.00	4926.09	5090.11
Displacement	4558.44	4719.35	4883.10	5049.24	5217.37
Vert. Centre Buoyancy	3.175	3.239	3.303	3.367	3.431
Long. Centre Buoyancy	54.621	54.356	54.088	53.820	53.558
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	10.564	10.606	10.648	10.682	10.700
KM longitudinal	261.408	263.953	265.742	265.684	263.923
Mom change trim 1 cm	102.36	106.99	111.44	115.17	118.18
Wetted surface	1951.5	1995.3	2035.1	2071.1	2103.8
Block coefficient	0.4071	0.4132	0.4193	0.4254	0.4314
Hor.prism.coef	0.6183	0.6225	0.6268	0.6310	0.6353
Vert.prism.coef	0.5715	0.5692	0.5686	0.5695	0.5715
Midship coefficient	0.6584	0.6637	0.6690	0.6741	0.6791
Waterplane coef.	0.7123	0.7258	0.7374	0.7469	0.7548
Waterplane coef. fore	0.5222	0.5256	0.5292	0.5326	0.5360

Draft from base	5.500	5.600	5.700	5.800	5.900
Waterplane area	1664.50	1676.66	1687.30	1696.39	1704.59
Centre of flotation	45.391	45.286	45.233	45.223	45.216
Mom. of inertia long.	1353136	1375497	1393233	1407707	1420100
Mom. of inertia tran.	37880	38647	39305	39890	40425
Ton/cm immersion	17.06	17.19	17.29	17.39	17.47
Volume	5255.76	5422.78	5590.94	5760.07	5930.08
Volume & appendages	5255.76	5422.78	5590.94	5760.07	5930.08
Displacement	5387.15	5558.35	5730.71	5904.07	6078.33
Vert. Centre Buoyancy	3.494	3.558	3.621	3.683	3.745
Long. Centre Buoyancy	53.303	53.058	52.824	52.601	52.389
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	10.702	10.684	10.651	10.608	10.562
KM longitudinal	260.952	257.209	252.815	248.074	243.219
Mom change trim 1 cm	120.61	122.60	124.18	125.47	126.57
Wetted surface	2134.2	2162.4	2188.9	2214.5	2239.7
Block coefficient	0.4373	0.4432	0.4489	0.4545	0.4600
Hor.prism.coef	0.6394	0.6435	0.6475	0.6513	0.6550
Vert.prism.coef	0.5741	0.5775	0.5813	0.5854	0.5896
Midship coefficient	0.6839	0.6887	0.6933	0.6979	0.7023
Waterplane coef.	0.7618	0.7674	0.7722	0.7764	0.7801
Waterplane coef. fore	0.5394	0.5427	0.5462	0.5494	0.5528

Draft from base	6.000	6.100	6.200	6.300	6.400
Waterplane area	1712.35	1719.78	1726.51	1733.35	1739.89
Centre of flotation	45.238	45.258	45.285	45.304	45.333
Mom. of inertia long.	1431272	1441687	1450497	1459611	1468219
Mom. of inertia tran.	40925	41391	41825	42237	42629
Ton/cm immersion	17.55	17.63	17.70	17.77	17.83
Volume	6100.90	6272.48	6444.78	6617.76	6791.39
Volume & appendages	6100.90	6272.48	6444.78	6617.76	6791.39
Displacement	6253.42	6429.30	6605.90	6783.21	6961.17
Vert. Centre Buoyancy	3.807	3.868	3.929	3.990	4.050
Long. Centre Buoyancy	52.189	51.998	51.818	51.647	51.485
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	10.515	10.467	10.419	10.372	10.327
KM longitudinal	238.407	233.711	228.995	224.550	220.239
Mom change trim 1 cm	127.57	128.50	129.28	130.10	130.86
Wetted surface	2264.5	2289.0	2313.4	2337.6	2361.7
Block coefficient	0.4654	0.4706	0.4757	0.4807	0.4857
Hor.prism.coef	0.6586	0.6621	0.6654	0.6687	0.6719
Vert.prism.coef	0.5938	0.5979	0.6021	0.6060	0.6099
Midship coefficient	0.7066	0.7108	0.7149	0.7189	0.7228
Waterplane coef.	0.7837	0.7871	0.7902	0.7933	0.7963
Waterplane coef. fore	0.5561	0.5592	0.5625	0.5656	0.5687

Draft from base	6.500	6.600	6.700	6.800	6.900
Waterplane area	1746.19	1751.32	1757.37	1762.35	1767.68
Centre of flotation	45.350	45.405	45.424	45.488	45.526
Mom. of inertia long.	1476283	1484542	1491841	1499340	1506372
Mom. of inertia tran.	43000	43355	43682	44006	44307
Ton/cm immersion	17.90	17.95	18.01	18.06	18.12
Volume	6965.63	7140.46	7315.85	7491.78	7668.23
Volume & appendages	6965.63	7140.46	7315.85	7491.78	7668.23
Displacement	7139.77	7318.97	7498.74	7679.07	7859.94
Vert. Centre Buoyancy	4.110	4.170	4.230	4.289	4.348
Long. Centre Buoyancy	51.332	51.186	51.048	50.917	50.792
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	10.283	10.242	10.200	10.163	10.126
KM longitudinal	216.049	212.076	208.149	204.420	200.791
Mom change trim 1 cm	131.58	132.32	132.97	133.64	134.26
Wetted surface	2385.7	2409.7	2433.5	2457.3	2481.0
Block coefficient	0.4905	0.4951	0.4997	0.5042	0.5086
Hor.prism.coef	0.6749	0.6779	0.6808	0.6836	0.6863
Vert.prism.coef	0.6137	0.6178	0.6213	0.6251	0.6287
Midship coefficient	0.7267	0.7304	0.7341	0.7376	0.7411
Waterplane coef.	0.7992	0.8015	0.8043	0.8066	0.8090
Waterplane coef. fore	0.5718	0.5750	0.5778	0.5811	0.5838

Draft from base	7.000
Waterplane area	1772.27
Centre of flotation	45.589
Mom. of inertia long.	1513467
Mom. of inertia tran.	44595
Ton/cm immersion	18.17
Volume	7845.19
Volume & appendages	7845.19
Displacement	8041.32
Vert. Centre Buoyancy	4.406
Long. Centre Buoyancy	50.674
Trans.Centre Buoyancy	0.000
KM transverse	10.091
KM longitudinal	197.323
Mom change trim 1 cm	134.90
Wetted surface	2504.9
Block coefficient	0.5129
Hor.prism.coef	0.6889
Vert.prism.coef	0.6324
Midship coefficient	0.7445
Waterplane coef.	0.8111
Waterplane coef. fore	0.5868

V Rules and regulations intact stability calculations

VI.A IMO A.749(18)

3.1 General intact stability criteria for all ships

3.1.1 Scope
. The following criteria are recommended for passenger and cargo ships.

3.1.2 Recommended general criteria
3.1.2.1. The area under the righting lever curve (GZ curve) should not be less than 0.055 metre-radians up to $\theta = 30°$ angle of heel and not less than 0.09 metre-radians up to $\theta = 40°$ or the angle of downflooding θ_f see footnote if this angle is less than 40°. Additionally, the area under the righting lever curve (GZ curve) between the angles of heel of 30° and 40° or between 30° and θ_f, if this angle is less than 40°, should not be less than 0.03 metre-radians.

3.1.2.2. The righting lever GZ should be at least 0.20 m at an angle of heel equal to or greater than 30°.

3.1.2.3. The maximum righting arm should occur at an angle of heel preferably exceeding 30° but not less than 25°.

3.1.2.4. The initial metacentric height GM_o should not be less than 0.15 m.

VI.B Accidental loss of load (DNV)

Rules (DNV):

Pt.5 Ch.7 Sec.17

D 200Accidental load drop

Pt.5 Ch.7 Sec.17 D

201 The effect of accidental drop of crane load shall be investigated and shall meet the following criteria:

- The restoring energy represented by area A2 in Fig.1 is to be at least 40% in excess of the potential energy represented by area A1.
- The angle of static equilibrium Qe after loss of crane load shall not be more than 15 degrees from the upright.

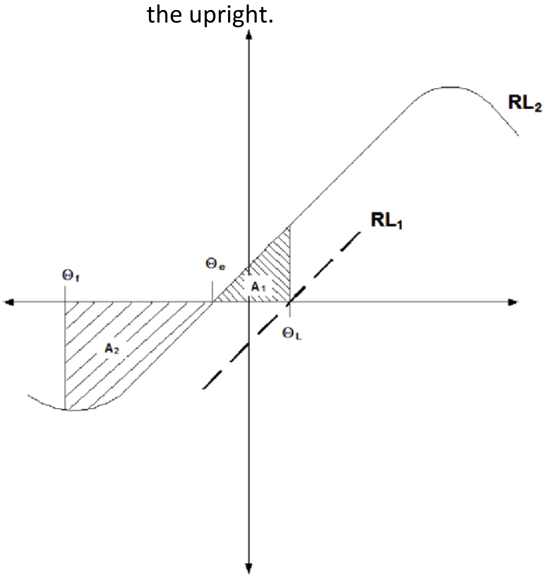


Figure 62, Stability with loss of crane load

RL1 = Net righting lever (GZ) curve for the condition before loss of crane load, corrected for crane heeling moment and for the righting moment provided by the counter ballast if applicable.

RL2= Net righting lever (GZ) curve for the condition after loss of crane load, corrected for the transverse moment provided by the counter ballast if applicable.

QL= Static angle of equilibrium before loss of crane load.
QL may alternatively be determined by the equation:

QL = arctan (TCG/GMt)

If this results in a small angle of heel.

TCG is then to be taken as the vessel's transverse centre of gravity before loss of crane load, and GMt is the corrected transverse metacentric height in the same condition.

Qe= Static angle of equilibrium after loss of crane load

Qf= Angle of down flooding as defined in Pt.3 Ch.3 Sec.9.

Guidance note:

Net righting lever implies that the calculation of the GZ curve includes the vessel's true transverse centre of gravity as function of the angle of heel.

VI Intact Stability calculations mono-hull

TRIM AND STABILITY CALCULATION
FIRM

11 Jun 2013 14:45:04

Condition : 1.1 Ballast condition T=6m

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm
Empty ship		4674.000	7.810	52.200	0.000	0.000
Subtotals for group : Ballast water						
BW FP	152-fwd	0.000	0.006	106.845	0.000	0.000
BW DB CT	133-142	28.522	1.100	95.462	0.000	46.161
BW DB SB	124-133	0.000	-0.000	89.873	0.115	0.000
BW DB PS	124-133	0.000	-0.000	89.873	-0.115	0.000
BW WT SB	124-133	0.000	2.500	89.957	3.058	0.000
BW WT PS	124-133	0.000	2.500	89.957	-3.058	0.000
BW DB SB	112-124	0.000	-0.000	82.488	0.133	0.000
BW DB PS	112-124	0.000	-0.000	82.488	-0.133	0.000
BW WT SB	112-124	0.000	2.500	82.667	4.083	0.000
BW WT PS	112-124	0.000	2.500	82.667	-4.083	0.000
BW DB SB	100-112	0.000	-0.000	74.228	0.150	0.000
BW DB PS	100-112	0.000	-0.000	74.228	-0.150	0.000
BW WT SB	100-112	0.000	2.500	73.745	4.922	0.000
BW WT PS	100-112	0.000	2.500	73.745	-4.922	0.000
BW DB SB	88-100	0.000	-0.000	66.838	0.124	0.000
BW DB PS	88-100	0.000	-0.000	66.838	-0.124	0.000
BW WT SB	88-100	0.000	2.500	65.590	5.297	0.000
BW WT PS	88-100	0.000	2.500	65.590	-5.297	0.000
BW DB SB	73-88	0.000	0.006	60.835	0.073	0.000
BW DB PS	73-88	0.000	0.006	60.835	-0.073	0.000
BW WT SB	73-88	0.000	2.500	55.809	6.620	0.000
BW WT PS	73-88	0.000	2.500	55.809	-6.620	0.000
BW DB SB	61-73	88.917	1.612	46.966	2.662	0.000
BW DB PS	61-73	88.917	1.612	46.966	-2.662	0.000
BW WT SB	61-73	81.731	5.256	46.871	7.863	0.000
BW WT PS	61-73	81.731	5.256	46.871	-7.863	0.000
BW DB SB	49-61	76.897	1.698	38.644	2.548	0.000
BW DB PS	49-61	76.897	1.698	38.644	-2.548	0.000
BW WT SB	49-61	82.189	5.298	38.518	7.892	0.000
BW WT PS	49-61	82.189	5.298	38.518	-7.892	0.000
BW SB	4-19	65.043	6.711	8.106	8.139	0.000
BW PS	4-19	65.043	6.711	8.106	-8.139	0.000
SUBTOTAL		818.079	3.890	39.197	-0.000	46.161
Subtotals for group : Fuel oil						
FO CT	124-133	71.281	3.847	89.765	0.000	59.115
FO CT	112-124	134.176	3.847	82.367	0.000	221.059
FO CT	100-112	156.539	3.847	74.200	0.000	341.541
FO CT	88-100	156.539	3.847	65.800	0.000	341.541
FO SB	4-19	65.224	6.597	8.050	5.600	15.812
FO PS	4-19	65.224	6.597	8.050	-5.600	15.812
SUBTOTAL		648.982	4.400	62.275	0.000	994.881
Subtotals for group : Fresh water						
FW WT SB	133-142	46.074	5.113	96.184	2.851	1.797
FW WT PS	133-142	46.074	5.113	96.184	-2.851	1.797
SUBTOTAL		92.149	5.113	96.184	-0.000	3.594

Subtotals for group : Crew and stores

Crew and stores	15.000	14.000	75.000	0.000	0.000
SUBTOTAL	15.000	14.000	75.000	0.000	0.000
TOTAL	**6248.210**	**6.918**	**52.247**	**-0.000**	**1044.635**

Hydrostatics		Drafts and trim	
Volume	6095.862 m^3	Drafts above base :	
LCF	45.226 m	Draft mean (Lpp/2)	6.000 m
Mom. change trim	127.551 tonm/cm	Draft aft (App)	5.987 m
Ton/cm immersion	17.555 ton/cm	Draft fore (Fpp)	6.013 m
Specific weight	1.025 ton/m^3	Trim	0.026 m

Transverse stability			
KM transverse	10.514 m		
VCG	6.918 m		
GM solid	3.597 m		
GG' correction	0.167 m		
G'M liquid	3.430 m	VCG'	7.085 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	6.000	0.026	0.000	0.000	-0.000	0.000	0.000
2.00	5.998	0.029	0.367	0.247	-0.000	0.120	0.002
5.00	5.990	0.045	0.913	0.617	-0.000	0.296	0.013
10.00	5.959	0.126	1.799	1.230	-0.000	0.569	0.051
15.00	5.903	0.259	2.634	1.834	-0.000	0.801	0.111
20.00	5.840	0.288	3.366	2.423	-0.000	0.943	0.188
25.00	5.762	0.232	4.032	2.994	-0.000	1.038	0.274
30.00	5.657	0.120	4.655	3.542	-0.000	1.112	0.368
35.00	5.514	-0.028	5.244	4.064	-0.000	1.180	0.468
40.00	5.317	-0.203	5.810	4.554	-0.000	1.256	0.575
50.00	4.749	-0.694	6.779	5.427	-0.000	1.351	0.804
60.00	3.926	-1.500	7.389	6.136	-0.000	1.253	1.035

Statical angle of inclination is 0.000 degrees to starboard
Contour : FIRM

Opening	is submerged at [degrees]
ER Vent in	55.35

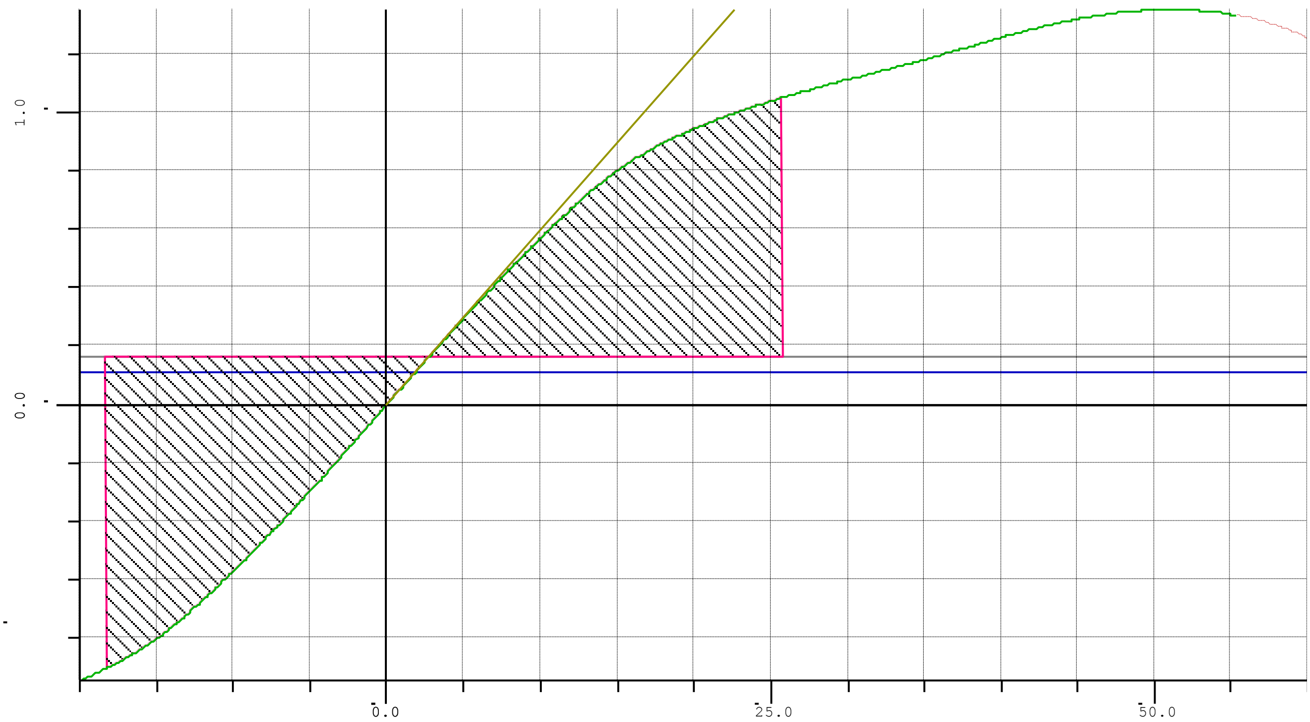
Summary

Hydrostatics		Criterion	Value	
Draft mld.		6.000	6.000	m
Trim	0.026 m			
Statical angle of inclination	0.00 degrees SB			
Flooding angle	55.35 degrees			

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value	
Minimum metacentric height G'M	0.150	3.430	meter
Maximum GZ at 30 degrees or more	0.200	1.352	meter
Top of the GZ curve at least at	15.000	51.042	degrees
Area under the GZ curve up to 30 degrees	0.055	0.368	mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.206	mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	25.731	degrees
Maximum statical angle due to wind	13.231	1.833	degrees
Maximum statical angle 80% of angle of deck immersion	9.984	1.833	degrees

VCG'	
Actual	7.085 m
Maximum allowable	8.612 m

Loading condition complies with the stated criteria.



Angle of inclination in degrees 1/4.92

TRIM AND STABILITY CALCULATION
FIRM

11 Jun 2013 14:45:31

Condition : 2.1 Departure 100% consumables

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm
Empty ship		4674.000	7.810	52.200	0.000	0.000
Subtotals for group : Ballast water						
BW FP	152-fwd	0.000	0.006	106.845	0.000	0.000
BW DB CT	133-142	0.000	-0.000	95.538	0.000	0.000
BW DB SB	124-133	0.000	-0.000	89.873	0.115	0.000
BW DB PS	124-133	0.000	-0.000	89.873	-0.115	0.000
BW WT SB	124-133	0.000	2.500	89.957	3.058	0.000
BW WT PS	124-133	0.000	2.500	89.957	-3.058	0.000
BW DB SB	112-124	0.000	-0.000	82.488	0.133	0.000
BW DB PS	112-124	0.000	-0.000	82.488	-0.133	0.000
BW WT SB	112-124	0.000	2.500	82.667	4.083	0.000
BW WT PS	112-124	0.000	2.500	82.667	-4.083	0.000
BW DB SB	100-112	0.000	-0.000	74.228	0.150	0.000
BW DB PS	100-112	0.000	-0.000	74.228	-0.150	0.000
BW WT SB	100-112	0.000	2.500	73.745	4.922	0.000
BW WT PS	100-112	0.000	2.500	73.745	-4.922	0.000
BW DB SB	88-100	0.000	-0.000	66.838	0.124	0.000
BW DB PS	88-100	0.000	-0.000	66.838	-0.124	0.000
BW WT SB	88-100	0.000	2.500	65.590	5.297	0.000
BW WT PS	88-100	0.000	2.500	65.590	-5.297	0.000
BW DB SB	73-88	0.000	0.006	60.835	0.073	0.000
BW DB PS	73-88	0.000	0.006	60.835	-0.073	0.000
BW WT SB	73-88	0.000	2.500	55.809	6.620	0.000
BW WT PS	73-88	0.000	2.500	55.809	-6.620	0.000
BW DB SB	61-73	0.000	0.084	50.888	0.053	0.000
BW DB PS	61-73	0.000	0.084	50.888	-0.053	0.000
BW WT SB	61-73	0.000	2.500	46.960	6.681	0.000
BW WT PS	61-73	0.000	2.500	46.960	-6.681	0.000
BW DB SB	49-61	0.000	0.241	42.533	0.040	0.000
BW DB PS	49-61	0.000	0.241	42.533	-0.040	0.000
BW WT SB	49-61	0.000	2.500	38.976	6.584	0.000
BW WT PS	49-61	0.000	2.500	38.976	-6.584	0.000
BW SB	4-19	65.043	6.711	8.106	8.139	0.000
BW PS	4-19	65.043	6.711	8.106	-8.139	0.000
SUBTOTAL		130.086	6.711	8.106	-0.000	0.000
Subtotals for group : Fuel oil						
FO CT	124-133	71.281	3.847	89.765	0.000	59.115
FO CT	112-124	134.176	3.847	82.367	0.000	221.059
FO CT	100-112	156.539	3.847	74.200	0.000	341.541
FO CT	88-100	156.539	3.847	65.800	0.000	341.541
FO SB	4-19	65.224	6.597	8.050	5.600	15.812
FO PS	4-19	65.224	6.597	8.050	-5.600	15.812
SUBTOTAL		648.982	4.400	62.275	0.000	994.881
Subtotals for group : Fresh water						
FW WT SB	133-142	46.074	5.113	96.184	2.851	1.797
FW WT PS	133-142	46.074	5.113	96.184	-2.851	1.797
SUBTOTAL		92.149	5.113	96.184	-0.000	3.594

Subtotals for group : Crew and stores

Crew and stores	15.000	14.000	75.000	0.000	0.000
SUBTOTAL	15.000	14.000	75.000	0.000	0.000
TOTAL	**5560.217**	**7.358**	**53.135**	**-0.000**	**998.475**

Hydrostatics		
Volume	5424.743	m^3
LCF	45.328	m
Mom. change trim	122.509	tonm/cm
Ton/cm immersion	17.182	ton/cm
Specific weight	1.025	ton/m^3

Drafts and trim		
Drafts above base :		
Draft mean (Lpp/2)	5.605	m
Draft aft (App)	5.587	m
Draft fore (Fpp)	5.623	m
Trim	0.036	m

Transverse stability		
KM transverse	10.676	m
VCG	7.358	m
GM solid	3.318	m
GG' correction	0.180	m
G'M liquid	3.138	m

VCG' 7.538 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	5.605	0.036	0.000	0.000	-0.000	0.000	0.000
2.00	5.603	0.043	0.372	0.263	-0.000	0.109	0.002
5.00	5.593	0.083	0.922	0.657	-0.000	0.265	0.012
10.00	5.554	0.222	1.808	1.309	-0.000	0.499	0.045
15.00	5.485	0.438	2.650	1.951	-0.000	0.699	0.098
20.00	5.389	0.667	3.421	2.578	-0.000	0.843	0.166
25.00	5.275	0.807	4.105	3.186	-0.000	0.919	0.243
30.00	5.130	0.892	4.730	3.769	-0.000	0.961	0.325
35.00	4.943	0.946	5.312	4.324	-0.000	0.988	0.410
40.00	4.695	0.985	5.863	4.845	-0.000	1.018	0.498
50.00	3.947	1.043	6.863	5.774	-0.000	1.088	0.682
60.00	2.803	1.051	7.518	6.528	-0.000	0.990	0.868

Statical angle of inclination is 0.000 degrees to starboard
Contour : FIRM

Opening	is submerged at [degrees]
ER Vent in	58.59

Summary

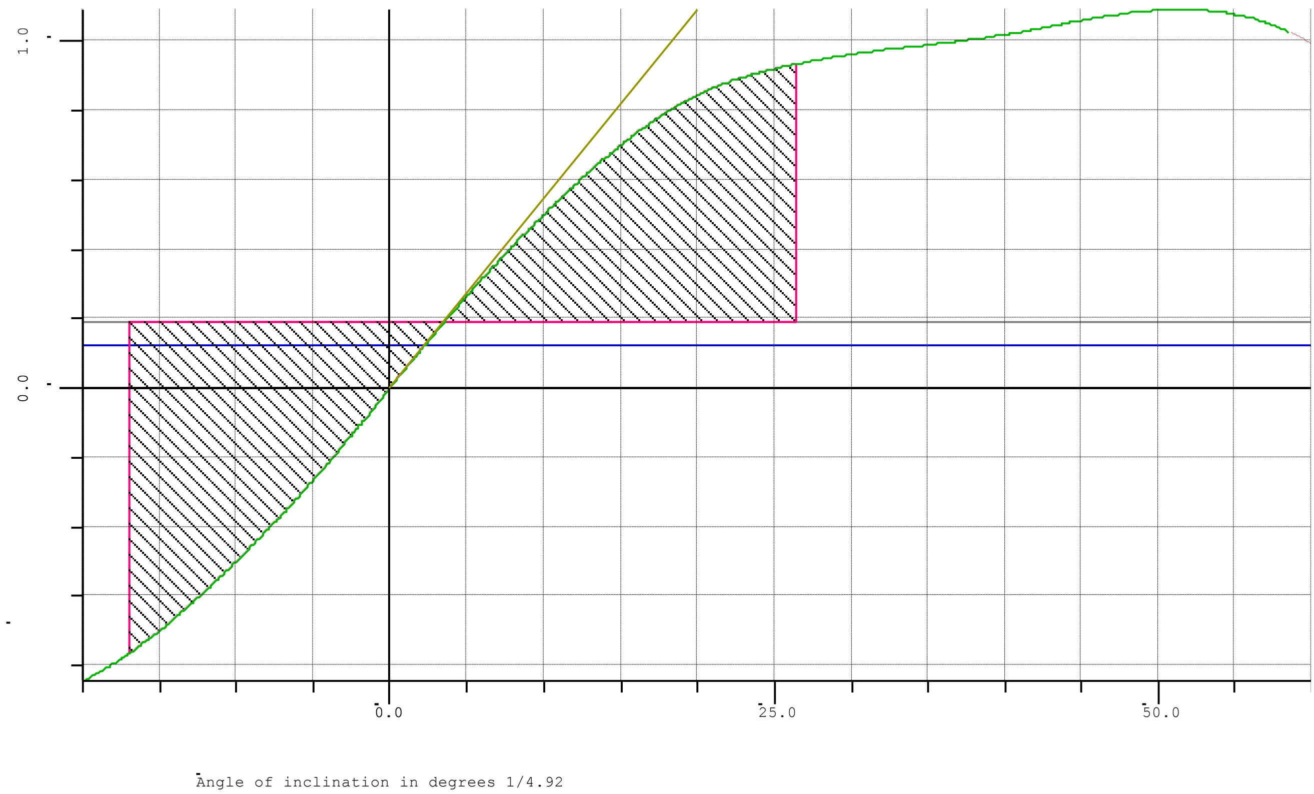
Hydrostatics		Criterion	Value
Draft mld.		6.000	5.605 m
Trim	0.036 m		
Statical angle of inclination	0.00 degrees SB		
Flooding angle	58.59 degrees		

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	3.138 meter
Maximum GZ at 30 degrees or more	0.200	1.090 meter
Top of the GZ curve at least at	15.000	51.469 degrees
Area under the GZ curve up to 30 degrees	0.055	0.325 mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.173 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	26.405 degrees
Maximum statical angle due to wind	16.000	2.310 degrees
Maximum statical angle 80% of angle of deck immersion	12.268	2.310 degrees

VCG'

Actual	7.538 m
Maximum allowable	8.685 m

Loading condition complies with the stated criteria.



TRIM AND STABILITY CALCULATION
FIRM

11 Jun 2013 14:45:56

Condition : 2.2 Arrival 10% consumables

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm
Empty ship		4674.000	7.810	52.200	0.000	0.000
Subtotals for group : Ballast water						
BW FP	152-fwd	0.000	0.006	106.845	0.000	0.000
BW DB CT	133-142	45.273	1.509	95.456	0.000	0.000
BW DB SB	124-133	36.607	1.528	89.832	1.339	0.000
BW DB PS	124-133	36.607	1.528	89.832	-1.339	0.000
BW WT SB	124-133	0.000	2.500	89.957	3.058	0.000
BW WT PS	124-133	0.000	2.500	89.957	-3.058	0.000
BW DB SB	112-124	0.000	-0.000	82.488	0.133	0.000
BW DB PS	112-124	0.000	-0.000	82.488	-0.133	0.000
BW WT SB	112-124	0.000	2.500	82.667	4.083	0.000
BW WT PS	112-124	0.000	2.500	82.667	-4.083	0.000
BW DB SB	100-112	0.000	-0.000	74.228	0.150	0.000
BW DB PS	100-112	0.000	-0.000	74.228	-0.150	0.000
BW WT SB	100-112	0.000	2.500	73.745	4.922	0.000
BW WT PS	100-112	0.000	2.500	73.745	-4.922	0.000
BW DB SB	88-100	0.000	-0.000	66.838	0.124	0.000
BW DB PS	88-100	0.000	-0.000	66.838	-0.124	0.000
BW WT SB	88-100	0.000	2.500	65.590	5.297	0.000
BW WT PS	88-100	0.000	2.500	65.590	-5.297	0.000
BW DB SB	73-88	0.000	0.006	60.835	0.073	0.000
BW DB PS	73-88	0.000	0.006	60.835	-0.073	0.000
BW WT SB	73-88	0.000	2.500	55.809	6.620	0.000
BW WT PS	73-88	0.000	2.500	55.809	-6.620	0.000
BW DB SB	61-73	0.000	0.084	50.888	0.053	0.000
BW DB PS	61-73	0.000	0.084	50.888	-0.053	0.000
BW WT SB	61-73	0.000	2.500	46.960	6.681	0.000
BW WT PS	61-73	0.000	2.500	46.960	-6.681	0.000
BW DB SB	49-61	0.000	0.241	42.533	0.040	0.000
BW DB PS	49-61	0.000	0.241	42.533	-0.040	0.000
BW WT SB	49-61	0.000	2.500	38.976	6.584	0.000
BW WT PS	49-61	0.000	2.500	38.976	-6.584	0.000
BW SB	4-19	0.000	5.250	8.706	7.765	0.000
BW PS	4-19	0.000	5.250	8.706	-7.765	0.000
SUBTOTAL		118.488	1.521	91.980	-0.000	0.000
Subtotals for group : Fuel oil						
FO CT	124-133	7.274	2.637	89.765	0.000	59.115
FO CT	112-124	13.691	2.638	82.367	0.000	221.055
FO CT	100-112	15.973	2.638	74.200	0.000	341.540
FO CT	88-100	15.973	2.637	65.800	0.000	341.540
FO SB	4-19	6.656	5.387	8.050	5.600	15.812
FO PS	4-19	6.656	5.387	8.050	-5.600	15.812
SUBTOTAL		66.223	3.190	62.275	-0.000	994.875
Subtotals for group : Fresh water						
FW WT SB	133-142	4.701	2.816	96.292	2.181	1.999
FW WT PS	133-142	4.701	2.816	96.292	-2.181	1.999
SUBTOTAL		9.403	2.816	96.292	0.000	3.997

Subtotals for group : Crew and stores

Crew and stores	15.000	14.000	75.000	0.000	0.000
SUBTOTAL	15.000	14.000	75.000	0.000	0.000
TOTAL	**4883.113**	**7.604**	**53.457**	**-0.000**	**998.872**

Hydrostatics		Drafts and trim	
Volume	4764.014 m^3	Drafts above base :	
LCF	45.624 m	Draft mean (Lpp/2)	5.173 m
Mom. change trim	114.257 tonm/cm	Draft aft (App)	5.307 m
Ton/cm immersion	16.640 ton/cm	Draft fore (Fpp)	5.039 m
Specific weight	1.025 ton/m^3	Trim	-0.268 m

Transverse stability			
KM transverse	10.778 m		
VCG	7.604 m		
GM solid	3.174 m		
GG' correction	0.205 m		
G'M liquid	2.970 m	VCG'	7.809 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	5.173	-0.268	0.000	0.000	-0.000	0.000	0.000
2.00	5.170	-0.255	0.376	0.273	-0.000	0.103	0.002
5.00	5.158	-0.193	0.931	0.681	-0.000	0.251	0.011
10.00	5.112	-0.007	1.822	1.356	-0.000	0.466	0.043
15.00	5.033	0.258	2.664	2.021	-0.000	0.643	0.091
20.00	4.916	0.588	3.455	2.671	-0.000	0.784	0.154
25.00	4.770	0.884	4.159	3.300	-0.000	0.859	0.226
30.00	4.590	1.121	4.789	3.904	-0.000	0.885	0.302
35.00	4.361	1.332	5.367	4.479	-0.000	0.888	0.380
40.00	4.066	1.535	5.906	5.019	-0.000	0.887	0.457
50.00	3.171	1.993	6.915	5.982	-0.000	0.933	0.616
60.00	1.728	2.600	7.635	6.763	-0.000	0.873	0.777

Statical angle of inclination is 0.000 degrees to starboard
Contour : FIRM

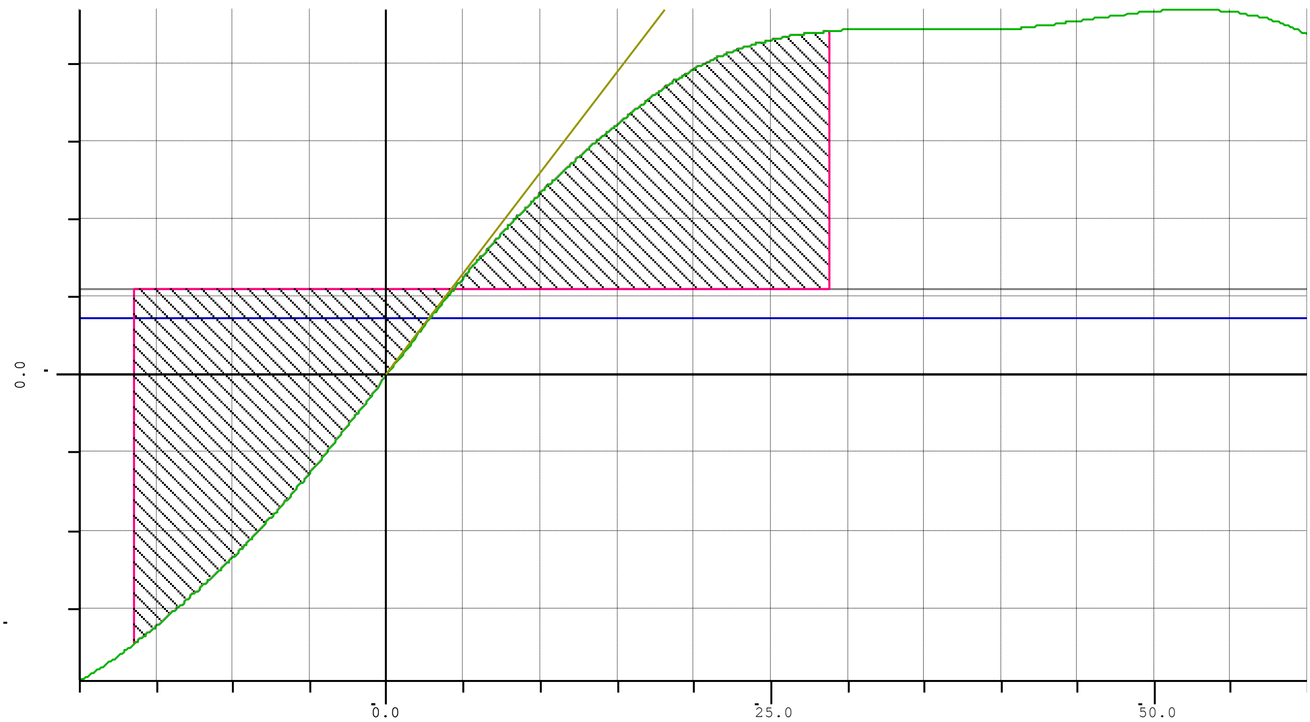
Summary

Hydrostatics		Criterion	Value
Draft mld.		6.000	5.173 m
Trim	-0.268 m		
Statical angle of inclination	0.00 degrees SB		
Flooding angle	60.00 degrees		

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	2.970 meter
Maximum GZ at 30 degrees or more	0.200	0.938 meter
Top of the GZ curve at least at	15.000	52.479 degrees
Area under the GZ curve up to 30 degrees	0.055	0.302 mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.155 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	28.763 degrees
Maximum statical angle due to wind	16.000	2.867 degrees
Maximum statical angle 80% of angle of deck immersion	14.566	2.867 degrees

VCG'	
Actual	7.809 m
Maximum allowable	8.665 m

Loading condition complies with the stated criteria.



TRIM AND STABILITY CALCULATION
FIRM

11 Jun 2013 14:46:17

Condition : 3.1 Departure 600t deckload

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm
Empty ship		4674.000	7.810	52.200	0.000	0.000
Subtotals for group : Ballast water						
BW FP	152-fwd	0.000	0.006	106.845	0.000	0.000
BW DB CT	133-142	0.000	-0.000	95.538	0.000	0.000
BW DB SB	124-133	36.607	1.528	89.832	1.339	0.000
BW DB PS	124-133	36.607	1.528	89.832	-1.339	0.000
BW WT SB	124-133	0.000	2.500	89.957	3.058	0.000
BW WT PS	124-133	0.000	2.500	89.957	-3.058	0.000
BW DB SB	112-124	61.737	1.542	82.434	1.718	0.000
BW DB PS	112-124	61.737	1.542	82.434	-1.718	0.000
BW WT SB	112-124	0.000	2.500	82.667	4.083	0.000
BW WT PS	112-124	0.000	2.500	82.667	-4.083	0.000
BW DB SB	100-112	0.000	-0.000	74.228	0.150	0.000
BW DB PS	100-112	0.000	-0.000	74.228	-0.150	0.000
BW WT SB	100-112	0.000	2.500	73.745	4.922	0.000
BW WT PS	100-112	0.000	2.500	73.745	-4.922	0.000
BW DB SB	88-100	0.000	-0.000	66.838	0.124	0.000
BW DB PS	88-100	0.000	-0.000	66.838	-0.124	0.000
BW WT SB	88-100	0.000	2.500	65.590	5.297	0.000
BW WT PS	88-100	0.000	2.500	65.590	-5.297	0.000
BW DB SB	73-88	0.000	0.006	60.835	0.073	0.000
BW DB PS	73-88	0.000	0.006	60.835	-0.073	0.000
BW WT SB	73-88	0.000	2.500	55.809	6.620	0.000
BW WT PS	73-88	0.000	2.500	55.809	-6.620	0.000
BW DB SB	61-73	0.000	0.084	50.888	0.053	0.000
BW DB PS	61-73	0.000	0.084	50.888	-0.053	0.000
BW WT SB	61-73	0.000	2.500	46.960	6.681	0.000
BW WT PS	61-73	0.000	2.500	46.960	-6.681	0.000
BW DB SB	49-61	0.000	0.241	42.533	0.040	0.000
BW DB PS	49-61	0.000	0.241	42.533	-0.040	0.000
BW WT SB	49-61	0.000	2.500	38.976	6.584	0.000
BW WT PS	49-61	0.000	2.500	38.976	-6.584	0.000
BW SB	4-19	0.000	5.250	8.706	7.765	0.000
BW PS	4-19	0.000	5.250	8.706	-7.765	0.000
SUBTOTAL		196.688	1.537	85.188	-0.000	0.000
Subtotals for group : Fuel oil						
FO CT	124-133	71.281	3.847	89.765	0.000	59.115
FO CT	112-124	134.176	3.847	82.367	0.000	221.059
FO CT	100-112	156.539	3.847	74.200	0.000	341.541
FO CT	88-100	156.539	3.847	65.800	0.000	341.541
FO SB	4-19	65.224	6.597	8.050	5.600	15.812
FO PS	4-19	65.224	6.597	8.050	-5.600	15.812
SUBTOTAL		648.982	4.400	62.275	0.000	994.881
Subtotals for group : Fresh water						
FW WT SB	133-142	46.074	5.113	96.184	2.851	1.797
FW WT PS	133-142	46.074	5.113	96.184	-2.851	1.797
SUBTOTAL		92.149	5.113	96.184	-0.000	3.594

Subtotals for group : Crew and stores					
Crew and stores	15.000	14.000	75.000	0.000	0.000
SUBTOTAL	15.000	14.000	75.000	0.000	0.000
Subtotals for group : Deck load					
Deckload	600.000	9.000	23.000	0.000	0.000
SUBTOTAL	600.000	9.000	23.000	0.000	0.000
TOTAL	**6226.818**	**7.346**	**52.184**	**-0.000**	**998.475**

Hydrostatics		Drafts and trim	
Volume	6075.012 m^3	Drafts above base :	
LCF	45.219 m	Draft mean (Lpp/2)	5.983 m
Mom. change trim	127.416 tonm/cm	Draft aft (App)	5.991 m
Ton/cm immersion	17.544 ton/cm	Draft fore (Fpp)	5.975 m
Specific weight	1.025 ton/m^3	Trim	-0.017 m

Transverse stability			
KM transverse	10.523 m		
VCG	7.346 m		
GM solid	3.177 m		
GG' correction	0.160 m		
G'M liquid	3.017 m	VCG'	7.506 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	5.983	-0.017	0.000	0.000	0.000	-0.000	0.000
2.00	5.982	-0.014	0.367	0.262	0.000	0.105	0.002
5.00	5.974	0.002	0.914	0.654	0.000	0.260	0.011
10.00	5.942	0.083	1.801	1.303	0.000	0.497	0.045
15.00	5.886	0.215	2.636	1.943	0.000	0.693	0.097
20.00	5.823	0.244	3.368	2.567	0.000	0.801	0.163
25.00	5.744	0.187	4.034	3.172	0.000	0.862	0.236
30.00	5.639	0.076	4.656	3.753	0.000	0.903	0.313
35.00	5.495	-0.072	5.245	4.306	0.000	0.940	0.393
40.00	5.297	-0.248	5.811	4.825	0.000	0.986	0.477
50.00	4.725	-0.740	6.780	5.750	0.000	1.030	0.655
60.00	3.894	-1.552	7.391	6.501	0.000	0.891	0.826

Statical angle of inclination is 0.000 degrees to starboard
Contour : FIRM

Opening	is submerged at [degrees]
ER Vent in	55.42

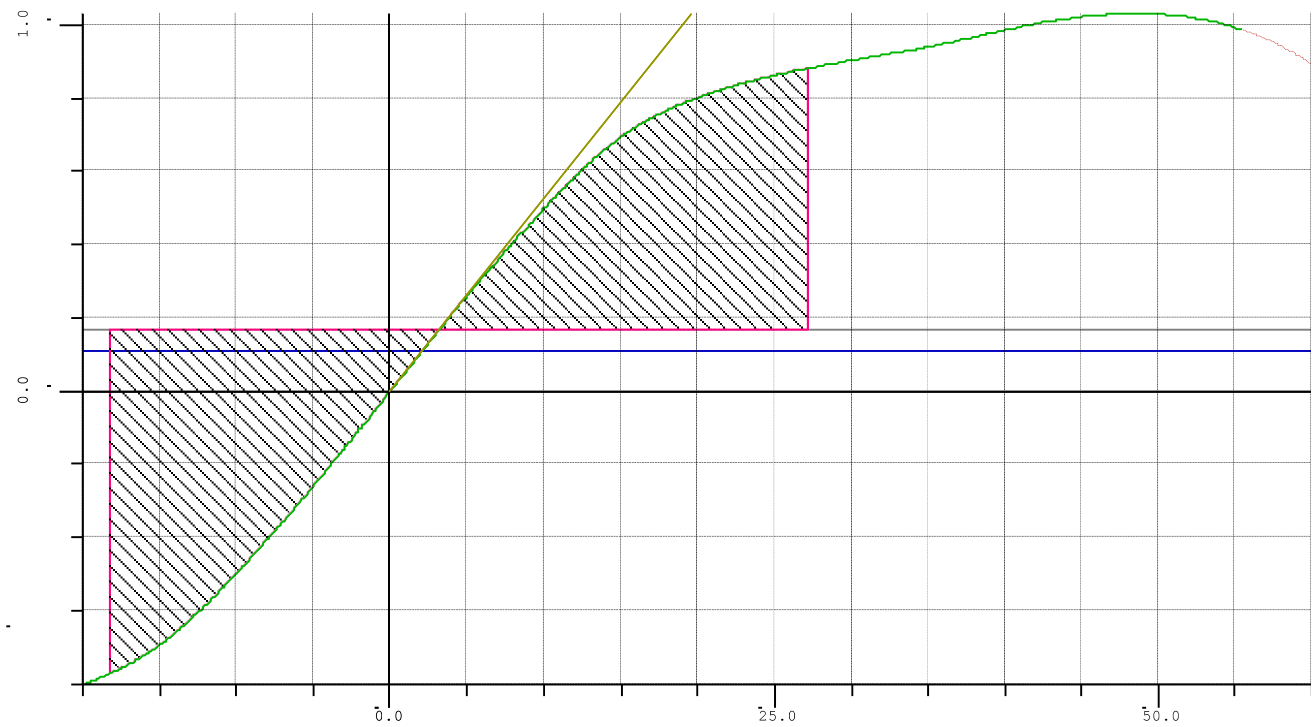
Summary

Hydrostatics		Criterion	Value
Draft mld.		6.000	5.983 m
Trim	-0.017 m		
Statical angle of inclination	0.00 degrees SB		
Flooding angle	55.42 degrees		

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	3.017 meter
Maximum GZ at 30 degrees or more	0.200	1.032 meter
Top of the GZ curve at least at	15.000	48.583 degrees
Area under the GZ curve up to 30 degrees	0.055	0.313 mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.164 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	27.225 degrees
Maximum statical angle due to wind	13.288	2.097 degrees
Maximum statical angle 80% of angle of deck immersion	10.029	2.097 degrees

VCG'	
Actual	7.506 m
Maximum allowable	8.611 m

Loading condition complies with the stated criteria.



Angle of inclination in degrees 1/4.92

TRIM AND STABILITY CALCULATION
FIRM

11 Jun 2013 14:46:43

Condition : 3.2 Arrival 600t deckload

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm
Empty ship		4674.000	7.810	52.200	0.000	0.000
Subtotals for group : Ballast water						
BW FP	152-fwd	127.243	7.159	108.790	0.000	0.000
BW DB CT	133-142	45.273	1.509	95.456	0.000	0.000
BW DB SB	124-133	36.607	1.528	89.832	1.339	0.000
BW DB PS	124-133	36.607	1.528	89.832	-1.339	0.000
BW WT SB	124-133	52.429	5.251	89.930	3.944	0.000
BW WT PS	124-133	52.429	5.251	89.930	-3.944	0.000
BW DB SB	112-124	61.737	1.542	82.434	1.718	0.000
BW DB PS	112-124	61.737	1.542	82.434	-1.718	0.000
BW WT SB	112-124	0.000	2.500	82.667	4.083	0.000
BW WT PS	112-124	0.000	2.500	82.667	-4.083	0.000
BW DB SB	100-112	0.000	-0.000	74.228	0.150	0.000
BW DB PS	100-112	0.000	-0.000	74.228	-0.150	0.000
BW WT SB	100-112	0.000	2.500	73.745	4.922	0.000
BW WT PS	100-112	0.000	2.500	73.745	-4.922	0.000
BW DB SB	88-100	0.000	-0.000	66.838	0.124	0.000
BW DB PS	88-100	0.000	-0.000	66.838	-0.124	0.000
BW WT SB	88-100	0.000	2.500	65.590	5.297	0.000
BW WT PS	88-100	0.000	2.500	65.590	-5.297	0.000
BW DB SB	73-88	0.000	0.006	60.835	0.073	0.000
BW DB PS	73-88	0.000	0.006	60.835	-0.073	0.000
BW WT SB	73-88	0.000	2.500	55.809	6.620	0.000
BW WT PS	73-88	0.000	2.500	55.809	-6.620	0.000
BW DB SB	61-73	0.000	0.084	50.888	0.053	0.000
BW DB PS	61-73	0.000	0.084	50.888	-0.053	0.000
BW WT SB	61-73	0.000	2.500	46.960	6.681	0.000
BW WT PS	61-73	0.000	2.500	46.960	-6.681	0.000
BW DB SB	49-61	0.000	0.241	42.533	0.040	0.000
BW DB PS	49-61	0.000	0.241	42.533	-0.040	0.000
BW WT SB	49-61	0.000	2.500	38.976	6.584	0.000
BW WT PS	49-61	0.000	2.500	38.976	-6.584	0.000
BW SB	4-19	0.000	5.250	8.706	7.765	0.000
BW PS	4-19	0.000	5.250	8.706	-7.765	0.000
SUBTOTAL		474.063	3.865	93.552	-0.000	0.000
Subtotals for group : Fuel oil						
FO CT	124-133	7.274	2.637	89.765	0.000	59.115
FO CT	112-124	13.691	2.638	82.367	0.000	221.055
FO CT	100-112	15.973	2.638	74.200	0.000	341.540
FO CT	88-100	15.973	2.637	65.800	0.000	341.540
FO SB	4-19	6.656	5.387	8.050	5.600	15.812
FO PS	4-19	6.656	5.387	8.050	-5.600	15.812
SUBTOTAL		66.223	3.190	62.275	-0.000	994.875
Subtotals for group : Fresh water						
FW WT SB	133-142	4.701	2.816	96.292	2.181	1.999
FW WT PS	133-142	4.701	2.816	96.292	-2.181	1.999
SUBTOTAL		9.403	2.816	96.292	0.000	3.997

Subtotals for group : Crew and stores

Crew and stores	15.000	14.000	75.000	0.000	0.000
SUBTOTAL	15.000	14.000	75.000	0.000	0.000

Subtotals for group : Deck load

Deckload	600.000	9.000	23.000	0.000	0.000
SUBTOTAL	600.000	9.000	23.000	0.000	0.000

TOTAL	**5838.688**	**7.567**	**52.801**	**-0.000**	**998.872**

Hydrostatics

Volume	5696.363	m^3
LCF	45.279	m
Mom. change trim	124.970	tonm/cm
Ton/cm immersion	17.348	ton/cm
Specific weight	1.025	ton/m^3

Drafts and trim

Drafts above base :

Draft mean (Lpp/2)	5.768	m
Draft aft (App)	5.741	m
Draft fore (Fpp)	5.796	m
Trim	0.055	m

Transverse stability

KM transverse	10.618	m
VCG	7.567	m
GM solid	3.051	m
GG' correction	0.171	m
G'M liquid	2.879	m

VCG'	7.739	m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB)	Draft mld.	Trim	KNsinφ	VCG'sinφ	TCGcosφ	G'Nsinφ	Area
degrees	m	m	m	m	m	m	mrad
0.00	5.768	0.055	0.000	0.000	-0.000	0.000	0.000
2.00	5.767	0.060	0.370	0.270	-0.000	0.100	0.002
5.00	5.757	0.089	0.919	0.674	-0.000	0.245	0.011
10.00	5.722	0.205	1.805	1.344	-0.000	0.461	0.042
15.00	5.657	0.397	2.648	2.003	-0.000	0.645	0.090
20.00	5.574	0.550	3.403	2.647	-0.000	0.756	0.152
25.00	5.474	0.613	4.079	3.270	-0.000	0.808	0.221
30.00	5.345	0.622	4.702	3.869	-0.000	0.833	0.292
35.00	5.175	0.597	5.287	4.439	-0.000	0.848	0.366
40.00	4.948	0.552	5.843	4.974	-0.000	0.869	0.441
50.00	4.270	0.400	6.832	5.928	-0.000	0.904	0.596
60.00	3.254	0.095	7.467	6.702	-0.000	0.765	0.746

Statical angle of inclination is 0.000 degrees to starboard

Contour : FIRM

Opening	is submerged at [degrees]
ER Vent in	57.29

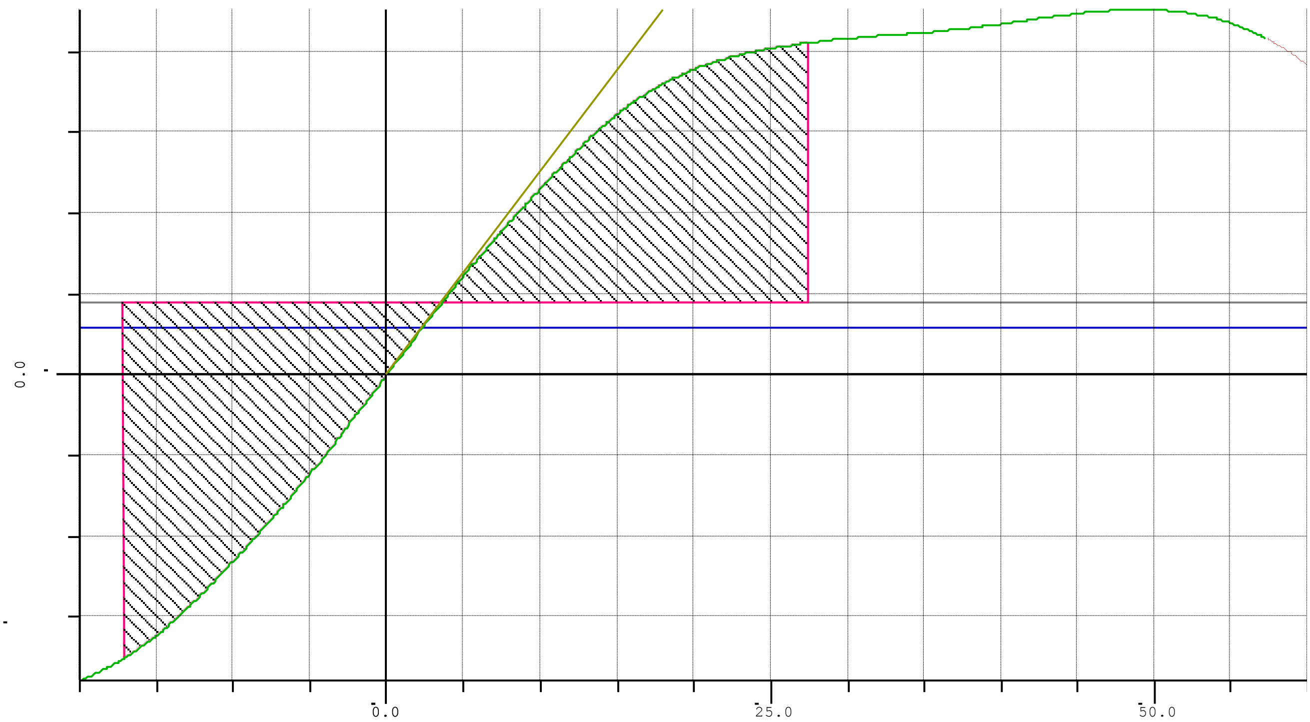
Summary

Hydrostatics		Criterion	Value
Draft mld.		6.000	5.768 m
Trim	0.055 m		
Statical angle of inclination	0.00 degrees SB		
Flooding angle	57.29 degrees		

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	2.879 meter
Maximum GZ at 30 degrees or more	0.200	0.905 meter
Top of the GZ curve at least at	15.000	49.012 degrees
Area under the GZ curve up to 30 degrees	0.055	0.292 mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.148 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	27.421 degrees
Maximum statical angle due to wind	15.055	2.373 degrees
Maximum statical angle 80% of angle of deck immersion	11.334	2.373 degrees

VCG'	
Actual	7.739 m
Maximum allowable	8.667 m

Loading condition complies with the stated criteria.



Angle of inclination in degrees 1/4.92

TRIM AND STABILITY CALCULATION
FIRM

11 Jun 2013 14:47:08

Condition : 4.1 Crane operation 100t@15m 100% consumables

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm
Empty ship		4674.000	7.810	52.200	0.000	0.000
Subtotals for group : Ballast water						
BW FP	152-fwd	0.000	0.006	106.845	0.000	0.000
BW DB CT	133-142	45.273	1.509	95.456	0.000	0.000
BW DB SB	124-133	0.000	-0.000	89.873	0.115	0.000
BW DB PS	124-133	0.000	-0.000	89.873	-0.115	0.000
BW WT SB	124-133	0.000	2.500	89.957	3.058	0.000
BW WT PS	124-133	0.000	2.500	89.957	-3.058	0.000
BW DB SB	112-124	0.000	-0.000	82.488	0.133	0.000
BW DB PS	112-124	0.000	-0.000	82.488	-0.133	0.000
BW WT SB	112-124	0.000	2.500	82.667	4.083	0.000
BW WT PS	112-124	0.000	2.500	82.667	-4.083	0.000
BW DB SB	100-112	0.000	-0.000	74.228	0.150	0.000
BW DB PS	100-112	0.000	-0.000	74.228	-0.150	0.000
BW WT SB	100-112	0.000	2.500	73.745	4.922	0.000
BW WT PS	100-112	0.000	2.500	73.745	-4.922	0.000
BW DB SB	88-100	0.000	-0.000	66.838	0.124	0.000
BW DB PS	88-100	0.000	-0.000	66.838	-0.124	0.000
BW WT SB	88-100	0.000	2.500	65.590	5.297	0.000
BW WT PS	88-100	0.000	2.500	65.590	-5.297	0.000
BW DB SB	73-88	0.000	0.006	60.835	0.073	0.000
BW DB PS	73-88	0.000	0.006	60.835	-0.073	0.000
BW WT SB	73-88	89.737	5.290	56.126	7.765	0.000
BW WT PS	73-88	0.000	2.500	55.809	-6.620	0.000
BW DB SB	61-73	58.063	1.276	46.999	2.283	171.101
BW DB PS	61-73	0.000	0.084	50.888	-0.053	0.000
BW WT SB	61-73	81.731	5.256	46.871	7.863	0.000
BW WT PS	61-73	0.000	2.500	46.960	-6.681	0.000
BW DB SB	49-61	0.000	0.241	42.533	0.040	0.000
BW DB PS	49-61	0.000	0.241	42.533	-0.040	0.000
BW WT SB	49-61	82.189	5.298	38.518	7.892	0.000
BW WT PS	49-61	0.000	2.500	38.976	-6.584	0.000
BW SB	4-19	65.043	6.711	8.106	8.139	0.000
BW PS	4-19	0.000	5.250	8.706	-7.765	0.000
SUBTOTAL		422.037	4.546	46.467	6.279	171.101
Subtotals for group : Fuel oil						
FO CT	124-133	71.281	3.847	89.765	0.000	59.115
FO CT	112-124	134.176	3.847	82.367	0.000	221.059
FO CT	100-112	156.539	3.847	74.200	0.000	341.541
FO CT	88-100	156.539	3.847	65.800	0.000	341.541
FO SB	4-19	65.224	6.597	8.050	5.600	15.812
FO PS	4-19	65.224	6.597	8.050	-5.600	15.812
SUBTOTAL		648.982	4.400	62.275	0.000	994.881
Subtotals for group : Fresh water						
FW WT SB	133-142	46.074	5.113	96.184	2.851	1.797
FW WT PS	133-142	46.074	5.113	96.184	-2.851	1.797
SUBTOTAL		92.149	5.113	96.184	-0.000	3.594

Subtotals for group : Crew and stores

Crew and stores	15.000	14.000	75.000	0.000	0.000
SUBTOTAL	15.000	14.000	75.000	0.000	0.000

Subtotals for group : Deck load

Deckload 250t	250.000	9.000	23.000	0.000	0.000
SUBTOTAL	250.000	9.000	23.000	0.000	0.000

Subtotals for group : Crane

Crane load 100t	100.000	27.000	20.000	-20.500	0.000
Crane boom	50.000	25.000	20.000	-12.000	0.000
SUBTOTAL	150.000	26.333	20.000	-17.667	0.000
TOTAL	**6252.168**	**7.703**	**51.622**	**0.000**	**1169.575**

Hydrostatics

Volume	6099.719	m^3
LCF	45.096	m
Mom. change trim	127.400	tonm/cm
Ton/cm immersion	17.544	ton/cm
Specific weight	1.025	ton/m^3

Drafts and trim

Drafts above base :

Draft mean (Lpp/2)	5.969	m
Draft aft (App)	6.109	m
Draft fore (Fpp)	5.830	m
Trim	-0.279	m

Transverse stability

KM transverse	10.534	m
VCG	7.703	m
GM solid	2.831	m
GG' correction	0.187	m
G'M liquid	2.644	m

VCG' 7.890 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	5.969	-0.279	0.000	0.000	0.000	-0.000	0.000
2.00	5.968	-0.277	0.367	0.275	0.000	0.092	0.002
5.00	5.960	-0.265	0.916	0.688	0.000	0.228	0.010
10.00	5.930	-0.197	1.806	1.370	0.000	0.436	0.039
15.00	5.878	-0.097	2.638	2.042	0.000	0.596	0.085
20.00	5.820	-0.115	3.363	2.699	0.000	0.665	0.140
25.00	5.746	-0.217	4.026	3.334	0.000	0.691	0.200
30.00	5.647	-0.374	4.646	3.945	0.000	0.701	0.260
35.00	5.509	-0.570	5.235	4.525	0.000	0.710	0.322
40.00	5.317	-0.798	5.801	5.072	0.000	0.730	0.385
50.00	4.762	-1.429	6.768	6.044	0.000	0.724	0.513
60.00	3.957	-2.464	7.379	6.833	0.000	0.546	0.627

Statical angle of inclination is 0.000 degrees to starboard

Contour : FIRM

Opening	is submerged at [degrees]
ER Vent in	55.09

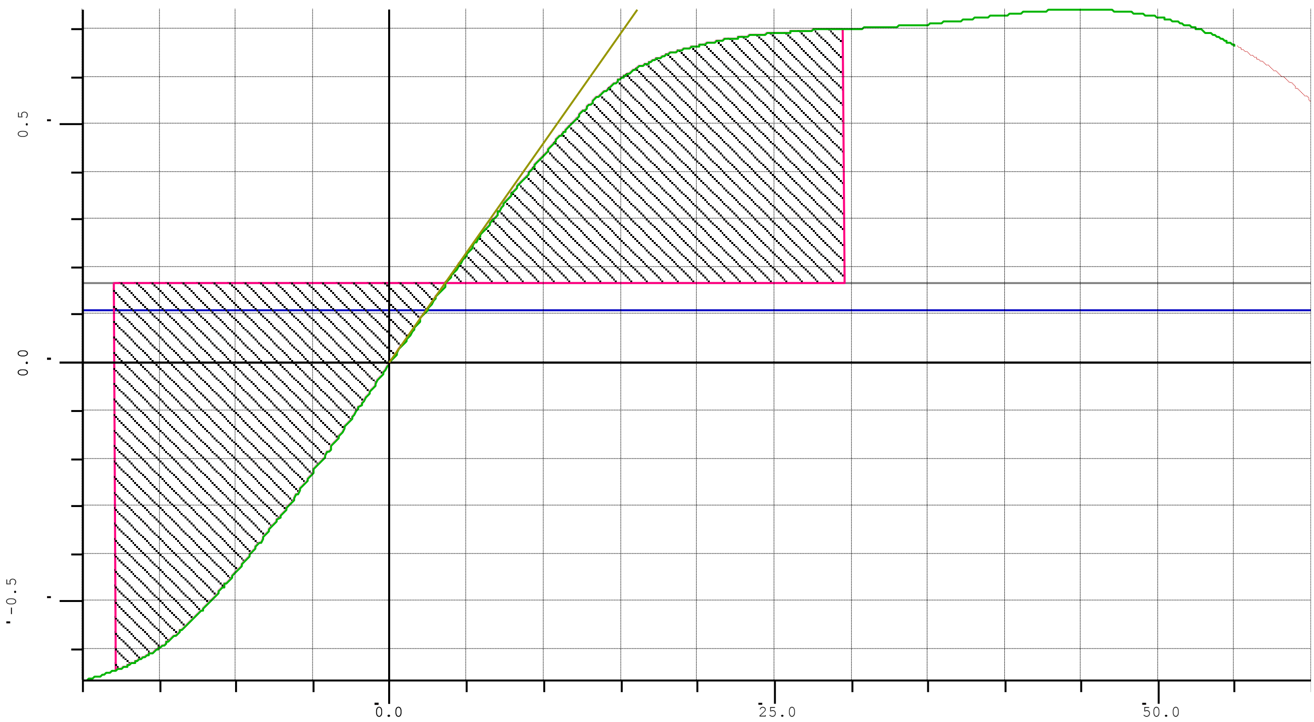
Summary

Hydrostatics		Criterion	Value
Draft mld.		6.000	5.969 m
Trim	-0.279 m		
Statical angle of inclination	0.00 degrees SB		
Flooding angle	55.09 degrees		

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	2.644 meter
Maximum GZ at 30 degrees or more	0.200	0.741 meter
Top of the GZ curve at least at	15.000	44.956 degrees
Area under the GZ curve up to 30 degrees	0.055	0.260 mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.124 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	29.537 degrees
Maximum statical angle due to wind	12.666	2.405 degrees
Maximum statical angle 80% of angle of deck immersion	9.546	2.405 degrees

VCG'	
Actual	7.890 m
Maximum allowable	8.585 m

Loading condition complies with the stated criteria.



TRIM AND STABILITY CALCULATION
FIRM

11 Jun 2013 14:47:32

Condition : 4.2 Crane operation 100t@15m 10% consumables

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm
Empty ship		4674.000	7.810	52.200	0.000	0.000
Subtotals for group : Ballast water						
BW FP	152-fwd	0.000	0.006	106.845	0.000	0.000
BW DB CT	133-142	45.273	1.509	95.456	0.000	0.000
BW DB SB	124-133	36.607	1.528	89.832	1.339	0.000
BW DB PS	124-133	36.607	1.528	89.832	-1.339	0.000
BW WT SB	124-133	52.429	5.251	89.930	3.944	0.000
BW WT PS	124-133	52.429	5.251	89.930	-3.944	0.000
BW DB SB	112-124	61.737	1.542	82.434	1.718	0.000
BW DB PS	112-124	61.737	1.542	82.434	-1.718	0.000
BW WT SB	112-124	0.000	2.500	82.667	4.083	0.000
BW WT PS	112-124	0.000	2.500	82.667	-4.083	0.000
BW DB SB	100-112	0.000	-0.000	74.228	0.150	0.000
BW DB PS	100-112	0.000	-0.000	74.228	-0.150	0.000
BW WT SB	100-112	0.000	2.500	73.745	4.922	0.000
BW WT PS	100-112	0.000	2.500	73.745	-4.922	0.000
BW DB SB	88-100	0.000	-0.000	66.838	0.124	0.000
BW DB PS	88-100	0.000	-0.000	66.838	-0.124	0.000
BW WT SB	88-100	0.000	2.500	65.590	5.297	0.000
BW WT PS	88-100	0.000	2.500	65.590	-5.297	0.000
BW DB SB	73-88	0.000	0.006	60.835	0.073	0.000
BW DB PS	73-88	0.000	0.006	60.835	-0.073	0.000
BW WT SB	73-88	89.737	5.290	56.126	7.765	0.000
BW WT PS	73-88	0.000	2.500	55.809	-6.620	0.000
BW DB SB	61-73	58.063	1.276	46.999	2.283	171.101
BW DB PS	61-73	0.000	0.084	50.888	-0.053	0.000
BW WT SB	61-73	81.731	5.256	46.871	7.863	0.000
BW WT PS	61-73	0.000	2.500	46.960	-6.681	0.000
BW DB SB	49-61	0.000	0.241	42.533	0.040	0.000
BW DB PS	49-61	0.000	0.241	42.533	-0.040	0.000
BW WT SB	49-61	82.189	5.298	38.518	7.892	0.000
BW WT PS	49-61	0.000	2.500	38.976	-6.584	0.000
BW SB	4-19	65.043	6.711	8.106	8.139	0.000
BW PS	4-19	0.000	5.250	8.706	-7.765	0.000
SUBTOTAL		723.584	3.830	63.291	3.662	171.101
Subtotals for group : Fuel oil						
FO CT	124-133	7.274	2.637	89.765	0.000	59.115
FO CT	112-124	13.691	2.638	82.367	0.000	221.055
FO CT	100-112	15.973	2.638	74.200	0.000	341.540
FO CT	88-100	15.973	2.637	65.800	0.000	341.540
FO SB	4-19	6.656	5.387	8.050	5.600	15.812
FO PS	4-19	6.656	5.387	8.050	-5.600	15.812
SUBTOTAL		66.223	3.190	62.275	-0.000	994.875
Subtotals for group : Fresh water						
FW WT SB	133-142	4.701	2.816	96.292	2.181	1.999
FW WT PS	133-142	4.701	2.816	96.292	-2.181	1.999
SUBTOTAL		9.403	2.816	96.292	0.000	3.997

Subtotals for group : Crew and stores

Crew and stores	15.000	14.000	75.000	0.000	0.000
SUBTOTAL	15.000	14.000	75.000	0.000	0.000

Subtotals for group : Deck load

Deckload 250t	250.000	9.000	23.000	0.000	0.000
SUBTOTAL	250.000	9.000	23.000	0.000	0.000

Subtotals for group : Crane

Crane load 100t	100.000	27.000	20.000	-20.500	0.000
Crane boom	50.000	25.000	20.000	-12.000	0.000
SUBTOTAL	150.000	26.333	20.000	-17.667	0.000

TOTAL	**5888.209**	**7.799**	**51.745**	**0.000**	**1169.973**

Hydrostatics

Volume	5744.709	m^3
LCF	44.994	m
Mom. change trim	125.351	tonm/cm
Ton/cm immersion	17.379	ton/cm
Specific weight	1.025	ton/m^3

Drafts and trim

Drafts above base :

Draft mean (Lpp/2)	5.747	m
Draft aft (App)	5.952	m
Draft fore (Fpp)	5.541	m
Trim	-0.411	m

Transverse stability

KM transverse	10.655	m
VCG	7.799	m
GM solid	2.856	m
GG' correction	0.199	m
G'M liquid	2.657	m

VCG' 7.998 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	5.747	-0.411	0.000	0.000	0.000	-0.000	0.000
2.00	5.745	-0.409	0.372	0.279	0.000	0.093	0.002
5.00	5.737	-0.390	0.924	0.697	0.000	0.227	0.010
10.00	5.703	-0.301	1.818	1.389	0.000	0.429	0.039
15.00	5.642	-0.146	2.663	2.070	0.000	0.593	0.084
20.00	5.569	-0.076	3.404	2.735	0.000	0.668	0.140
25.00	5.479	-0.093	4.071	3.380	0.000	0.691	0.199
30.00	5.361	-0.167	4.691	3.999	0.000	0.692	0.260
35.00	5.201	-0.278	5.274	4.587	0.000	0.687	0.320
40.00	4.985	-0.416	5.831	5.141	0.000	0.690	0.380
50.00	4.338	-0.813	6.816	6.127	0.000	0.689	0.501
60.00	3.369	-1.513	7.447	6.926	0.000	0.520	0.610

Statical angle of inclination is 0.000 degrees to starboard

Contour : FIRM

Opening	is submerged at [degrees]
ER Vent in	56.69

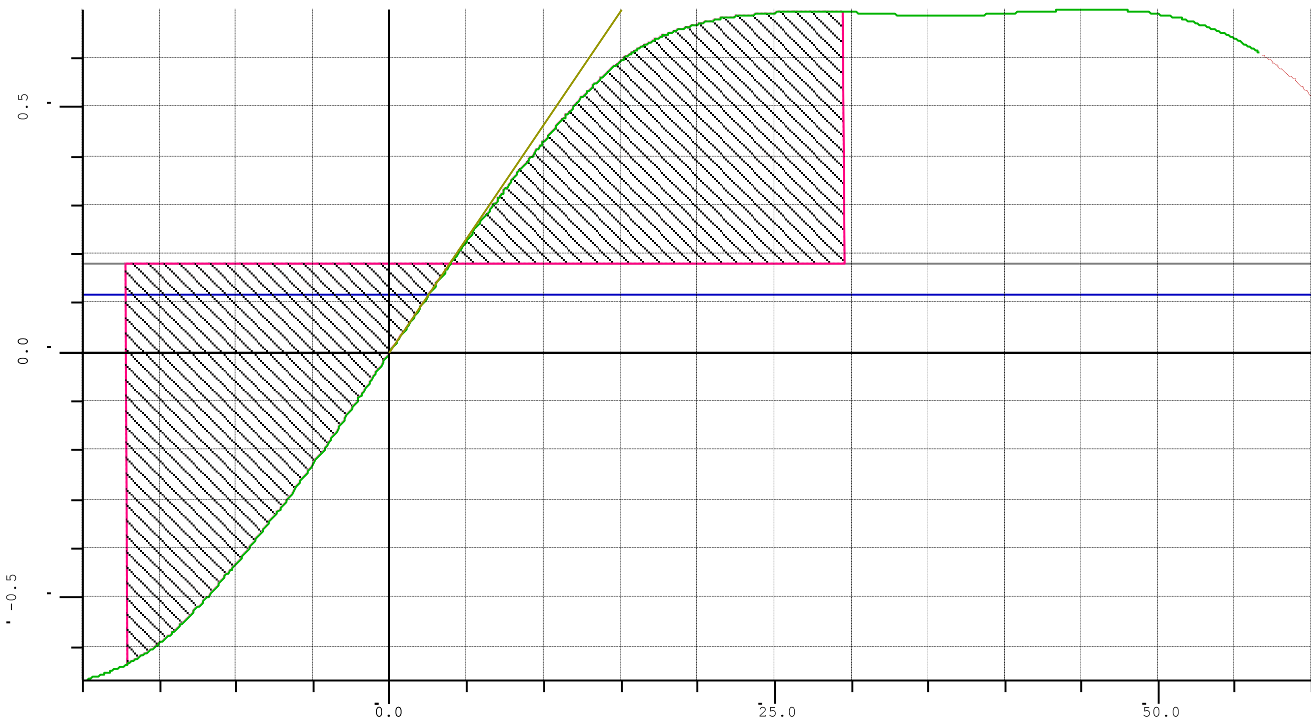
Summary

Hydrostatics		Criterion	Value
Draft mld.		6.000	5.747 m
Trim	-0.411 m		
Statical angle of inclination	0.00 degrees SB		
Flooding angle	56.69 degrees		

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	2.657 meter
Maximum GZ at 30 degrees or more	0.200	0.698 meter
Top of the GZ curve at least at	15.000	45.880 degrees
Area under the GZ curve up to 30 degrees	0.055	0.260 mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.120 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	29.493 degrees
Maximum statical angle due to wind	14.050	2.585 degrees
Maximum statical angle 80% of angle of deck immersion	10.560	2.585 degrees

VCG'	
Actual	7.998 m
Maximum allowable	8.631 m

Loading condition complies with the stated criteria.



Angle of inclination in degrees 1/4.92

VII Loss of load calculation mono-hull

TRIM AND STABILITY CALCULATION

FIRM

11 Jun 2013 14:48:43

Condition : 5.1 Crane operation 100t@15m 100% consumables LOL Calc

Description		Weight	VCG	LCG	TCG	FSM
		ton	m	m	m	tonm
Empty ship		4674.000	7.810	52.200	0.000	0.000
Subtotals for group : Ballast water						
BW FP	152-fwd	0.000	0.006	106.845	0.000	0.000
BW DB CT	133-142	45.273	1.509	95.456	0.000	0.000
BW DB SB	124-133	0.000	-0.000	89.873	0.115	0.000
BW DB PS	124-133	0.000	-0.000	89.873	-0.115	0.000
BW WT SB	124-133	0.000	2.500	89.957	3.058	0.000
BW WT PS	124-133	0.000	2.500	89.957	-3.058	0.000
BW DB SB	112-124	0.000	-0.000	82.488	0.133	0.000
BW DB PS	112-124	0.000	-0.000	82.488	-0.133	0.000
BW WT SB	112-124	0.000	2.500	82.667	4.083	0.000
BW WT PS	112-124	0.000	2.500	82.667	-4.083	0.000
BW DB SB	100-112	0.000	-0.000	74.228	0.150	0.000
BW DB PS	100-112	0.000	-0.000	74.228	-0.150	0.000
BW WT SB	100-112	0.000	2.500	73.745	4.922	0.000
BW WT PS	100-112	0.000	2.500	73.745	-4.922	0.000
BW DB SB	88-100	0.000	-0.000	66.838	0.124	0.000
BW DB PS	88-100	0.000	-0.000	66.838	-0.124	0.000
BW WT SB	88-100	0.000	2.500	65.590	5.297	0.000
BW WT PS	88-100	0.000	2.500	65.590	-5.297	0.000
BW DB SB	73-88	0.000	0.006	60.835	0.073	0.000
BW DB PS	73-88	0.000	0.006	60.835	-0.073	0.000
BW WT SB	73-88	0.000	2.500	55.809	6.620	0.000
BW WT PS	73-88	0.000	2.500	55.809	-6.620	0.000
BW DB SB	61-73	0.000	0.084	50.888	0.053	0.000
BW DB PS	61-73	0.000	0.084	50.888	-0.053	0.000
BW WT SB	61-73	0.000	2.500	46.960	6.681	0.000
BW WT PS	61-73	0.000	2.500	46.960	-6.681	0.000
BW DB SB	49-61	0.000	0.241	42.533	0.040	0.000
BW DB PS	49-61	0.000	0.241	42.533	-0.040	0.000
BW WT SB	49-61	0.000	2.500	38.976	6.584	0.000
BW WT PS	49-61	0.000	2.500	38.976	-6.584	0.000
BW SB	4-19	0.000	5.250	8.706	7.765	0.000
BW PS	4-19	0.000	5.250	8.706	-7.765	0.000
SUBTOTAL		45.273	1.509	95.455	0.000	0.000
Subtotals for group : Fuel oil						
FO CT	124-133	71.281	3.847	89.765	0.000	59.115
FO CT	112-124	134.176	3.847	82.367	0.000	221.059
FO CT	100-112	156.539	3.847	74.200	0.000	341.541
FO CT	88-100	156.539	3.847	65.800	0.000	341.541
FO SB	4-19	65.224	6.597	8.050	5.600	15.812
FO PS	4-19	65.224	6.597	8.050	-5.600	15.812
SUBTOTAL		648.982	4.400	62.275	0.000	994.881
Subtotals for group : Fresh water						
FW WT SB	133-142	46.074	5.113	96.184	2.851	1.797
FW WT PS	133-142	46.074	5.113	96.184	-2.851	1.797
SUBTOTAL		92.149	5.113	96.184	-0.000	3.594

Subtotals for group : Crew and stores					
Crew and stores	15.000	14.000	75.000	0.000	0.000
SUBTOTAL	15.000	14.000	75.000	0.000	0.000
Subtotals for group : Deck load					
Deckload 250t	250.000	9.000	23.000	0.000	0.000
SUBTOTAL	250.000	9.000	23.000	0.000	0.000
Subtotals for group : Crane					
Crane boom	50.000	25.000	20.000	-12.000	0.000
SUBTOTAL	50.000	25.000	20.000	-12.000	0.000
TOTAL	**5775.404**	**7.551**	**52.889**	**-0.104**	**998.475**

Hydrostatics		Drafts and trim	
Volume	5634.659 m^3	Drafts above base :	
LCF	45.271 m	Draft mean (Lpp/2)	5.732 m
Mom. change trim	124.475 tonm/cm	Draft aft (App)	5.703 m
Ton/cm immersion	17.314 ton/cm	Draft fore (Fpp)	5.761 m
Specific weight	1.025 ton/m^3	Trim	0.058 m

Transverse stability			
KM transverse	10.632 m		
VCG	7.551 m		
GM solid	3.081 m		
GG' correction	0.173 m		
G'M liquid	2.908 m	VCG'	7.724 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(PS) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	5.732	0.058	0.000	0.000	0.104	-0.104	0.000
2.00	5.730	0.063	0.371	0.270	0.104	-0.003	0.000
5.00	5.721	0.094	0.920	0.673	0.103	0.143	0.004
10.00	5.684	0.216	1.805	1.341	0.102	0.362	0.026
15.00	5.618	0.414	2.648	1.999	0.100	0.549	0.066
20.00	5.532	0.587	3.408	2.642	0.098	0.668	0.120
25.00	5.429	0.672	4.085	3.264	0.094	0.727	0.181
30.00	5.297	0.696	4.709	3.862	0.090	0.757	0.246
35.00	5.123	0.690	5.293	4.430	0.085	0.777	0.313
40.00	4.891	0.665	5.848	4.965	0.080	0.804	0.382
50.00	4.196	0.564	6.840	5.917	0.067	0.856	0.527
60.00	3.151	0.335	7.479	6.689	0.052	0.738	0.671

Statical angle of inclination is 2.056 degrees to portside

Opening	is submerged at [degrees]
ER Vent out	57.59

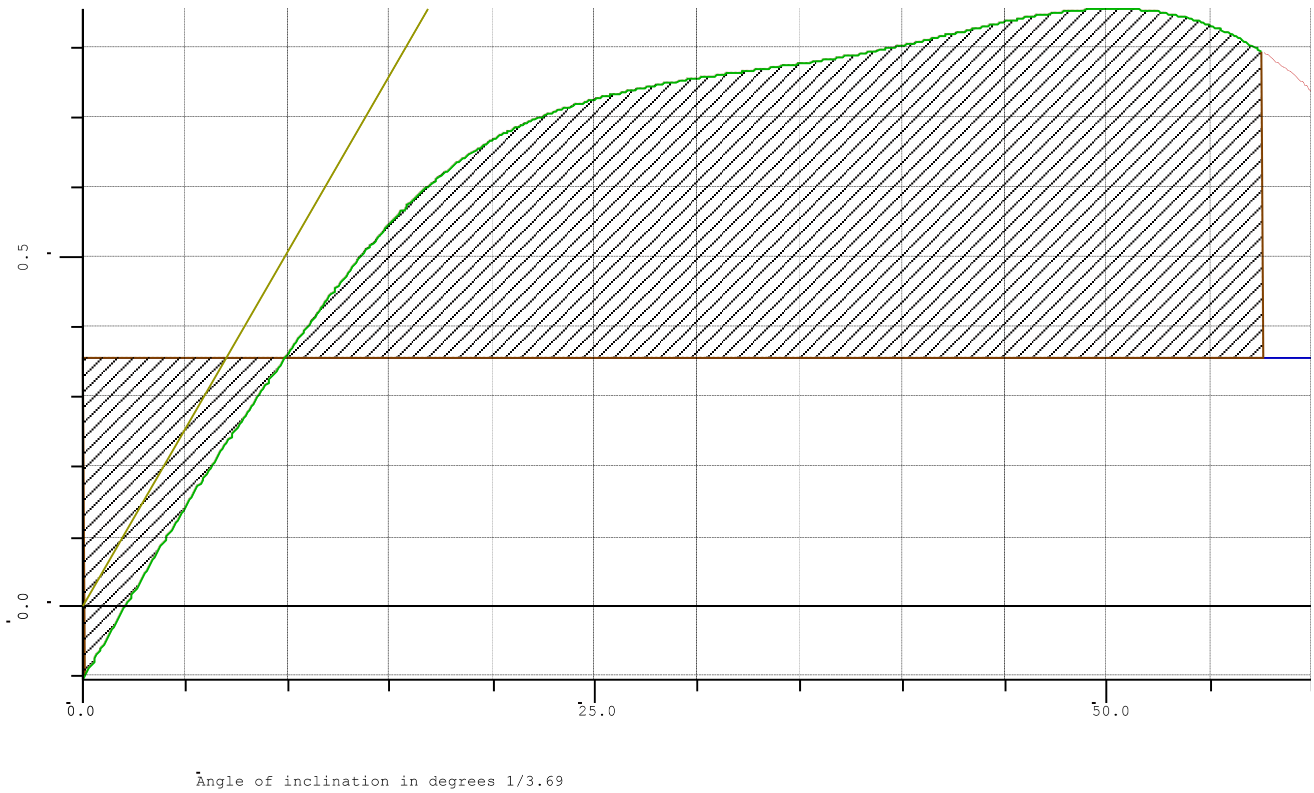
Summary

Hydrostatics		Criterion	Value
Draft mld.		6.000	5.732 m
Trim	0.058 m		
Statical angle of inclination	2.06 degrees PS		
Flooding angle	57.59 degrees		

DNV loss load	Criterion	Value
DNV Loss of Load (Pt. 5 Ch. 7 Sec 17 D) Area A2> 1,4 A1	1.400	8.382 -
DNV Loss of Load, angle max 15 degrees	15.000	5.743 degrees

VCG'

A non-zero statical angle of equilibrium occurs,
No maximum allowable VCG' is calculated.
Loading condition complies with the stated criteria.



TRIM AND STABILITY CALCULATION
FIRM

11 Jun 2013 14:49:35

Condition : 5.2 Crane operation 100t@15m 10% consumables LOL Calc

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm
Empty ship		4674.000	7.810	52.200	0.000	0.000
Subtotals for group : Ballast water						
BW FP	152-fwd	0.000	0.006	106.845	0.000	0.000
BW DB CT	133-142	45.273	1.509	95.456	0.000	0.000
BW DB SB	124-133	36.607	1.528	89.832	1.339	0.000
BW DB PS	124-133	36.607	1.528	89.832	-1.339	0.000
BW WT SB	124-133	52.429	5.251	89.930	3.944	0.000
BW WT PS	124-133	52.429	5.251	89.930	-3.944	0.000
BW DB SB	112-124	61.737	1.542	82.434	1.718	0.000
BW DB PS	112-124	61.737	1.542	82.434	-1.718	0.000
BW WT SB	112-124	0.000	2.500	82.667	4.083	0.000
BW WT PS	112-124	0.000	2.500	82.667	-4.083	0.000
BW DB SB	100-112	0.000	-0.000	74.228	0.150	0.000
BW DB PS	100-112	0.000	-0.000	74.228	-0.150	0.000
BW WT SB	100-112	0.000	2.500	73.745	4.922	0.000
BW WT PS	100-112	0.000	2.500	73.745	-4.922	0.000
BW DB SB	88-100	0.000	-0.000	66.838	0.124	0.000
BW DB PS	88-100	0.000	-0.000	66.838	-0.124	0.000
BW WT SB	88-100	0.000	2.500	65.590	5.297	0.000
BW WT PS	88-100	0.000	2.500	65.590	-5.297	0.000
BW DB SB	73-88	0.000	0.006	60.835	0.073	0.000
BW DB PS	73-88	0.000	0.006	60.835	-0.073	0.000
BW WT SB	73-88	0.000	2.500	55.809	6.620	0.000
BW WT PS	73-88	0.000	2.500	55.809	-6.620	0.000
BW DB SB	61-73	0.000	0.084	50.888	0.053	0.000
BW DB PS	61-73	0.000	0.084	50.888	-0.053	0.000
BW WT SB	61-73	0.000	2.500	46.960	6.681	0.000
BW WT PS	61-73	0.000	2.500	46.960	-6.681	0.000
BW DB SB	49-61	0.000	0.241	42.533	0.040	0.000
BW DB PS	49-61	0.000	0.241	42.533	-0.040	0.000
BW WT SB	49-61	0.000	2.500	38.976	6.584	0.000
BW WT PS	49-61	0.000	2.500	38.976	-6.584	0.000
BW SB	4-19	0.000	5.250	8.706	7.765	0.000
BW PS	4-19	0.000	5.250	8.706	-7.765	0.000
SUBTOTAL		346.820	2.656	87.962	-0.000	0.000
Subtotals for group : Fuel oil						
FO CT	124-133	7.274	2.637	89.765	0.000	59.115
FO CT	112-124	13.691	2.638	82.367	0.000	221.055
FO CT	100-112	15.973	2.638	74.200	0.000	341.540
FO CT	88-100	15.973	2.637	65.800	0.000	341.540
FO SB	4-19	6.656	5.387	8.050	5.600	15.812
FO PS	4-19	6.656	5.387	8.050	-5.600	15.812
SUBTOTAL		66.223	3.190	62.275	-0.000	994.875
Subtotals for group : Fresh water						
FW WT SB	133-142	4.701	2.816	96.292	2.181	1.999
FW WT PS	133-142	4.701	2.816	96.292	-2.181	1.999
SUBTOTAL		9.403	2.816	96.292	0.000	3.997

Subtotals for group : Crew and stores					
Crew and stores	15.000	14.000	75.000	0.000	0.000
SUBTOTAL	15.000	14.000	75.000	0.000	0.000
Subtotals for group : Deck load					
Deckload 250t	250.000	9.000	23.000	0.000	0.000
SUBTOTAL	250.000	9.000	23.000	0.000	0.000
Subtotals for group : Crane					
Crane boom	50.000	25.000	20.000	-12.000	0.000
SUBTOTAL	50.000	25.000	20.000	-12.000	0.000
TOTAL	**5411.445**	**7.645**	**53.109**	**-0.111**	**998.872**

Hydrostatics		Drafts and trim	
Volume	5279.638 m^3	Drafts above base :	
LCF	45.309 m	Draft mean (Lpp/2)	5.507 m
Mom. change trim	121.204 tonm/cm	Draft aft (App)	5.542 m
Ton/cm immersion	17.090 ton/cm	Draft fore (Fpp)	5.472 m
Specific weight	1.025 ton/m^3	Trim	-0.070 m

Transverse stability			
KM transverse	10.720 m		
VCG	7.645 m		
GM solid	3.075 m		
GG' correction	0.185 m		
G'M liquid	2.890 m	VCG'	7.830 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(PS) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	5.507	-0.070	0.000	0.000	0.111	-0.111	0.000
2.00	5.505	-0.062	0.373	0.273	0.111	-0.011	0.000
5.00	5.494	-0.019	0.925	0.682	0.110	0.132	0.003
10.00	5.454	0.128	1.813	1.360	0.109	0.344	0.024
15.00	5.383	0.353	2.655	2.027	0.107	0.522	0.062
20.00	5.283	0.603	3.432	2.678	0.104	0.650	0.114
25.00	5.162	0.771	4.119	3.309	0.100	0.709	0.174
30.00	5.010	0.885	4.744	3.915	0.096	0.733	0.237
35.00	4.814	0.968	5.325	4.491	0.091	0.743	0.301
40.00	4.557	1.035	5.872	5.033	0.085	0.754	0.366
50.00	3.777	1.165	6.876	5.998	0.071	0.806	0.503
60.00	2.569	1.274	7.543	6.781	0.055	0.707	0.639

Statical angle of inclination is 2.217 degrees to portside

Opening	is submerged at [degrees]
ER Vent out	59.21

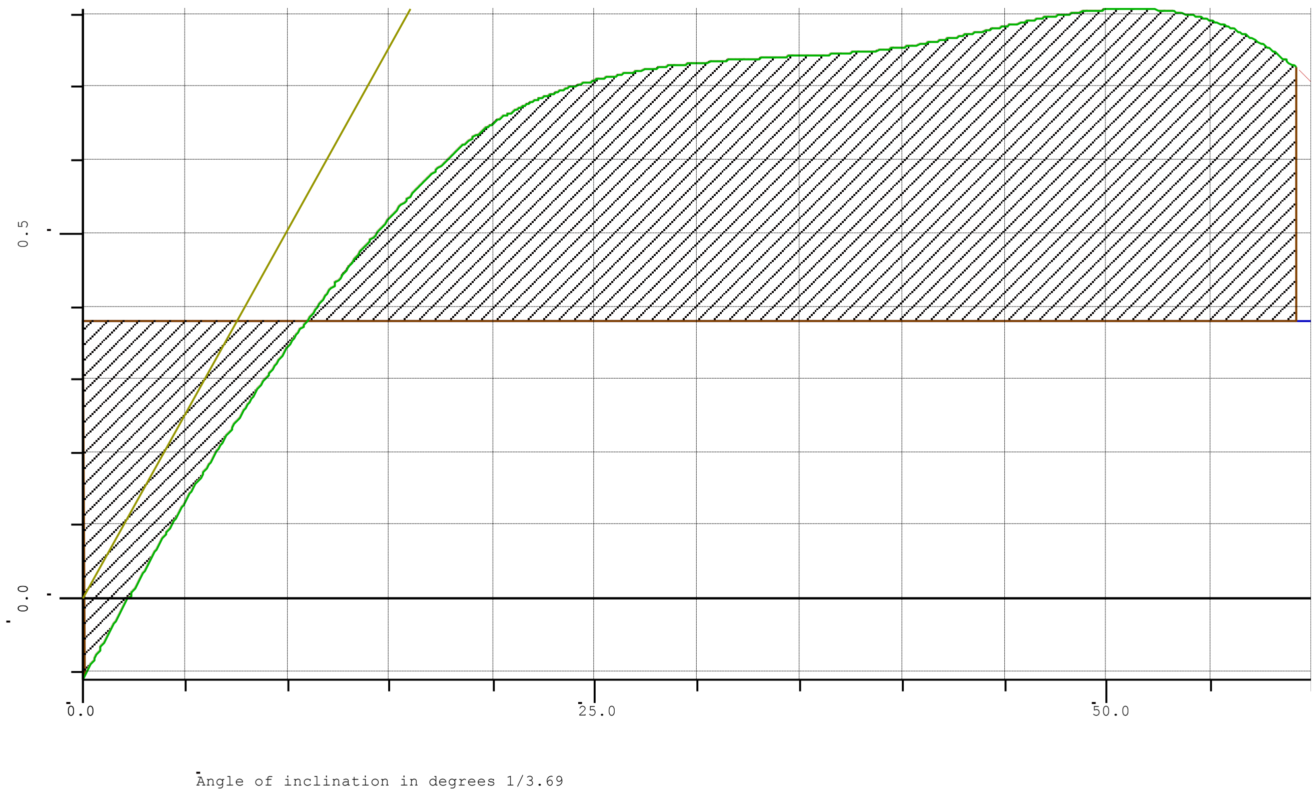
Summary

Hydrostatics		Criterion	Value
Draft mld.		6.000	5.507 m
Trim	-0.070 m		
Statical angle of inclination	2.22 degrees PS		
Flooding angle	59.21 degrees		

DNV loss load	Criterion	Value
DNV Loss of Load (Pt. 5 Ch. 7 Sec 17 D) Area A2> 1,4 A1	1.400	6.323 -
DNV Loss of Load, angle max 15 degrees	15.000	6.269 degrees

VCG'

A non-zero statical angle of equilibrium occurs,
No maximum allowable VCG' is calculated.
Loading condition complies with the stated criteria.



VIII Background information Strip Theory

A vessel sailing in waves has six degrees of freedom of and about the centre of gravity (CoG), as illustrated in the figure below.

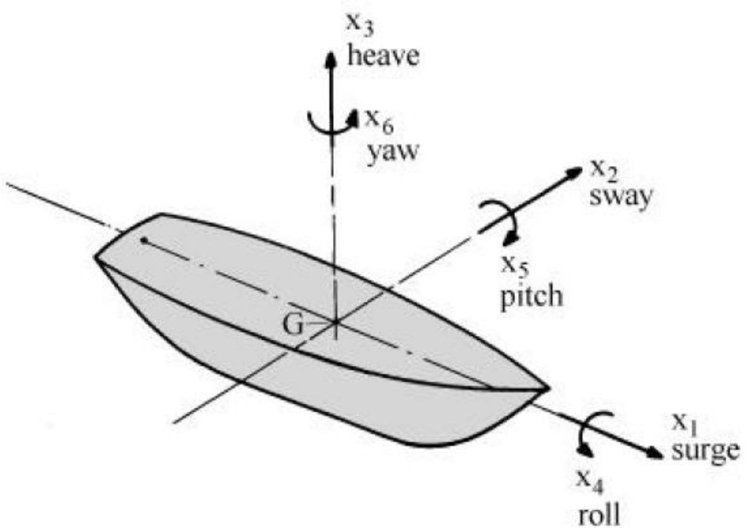


Figure 63, Definition of ship motions

The equations of motion of an oscillating ship with six degrees of freedom have to be written as follows (Newton's second law):

$$\sum_{j=1}^{6}\left\{M_{ij}\cdot\ddot{x}_i\right\}=\text{sum of all forces or moments in direction } i \quad \text{for: } i=1,...6$$

1 = Surge
2 = Sway
3 = Heave
4 = Roll
5 = Pitch
6 = Yaw

The right hand side of these equations consists of a superposition of:

- Exciting wave forces and moments on the restrained body, and
- Hydromechanic forces and moments, caused by a harmonic oscillation of the rigid body in the undisturbed surface of a fluid previously at rest.

Therefore a vessel moving in waves can be considered to be a linear mass-damper-spring system with frequency dependent coefficients and linear exciting forces and moments. Given Newton's second law and the six degrees of freedom, the equations of motions become:

$$\sum_{j=1}^{6}\left\{(M_{ij}+a_{ij})\cdot\ddot{x}_i+b_{ij}\cdot\dot{x}_i+c_{ij}\cdot x_i\right\}=F_i \qquad \text{for: } i=1,...6$$

M_{ij} = Solid mass or solid mass moments of inertia

a_{ij} = Added mass or added mass moments of inertia

$\ddot{x}_i$ = Acceleration of harmonic oscillation in direction i

$\dot{x}_i$ = Velocity of harmonic oscillation in direction i

x_i = Displacement of harmonic oscillation in direction i

b_{ij} = Hydrodynamic damping coefficient

c_{ij} = Spring coefficient

F_i = Harmonic exciting wave force or moment in direction i

Strip theory divides the ship in a finite number of cross sections, which are rigidly connected to each other, for which the 2 dimensional hydromechanics and exciting wave loads are calculated. These values are then integrated over the ships length numerically to obtain 3 dimensional values. Each 2 dimensional cross section is treated hydrodynamically as if it is a segment of an infinitely long floating cylinder;

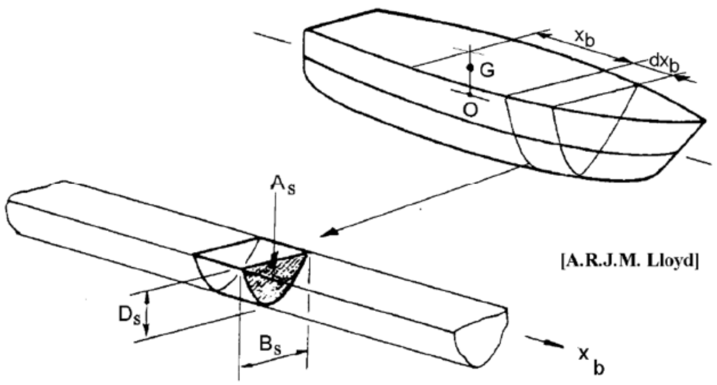


Figure 64, Definition of vessel cross sections, strip theory

Assumptions:

- For zero speed case, interactions between the cross sections are ignored.
- All waves which are produced by the oscillating ship (hydromechanics loads) and the diffracted waves (wave loads) are assumed to travel parallel to the (y,z)-plane of the ship.
- The fore and aft side of the body does not produce waves in the x-direction.
- Strip theory is valid for long and slender bodies only.

4. Criteria connected with motion parameters

4.1 Ship motions

Criteria for acceptable levels of ship motions, which are used in the procedure for predicting percentage operability, have been defined on the basis of full-scale data and criteria proposed in the literature. This information available has been supplemented with our own observations during seakeeping tests with small naval vessels.

In general the speed is reduced, the course is changed or the operations are discontinued by order of the captain if safety of the ship, cargo or personnel is in danger, the effectiveness of the personnel has dropped markedly or habitability onboard is significantly reduced. All ship responses are not equally important from the point of view of operation of different ship subsystems as the table below shows.

Table 4.1 Limiting criteria versus ship subsystems

Ship subsystem	Criteria with regard to Slam	Deck wetn.	Vert. acc.	Lat. acc.	Roll	Pitch	Vert. mot.	Vert. vel.	Rel. mot.
Ship hull	Ø	Ø	Ø						
Propulsion machinery									o
Ship equipment		o[1]	Ø	Ø	Ø	o			
Cargo		o[2]	Ø	Ø	Ø	o			
Personnel effectiveness		o[3]	Ø	Ø	Ø	o			
Passenger comfort			Ø	Ø	Ø	o			
Special operations									
helicopter					o	o	o	o	
sonar									o
lifting			o		o	o	o	o	

[1] For equipment on foredeck.
[2] For deck cargo.
[3] For operations on open lower decks.

For instance, vertical velocity is important only from the point of view of helicopter recovery and lifting operations while vertical acceleration has an effect on almost all activities onboard. In the operability prediction procedure criteria have been defined with regard to all responses marked with a ø in Table 4.1. A criterion for pitch has not been considered necessary since on merchant ships large pitch angles in themselves are usually not a problem. The effects of pitch that may be experienced by the people onboard are accounted for by the criteria for slamming, deck wetness and vertical acceleration.

The basic set of criteria used in the operability prediction procedure is given in the following table.

Table 4.2 General operability limiting criteria for ships

	Merchant ships	Naval vessels	Fast small craft
Vert. acc. rms, FP	Fig. 4.1	0.275 g	0.65 g
Vert. acc. rms, bridge	0.15 g	0.2 g	0.275 g
Lat. acc. rms, bridge	0.12 g	0.1 g	0.1 g
Roll rms	6.0 deg	4.0 deg	4.0 deg
Slamming, crit. prob.	Fig. 4.3	0.03	0.03
Deck wetn., crit. prob.	0.05	0.05	0.05

The slamming and deck wetness criteria have been defined in terms of critical probabilities (events per hundred wave encounters) while all other criteria are root mean square values. The different points of view considered in estimating the limiting magnitudes of ship motions given in Table 4.2 are presented in Table 4.3 below.

Table 4.3 Points of view considered in the criteria

Criterion	Hull safety	Equip. operat.	Cargo safety	Personnel safety and efficiency
Vert. acceleration, FP	Ø		Ø	
Vert. acc., bridge		Ø		Ø
Lateral acc., bridge		Ø	Ø	Ø
Roll		Ø	Ø	Ø
Slamming	Ø			
Deck wetness	Ø			

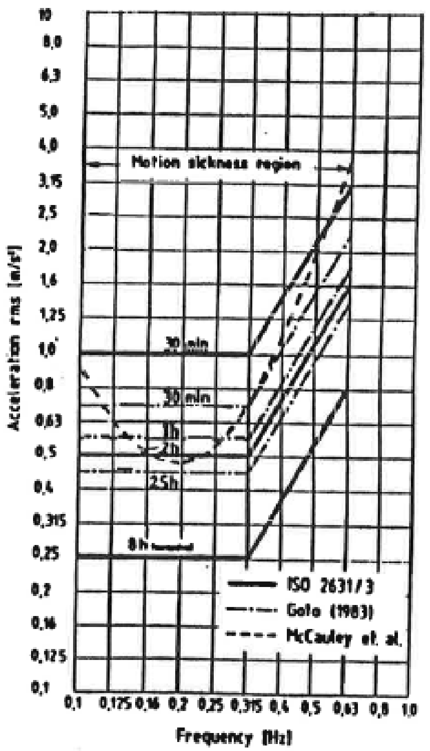


Figure 4.3 The severe discomfort boundary according to the International Standard ISO 2631/3-1985 with regard to vertical acceleration as a function of frequency for exposure times of 30 minutes, 2 hours and, tentatively, 8 hours. Also shown are Goto's (1983) proposal for a standard and results of laboratory experiments by McCauley et al. (1976) corresponding to a 10% motion sickness incidence ratio (vomiting) amongst unadapted healthy men.

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Table 4.4 Limiting criteria with regard to vertical acceleration

Vert. acc. rms	Description
0.275 g	Simple light work. Most of the attention must be devoted to keeping balance. Tolerable only for short periods on high speed craft. Connolly (1974), Bukenhus (1980).
0.2 g	Light manual work to be carried out by people adapted to ship motions. Not tolerable for longer periods. Causes fatigue quickly. Mackay & Schmitke (1978), Applebee & Baitis (1984).
0.15 g	Heavy manual work, for instance on fishing vessels and supply ships.
0.1 g	Intellectual work by people not so well adapted to ship motions. For instance scientific personnel on ocean research vessels (Hutchison & Laible, 1987). Work of a more demanding nature. Long-term tolerable for the crew according to Payne (1976). The International Standard ISO 2631/3 (1986) for half an hour exposure period for people unused to ship motions (Figure 4).
0.05 g	Passengers on a ferry. The International Standard for two hours exposure period for people unused to ship motions. Causes symptoms of motion sickness (vomiting) in approximately 10% of unacclimatized adults. Goto (1983), Lawther & Griffin (1985).
0.02 g	Passengers on a cruise liner. Older people. Close to the lower treshold below which vomiting is unlikely to take place. Lawther & Griffin (1985).

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The following table repeats vertical acceleration criteria and shows the corresponding criteria with regard to roll and lateral acceleration which may not be as reliable as the vertical acceleration criteria.

Table 4.5 Criteria with regard to accelerations and roll

Root Mean Square Criterion			Description
Vert. acc.	Lat. acc.	Roll	
0.20 g	0.10 g	6.0°	Light manual work
0.15 g	0.07 g	4.0°	Heavy manual work
0.10 g	0.05 g	3.0°	Intellectual work
0.05 g	0.04 g	2.5°	Transit passengers
0.02 g	0.03 g	2.0°	Cruise liner

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X Dynamic positioning calculations mono-hull

X.ABackground information on DP

There are three types of forces acting on a vessel in DP:

- Environmental forces
- Fluid reaction forces
- Thruster forces

In an idealized situation the sum of all the forces is zero, so the acceleration of the forces is zero.

$$F_{environment} = F_{reaction} + F_{DPsystem\_generated}$$

Environmental forces are excitation forces, forces that make the vessel move from target position. Due to the mass of the vessel it is not responsive to fast variations of the exciting forces. Environmental forces are built up from three components:

- Wind forces
- Current forces
- Wave forces

Wind

Two types of wind forces:

- Steady flow force
- Dynamic wind

The steady flow force is calculated with Bernoulli:

$$F = \frac{1}{2}\rho v^2 A C_D$$

The difficulty lies within the drag coefficient (C_D) value which is shape dependent and determined using wind tunnel tests and estimation of empirical coefficients for “standard shapes”. The C_D values are valid within a certain range of Reynolds numbers and a specific shape.

Dynamic wind (gusting) forces can be calculated using a wind spectrum:

- Harris
- Ochi Shin
- DnV

These are various wind spectrum formulations and the low frequency part is the most important and can be quite different, depending on the spectral fit formulation. Wind is normally defined to be 1 hour sustained (mean) wind speed, but the 10 minute and 1 minute values are about 25 and 40% higher.

Current

Current forces have similarity with wind flow forces and are calculated with the same equation.

$$F_C = \frac{1}{2}\rho v^2 A C_D$$

In addition to the effects which were also found for wind (velocity profile, Reynolds number dependency, vortex shedding and dynamic effects due to turbulence) there is another strong effect: Keel clearance (water depth to draft ratio) effect for shallow waters.

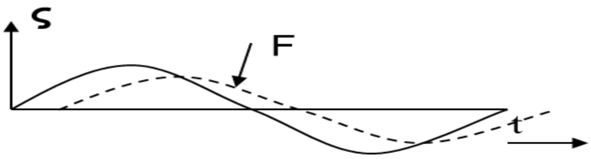
Waves

Third force on a vessel is caused by waves and is called wave drift forces; they are divided into two components:

- First order wave drift forces
- Second order wave drift forces

The first order wave drift forces are oscillatory forces around zero mean and described by the following equation:

Regular wave:
$\varsigma(t) - \varsigma_a \sin(\omega t)$
First order forces:
$F(t) = F_a \sin(\omega t + \varepsilon)$



Second order wave drift forces:

A floating body encounters incoming waves and these waves are reflected by the body. Second order wave forces are caused by second order pressures:

Bernoulli

Relative motion $$p - p_0 = -\rho g z - \frac{1}{2}\rho V^2 - \rho \frac{\delta \phi}{\delta t}$$

To calculate the wave drift forces, the pressure has to be integrated over the surface of the vessel. This force causes a body to slowly drift with the waves. For regular waves the wave drift forces are constant for a certain frequency and depend on the amplitude squared. In irregular waves it is more complicated, the drift forces slowly vary. The wave amplitude is dependent on the summation of multiple waves:

$$\varsigma(t) = \sum_{i=1}^{n} \varsigma_i \sin(\varpi_i + \varepsilon_i)$$

An example for 2 waves with different frequency and phase:

$$\varsigma(t) = \sum_{i=1}^{2} \varsigma_i \sin(\varpi_i + \varepsilon_i)$$
$$A^2(t) = \varsigma_1(t) + \varsigma_2(t)$$
$$= \varsigma_1{}^2 + \varsigma_2{}^2 + 2\varsigma_1\varsigma_2 \cos(\mu t + \Delta\varepsilon)$$
with $\mu = \omega_1 - \omega_2$

The low frequency part of the square of the wave envelope can now be defined as follows:

$$S_\varsigma \Delta\omega = \frac{1}{2}\varsigma_n{}^2 \text{ (definition of wave energy)}$$
$$S_{A^2}(\mu)\Delta\omega = \frac{1}{2}(2\varsigma_1\varsigma_2)^2$$
$$= 8 S_\varsigma(\omega_1)\Delta\omega S_\varsigma(\omega_2)\Delta\omega$$

Generalization for an irregular wave train with infinite frequencies yields the following expression for the spectral density of all wave groups with frequency difference μ:

$$S_{A^2}(\mu) = 8\int_0^\infty S_\varsigma(\omega) S_\varsigma(\omega + \mu) d\omega$$

The mean wave drift force in a regular wave with frequency ω and amplitude ς is given by: $X_i^{(2)} = \varsigma_1{}^2 \cdot P_{ii}$
In which P_{ii} is the quadratic transfer function, this can be computed using diffraction theory at V=0.

Using
$$A^2(t) = \varsigma_1{}^2 + \varsigma_2{}^2 + 2\varsigma_1\varsigma_2 \cos(\mu t + \Delta\varepsilon)$$
$$S_{A^2}(\mu) = 8\int_0^\infty S_\varsigma(\omega) S_\varsigma(\omega + \mu) d\omega$$

It can be derived that:

$$\overline{X_i^{(2)}} = \left\{ \sum_{i=1}^{n} \sum_{j=1}^{n} \varsigma_i \varsigma_j \cdot P_{ij} \right\} \Bigg|_{i=j} = 2 \int_0^{\infty} S_{\varsigma}(\omega) P(\omega, \omega) d\omega$$

$$S_F(\mu) = 8 \int_0^{\infty} S_{\varsigma}(\omega) S_{\varsigma}(\omega + \mu) P^2(\omega, \omega + \mu) d\omega$$

In which S_F is the low frequency spectral density of the wave drift force [kN^2m^4s]. So in order to calculate the wave drift forces on a vessel one needs to have a wave spectrum for a certain area and a transfer function of the mean second-order drift forces.

Other side of force balance

The forces on the vessel created by wind, current and waves have to be opposed by thruster forces. The types of thruster used are:

- Azimuth thrusters, or rudder propellers, with or without nozzles
- Podded thrusters
- Main propellers in combination with rudders
- Tunnel thrusters
- Voith Schneider propeller

Each of these systems are designed to accelerate water to create a reaction force. Open water thrust and torque for a propeller are calculated with:

$$T = K_T \rho D^4 n^2$$

$$Q = K_Q \rho D^5 n^2$$

In which K_T and K_Q are the dimensionless thrust and torque coefficients for a certain propeller. In case of DP the advance speed is 0, similar as in bollard condition. This means that the advance coefficient J is also 0, so values for K_T and K_Q are high for zero speed. Given an open water propeller diagram for a B-series propeller:

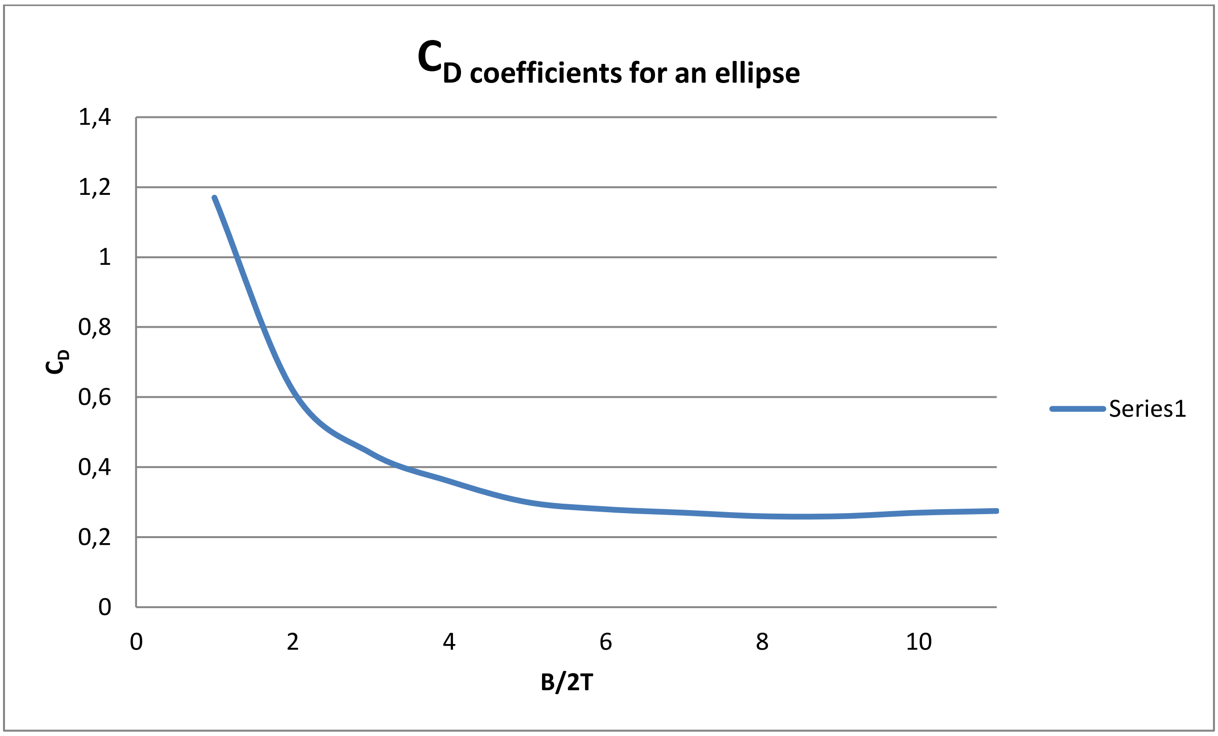


Figure 65, Cd coëfficient ellipse

Stations:

The vessels hull is subdivided in sections of 5 meters in length and a corresponding drag coefficient is calculated. Below there is a picture of all stations, mirrored at the design waterline. It is clearly visible that an ellipse is a good comparison for the stations, with horizontal orientated ellipses in the aft and vertical oriented ellipses in the front of the vessel.

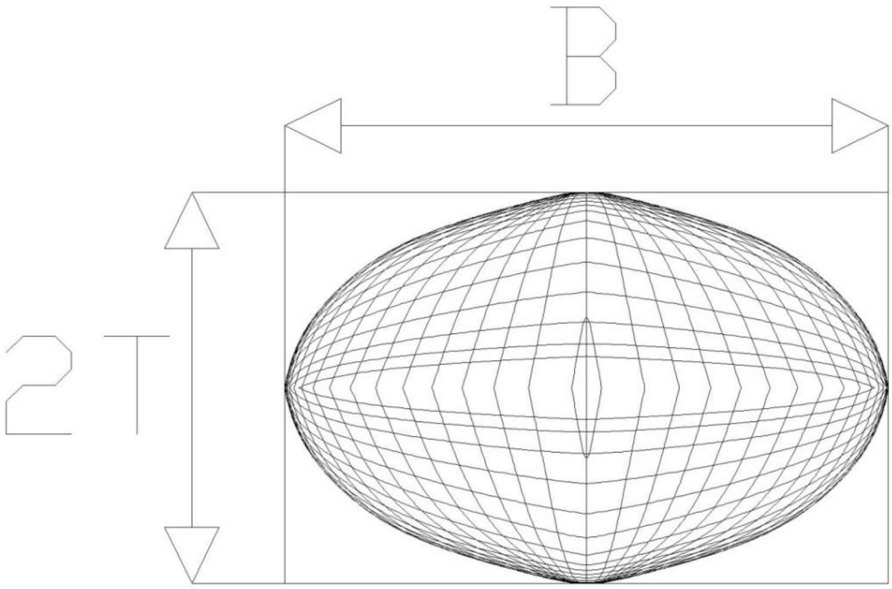


Figure 66, Stations mono-hull mirrored

Section	Shape	T [m]	2T [m]	B [m]	Re	B/2T [-]	Cd [-]	dX [m]	dF [kN]	x wrt L/2 [m]	M [kNm]
1	Ellipse	0.97	1.94	17.65	14242	9.10	0.31	5	0.82	-57.5	-47.37
2	Ellipse	1.35	2.7	18.21	14694	6.74	0.25	5	0.91	-52.5	-47.58
3	Ellipse	2.02	4.04	18.38	14831	4.55	0.33	5	1.79	-47.5	-84.84
4	Ellipse	2.94	5.88	18.46	14895	3.14	0.42	5	3.33	-42.5	-141.41
5	Ellipse	3.86	7.72	18.5	14928	2.40	0.52	5	5.49	-37.5	-205.86
6	Ellipse	4.61	9.22	18.51	14936	2.01	0.62	5	7.80	-32.5	-253.43
7	Ellipse	5.14	10.3	18.51	14936	1.80	0.70	5	9.70	-27.5	-266.69
8	Ellipse	5.44	10.9	18.5	14928	1.70	0.74	5	10.87	-22.5	-244.48
9	Ellipse	5.6	11.2	18.49	14919	1.65	0.76	5	11.52	-17.5	-201.52
10	Ellipse	5.72	11.4	18.46	14895	1.61	0.78	5	12.03	-12.5	-150.34
11	Ellipse	5.85	11.7	18.35	14807	1.57	0.80	5	12.64	-7.5	-94.83
12	Ellipse	5.92	11.8	18.22	14702	1.54	0.81	5	13.03	-2.5	-32.58
13	Ellipse	5.97	11.9	17.93	14468	1.50	0.83	5	13.45	2.5	33.63
14	Ellipse	5.99	12	17.46	14088	1.46	0.85	5	13.88	7.5	104.10
15	Ellipse	6	12	16.76	13524	1.40	0.89	5	14.46	12.5	180.76
16	Ellipse	6	12	15.77	12725	1.31	0.94	5	15.27	17.5	267.26
17	Ellipse	6	12	14.48	11684	1.21	1.01	5	16.43	22.5	369.71
18	Ellipse	6	12	12.94	10441	1.08	1.10	5	17.98	27.5	494.47
19	Ellipse	6	12	11.26	9086	0.94	1.22	5	19.90	32.5	646.66
20	Ellipse	6	12	9.48	7649	0.79	1.36	5	22.21	37.5	833.04
21	Ellipse	6	12	7.63	6157	0.64	1.53	5	24.97	42.5	1061.30
22	Ellipse	6	12	5.69	4591	0.47	1.74	5	28.29	47.5	1343.84
23	Ellipse	5.99	12	3.57	2881	0.30	1.99	5	32.41	52.5	1701.76
24	Ellipse	2.16	4.32	0.92	742	0.21	2.13	5	12.50	57.5	718.60
SUM							**0.94**		**321.67**		**5984.19**

Table 58, Current forces and moments mono-hull

Section	Shape	A [m^2]	Cd	dX [m]	dF wind [kN]	x wrt L/2 [m]	M wind [kN]
1	Solid area	10	1.2	5	1.751	-57.5	-100.66
2	Solid area	10	1.2	5	1.751	-52.5	-91.911
3	Solid area	10	1.2	5	1.751	-47.5	-83.157
4	Solid area	10	1.2	5	1.751	-42.5	-74.404
5	Solid area	10	1.2	5	1.751	-37.5	-65.651
6	Solid area	10	1.2	5	1.751	-32.5	-56.897
7	Solid area	10	1.2	5	1.751	-27.5	-48.144
8	Solid area	19.36	1.2	5	3.389	-22.5	-76.26
9	Solid area	54.85	1.2	5	9.602	-17.5	-168.04
10	Solid area	66.04	1.2	5	11.56	-12.5	-144.52
11	Solid area	78.12	1.2	5	13.68	-7.5	-102.57
12	Solid area	110.1	1.2	5	19.28	-2.5	-48.192
13	Solid area	109.7	1.2	5	19.21	2.5	48.021
14	Solid area	103.1	1.2	5	18.04	7.5	135.31
15	Solid area	91.63	1.2	5	16.04	12.5	200.52
16	Solid area	84.72	1.2	5	14.83	17.5	259.56
17	Solid area	82.77	1.2	5	14.49	22.5	326.03
18	Solid area	78.38	1.2	5	13.72	27.5	377.35
19	Solid area	71.56	1.2	5	12.53	32.5	407.16
20	Solid area	74.42	1.2	5	13.03	37.5	488.57
21	Solid area	71.95	1.2	5	12.6	42.5	535.34
22	Solid area	68.98	1.2	5	12.08	47.5	573.62
23	Solid area	65.25	1.2	5	11.42	52.5	599.72
24	Solid area	39.82	1.2	5	6.971	57.5	400.84
SUM		**1341**			**234.7**		**3291.6**

Table 59, Wind forces and moments mono-hull

XI Catamaran database

Name	Loa [m]	Lwl [m]	Beam [m]	Beam demihull [m]	Lwl/Bdemi	Lwl/B
Sun Eagle	29.2	26.6	9.5	2.5	10.64	2.80
Jet Caraibe	35	31.3	9.4	3.8	8.24	3.33
Seamax	39.5	33.3	11.4	3.6	9.25	2.92
Dodekanisos Express	40.05	34.6	11.5	3.5	9.89	3.01
Royal ferry	40.25	37	9.3	3.2	11.56	3.98
CNM Evolution	43.1	40.1	10.4	2.4	16.71	3.86
Brelyan	44	39	12	3.41	11.44	3.25
Eid Travel	46	41.7	12	4.33	9.63	3.48
Jade Express	48	41.6	13	4.88	8.52	3.20
San Gwann (KvFj)	49	43.1	12.5	3.1	13.90	3.45
Madikera	49.45	43.6	14			3.11
SSTH 50 (d) IHI LTD	49.9		8			
San Gwann (Fjellstrand)	51	48	12.5	3.3	14.55	3.84
FBM 53 Tricat	52.8	47.5	13			3.65
LA Viking Two	55	47.5	15.2	4.1	11.59	3.13
55m RO/RO PTE LTD	55		15			
Autoexpress 56	56	49.8	14			3.56
K40 Incat (d)	58	52	14.5			3.59
Turgut Reis 1	59.9	51.2	17.5	4.5	11.38	2.93
Nordic Jet	60	54.5	16.5	3.95	13.80	3.30
Solidor 5	60	56.5	16.9	3.9	14.49	3.34
Sea Bird	62	56.6	15.4	3.4	16.65	3.68
63m RO/RO PTE LTD	63		16			
Autoexpress 66 Austal	66.2	59	18.2			3.24
Juan Patricio	70.36	63.9	19.5	5	12.78	3.28
Highspeed 2	72	63.5	17.5	4.73	13.42	3.63
Ocean arrow	72.09	70.2	12.9	4.69	14.97	5.44
73m CAR FERRY (d) AMHS	73.4	63.8	18			3.54
Juan L	74.2	60.5	26	4.33	13.97	2.33
Mai Mols	76.12	63	23.4	4.6	13.70	2.69
HighSpeed 1	76.6	68	22.2	6.15	11.06	3.06
Luciano Fedderico L	77.32	69.9	19	5.65	12.37	3.68
Condor 11	77.5	63.9	26	4.33	14.76	2.46
Cat Link 3	78.6	66.5	23	4.3	15.47	2.89
Sunflower	79.25	72.3	19.5	5	14.46	3.71
A50 Afai ShipsLTD	80.1	72.3	19	5	14.46	3.81
Condor 12	81.15	66.3	26	4.33	15.31	2.55
Autoexpress82	82.3	69	23	5.2	13.27	3.00
INCAT 86	86.3	76.4	26	4.3	17.77	2.94
Autoexpress 86	86.6	74.2	24	5.31	13.97	3.09
Condor Express	86.62	76.4	26	4.33	17.64	2.94
Stena Charisma	88	76.4	30	7	10.91	2.55
90m Schelde (d0	89.8	81.6	24			3.40
Devil Cat	91.3	81.3	26	4.33	18.78	3.13
Highspeed 4	92.6	80.6	24	5.34	15.09	3.36
Incat Tasmania	92.7	92	26.6	4.33	21.25	3.46
Austal cargo 95	95		29			
Autoexpress 96 Austal	95.8	82.5	24.2			3.41
Bonanza express	96	86	26.2	4.5	19.11	3.28
Hayabusa	99.78	89	20	5.79	15.37	4.45
Hayabusa AMD	100		20			
Euroferrys Express	101	88.7	26.7	6.79	13.06	3.32
105m Schelde (d)	105.4	100.8	29.2			3.45
Austal Track Express 112	112		25			
INCAT 112 (d)	112.6	105.6	30.2			3.50
INCAT 120m	120	117.5	29			4.05
Pacificat Explorer	122.5	96	25.8	6	16.00	3.72
Autoexpress 125 (d)	125	106.5	31.7			3.36

Name	Depth [m]	Draft [m]	B/T	Tunnel width St [m]	(St+Bdemi)/LWL	Bdemi/Draft
Sun Eagle		1.5	1.67	4.5	0.26	1.67
Jet Caraibe	3.5	1.4	2.71	1.8	0.18	2.71
Seamax		1.9	1.89	4.2	0.23	1.89
Dodekanisos Express	3.2	1.81	1.93	4.5	0.23	1.93
Royal ferry	3.5	1.5	2.13	2.9	0.16	2.13
CNM Evolution	4.1	1.44	1.67	5.6	0.20	1.67
Brelyan		1.75	1.95	5.18	0.22	1.95
Eid Travel				3.34	0.18	
Jade Express	4	1.4	3.49	3.24	0.20	3.49
San Gwann (KvFj)	4.65	1.95	1.59	6.3	0.22	1.59
Madikera		2.35		14	0.32	0.00
SSTH 50 (d) IHI LTD				8		
San Gwann (Fjellstrand)	4.75	1.95	1.69	5.9	0.19	1.69
FBM 53 Tricat		1.62		13	0.27	
LA Viking Two	4.5	2	2.05	7	0.23	2.05
55m RO/RO PTE LTD		2		15		
Autoexpress 56		2.7		14	0.28	
K40 Incat (d)		2		14.5	0.28	
Turgut Reis 1	5.65	2	2.25	8.5	0.25	2.25
Nordic Jet	5.85	2.9	1.36	8.6	0.23	1.36
Solidor 5	5.85	2.7	1.44	9.1	0.23	1.44
Sea Bird	5.4	2.3	1.48	8.6	0.21	1.48
63m RO/RO PTE LTD		2		16		
Autoexpress 66 Austal		2.5		18.2	0.31	
Juan Patricio	5.65	2.1	2.38	9.5	0.23	2.38
Highspeed 2	5.9	2.5	1.89	8.04	0.20	1.89
Ocean arrow	4.5	2.05	2.29	3.52	0.12	2.29
73m CAR FERRY (d) AMHS		2.7		18	0.28	
Juan L		3	1.44	17.34	0.36	1.44
Mai Mols	8.05	3.38	1.36	14.2	0.30	1.36
HighSpeed 1	7.2	3	2.05	9.9	0.24	2.05
Luciano Fedderico L		2.23	2.53	7.7	0.19	2.53
Condor 11	7.2	3.4	1.27	17.34	0.34	1.27
Cat Link 3	7	2.5	1.72	14.4	0.28	1.72
Sunflower		2.16	2.31	9.5	0.20	2.31
A50 Afai ShipsLTD		1.2	4.17	9	0.19	4.17
Condor 12		3	1.44	17.34	0.33	1.44
Autoexpress82	6.5	2.5	2.08	12.6	0.26	2.08
INCAT 86		3.5	1.23	17.4	0.28	1.23
Autoexpress 86	7.3	3.2	1.66	13.38	0.25	1.66
Condor Express	6.75	3.5	1.24	17.34	0.28	1.24
Stena Charisma	12.6	3.7	1.89	16	0.30	1.89
90m Schelde (d0		3.2		24	0.29	
Devil Cat	6.8	3.7	1.17	17.34	0.27	1.17
Highspeed 4	7.8	3.9	1.37	13.32	0.23	1.37
Incat Tasmania		3.4	1.27	17.94	0.24	1.27
Austal cargo 95		4.1		29		
Autoexpress 96 Austal		4.2		24.2	0.29	
Bonanza express		3.7	1.22	17.2	0.25	1.22
Hayabusa	7.3	3.1	1.87	8.42	0.16	1.87
Hayabusa AMD		3.1		20		
Euroferrys Express	9.4	4.2	1.62	13.12	0.22	1.62
105m Schelde (d)		3.4		29.2	0.29	
Austal Track Express 112		3.6		25		
INCAT 112 (d)		3.3		30.2	0.29	
INCAT 120m		4.8		29	0.25	
Pacificat Explorer	6.6	3.9	1.54	13.8	0.21	1.54
Autoexpress 125 (d)		4.9		31.7	0.30	

Name	DWT [t]	Displ [t]	Vol/2	Cb	LWL/(Vol/2)^(1/3)	Light ship [t]
Sun Eagle		110	53.66	0.54	7.05	110
Jet Caraibe	30.7	121.8	59.41	0.36	8.02	91.1
Seamax		300	146.34	0.64	6.32	300
Dodekanisos Express						
Royal ferry						
CNM Evolution	60					
Brelyan						
Eid Travel	50					
Jade Express	54	250	121.95	0.43	8.39	196
San Gwann (KvFj)	50					
Madikera						
SSTH 50 (d) IHI LTD						
San Gwann (Fjellstrand)	89					
FBM 53 Tricat	68					
LA Viking Two	105					
55m RO/RO PTE LTD						
Autoexpress 56						
K40 Incat (d)	100					
Turgut Reis 1	173	680	331.71	0.72	7.40	507
Nordic Jet	135					
Solidor 5	110	800	390.24	0.66	7.73	690
Sea Bird	140					
63m RO/RO PTE LTD	340					
Autoexpress 66 Austal						
Juan Patricio	112					
Highspeed 2	190					
Ocean arrow	204					
73m CAR FERRY (d) AMHS	200					
Juan L	200	850	414.63	0.53	8.11	650
Mai Mols	250	890	434.15	0.44	8.32	640
HighSpeed 1	360					
Luciano Fedderico L	142	721	351.71	0.40	9.90	579
Condor 11	250	950	463.41	0.49	8.26	700
Cat Link 3	350	1240	604.88	0.85	7.86	890
Sunflower	123					
A50 Afai ShipsLTD						
Condor 12	320	1100	536.59	0.62	8.16	780
Autoexpress82	327	1250	609.76	0.68	8.14	923
INCAT 86	380					
Autoexpress 86	400	1380	673.17	0.53	8.47	980
Condor Express	345	1165	568.29	0.49	9.22	820
Stena Charisma	450					
90m Schelde (d0	450					
Devil Cat	500	1350	658.54	0.51	9.34	850
Highspeed 4	470	1600	780.49	0.46	8.75	1130
Incat Tasmania	650	1810	882.93	0.65	9.59	1160
Austal cargo 95	1172					
Autoexpress 96 Austal	750					
Bonanza express	800	1600	780.49	0.55	9.34	800
Hayabusa	570					
Hayabusa AMD						
Euroferrys Express	750	2000	975.61	0.39	8.94	1250
105m Schelde (d)	750					
Austal Track Express 112	1393					
INCAT 112 (d)	1500					
INCAT 120m	1200					
Pacificat Explorer		1816	885.85	0.39	10.00	1816
Autoexpress 125 (d)	1200					

Name	Speed Full Load	Nr. engines	Power [kW]	Power total [kW]	Fn	Propulser
Sun Eagle	30	2	1222	2444	0.96	wjets
Jet Caraibe	34	2	1939	3878	1.00	wjets
Seamax	45	4	2023	8092	1.28	wjets
Dodekanisos Express	35	4	788	3152	0.98	cpp
Royal ferry	40	2	2000	4000	1.08	wjets
CNM Evolution	30	4	2088	8352	0.78	wjets
Brelyan	29	2	2000	4000	0.76	wjets
Eid Travel	38	4	2000	8000	0.97	wjets
Jade Express	38	4	1980	7920	0.97	wjets
San Gwann (KvFj)	37.5	4	2320	9280	0.94	wjets
Madikera	35	4	2000	8000	0.87	wjets
SSTH 50 (d) IHI LTD	35			3640		wjets
San Gwann (Fjellstrand)	39	4	2320	9280	0.92	wjets
FBM 53 Tricat	40	2	4444	8888	0.95	wjets
LA Viking Two	36	4		9680	0.86	wjets
55m RO/RO PTE LTD	38	4		9680		wjets
Autoexpress 56	38	4	2320	9280	0.88	wjets
K40 Incat (d)	35	2	4320	8640	0.80	wjets
Turgut Reis 1	34.50	2	6500	13000	0.79	wjets
Nordic Jet	36.00	2	7200	14400	0.80	wjets
Solidor 5	36.00	2	7200	14400	0.79	wjets
Sea Bird	35.00	4	2023	8092	0.76	wjets
63m RO/RO PTE LTD	32.00	4	2320	9280		wjets
Autoexpress 66 Austal	31.00				0.66	wjets
Juan Patricio	45.00	4	5420	21680	0.92	wjets
Highspeed 2	41.00	4	3866	15464	0.85	wjets
Ocean arrow	30.00	2	3925	7850	0.59	fpp
73m CAR FERRY (d) AMHS	35.00	4	3600	14400	0.72	wjets
Juan L	43.00	4	4050	16200	0.91	wjets
Mai Mols	40.80	2	12400	24800	0.84	wjets
HighSpeed 1	36.00	4	5700	22800	0.72	wjets
Luciano Fedderico L	52.00	1	16100	16100	1.02	wjets
Condor 11	37.00	4	4320	17280	0.76	wjets
Cat Link 3	34.00	4	5500	22000	0.68	wjets
Sunflower	47.00	4	5420	21680	0.91	wjets
A50 Afai ShipsLTD	48.00	4	5500	22000	0.93	wjets
Condor 12	40.00	4	5500	22000	0.81	wjets
Autoexpress82	37.50	4	6000	24000	0.74	wjets
INCAT 86	42.00	4	7080	28320	0.79	wjets
Autoexpress 86	42.00	4	7200	28800	0.80	wjets
Condor Express	44.00	4	7080	28320	0.83	wjets
Stena Charisma	40.00	2	17000	34000	0.75	wjets
90m Schelde (d0	42.00			28800	0.76	wjets
Devil Cat	43.00	4	7080	28320	0.78	wjets
Highspeed 4	40.50	4	7200	28800	0.74	wjets
Incat Tasmania	42.00	4	7080	28320	0.72	wjets
Austal cargo 95				41000		wjets
Autoexpress 96 Austal	36.00	4	7200	28800	0.65	wjets
Bonanza express	37.50	4	7080	28320	0.66	wjets
Hayabusa	30.00	2	5420	10840	0.52	wjets
Hayabusa AMD	35.50			18960		wjets
Euroferrys Express	37.00	4	7200	28800	0.65	wjets
105m Schelde (d)	36.00			28800	0.59	wjets
Austal Track Express 112				43000		wjets
INCAT 112 (d)	40.00	4	9000	36000	0.64	wjets
INCAT 120m				52496		wjets
Pacificat Explorer	34.00	4	7000	28000	0.57	wjets
Autoexpress 125 (d)	40.00			45000	0.64	wjets

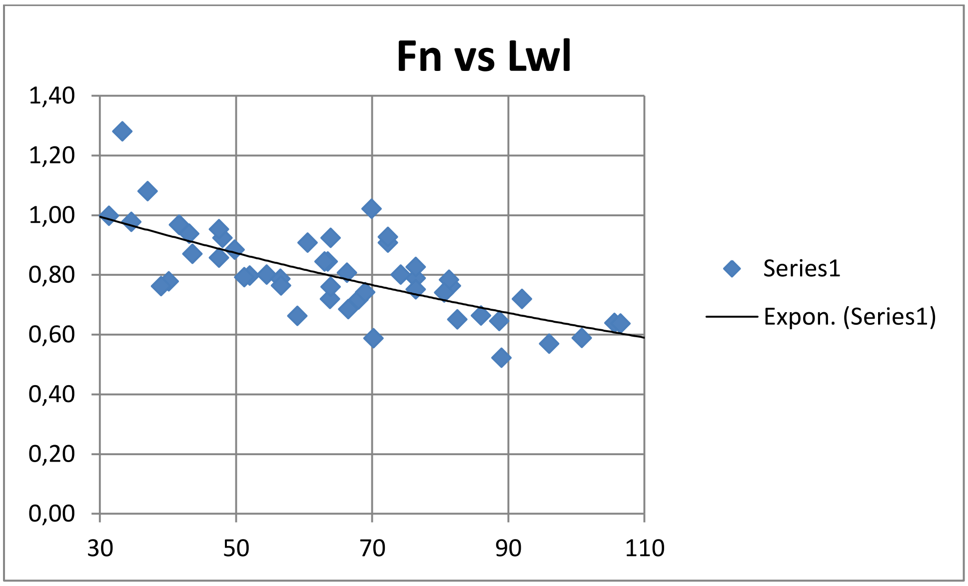


Figure 67, Trendline catamaran database, Fn vs lwl

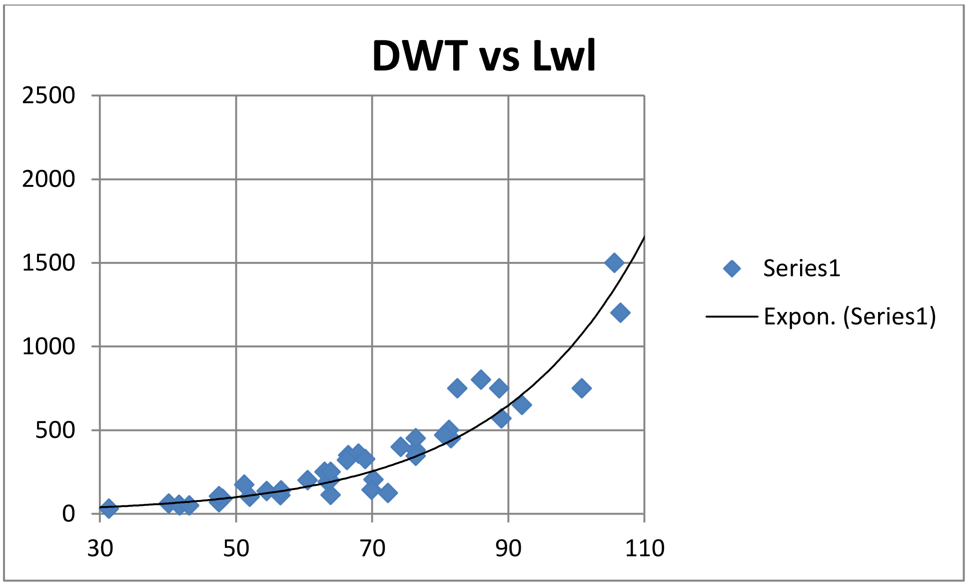


Figure 68, Trendline catamaran database, DWT vs lwl

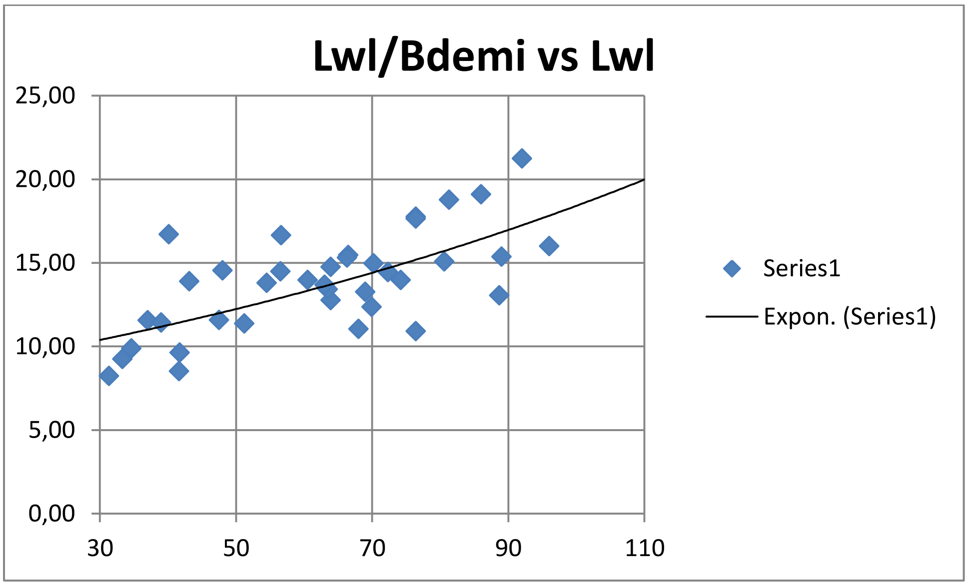


Figure 69, Trendline catamaran database, lwl/Bdemi vs lwl

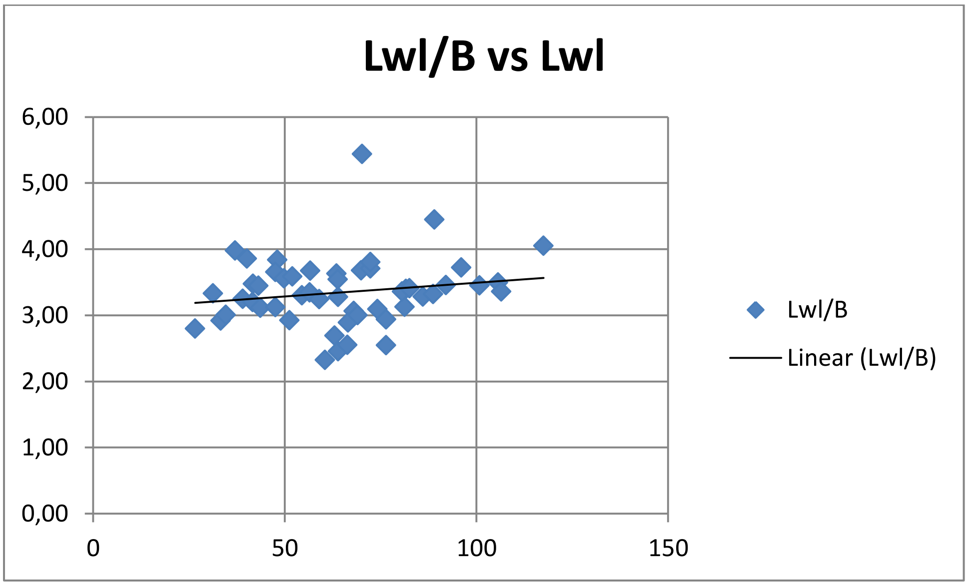


Figure 70, Trendline catamaran database, lwl/B vs lwl

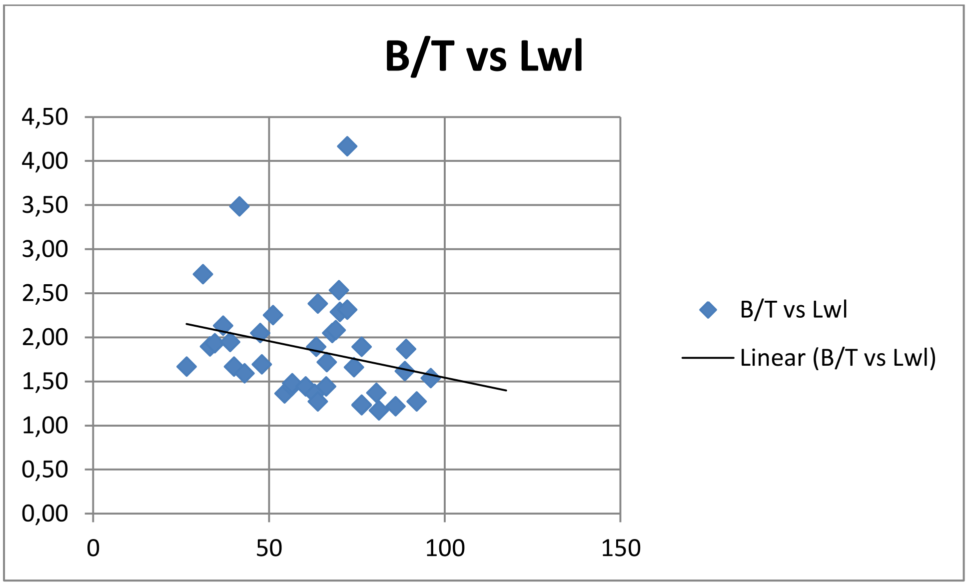


Figure 71, Trendline catamaran database, B/T vs lwl

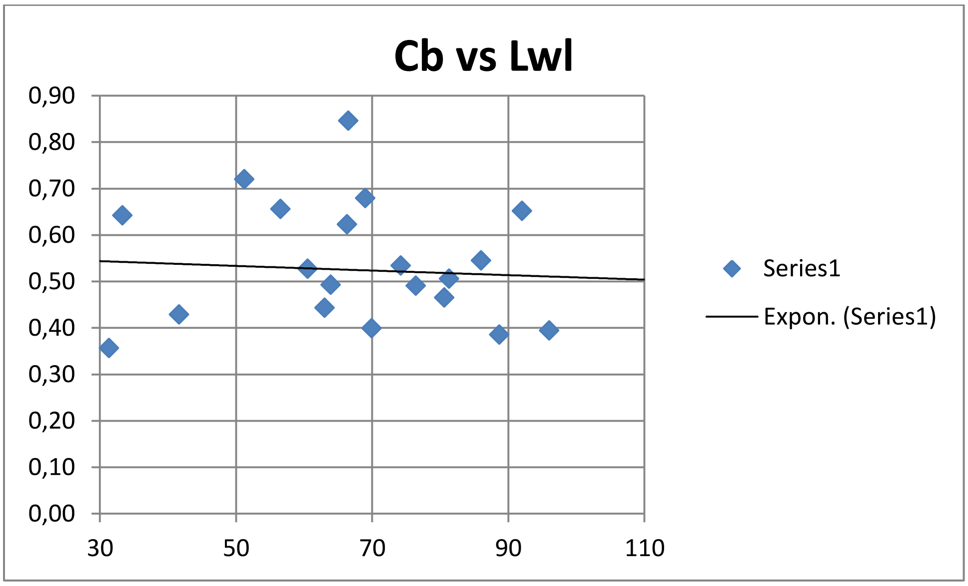


Figure 72, Trendline catamaran database, Cb vs lwl

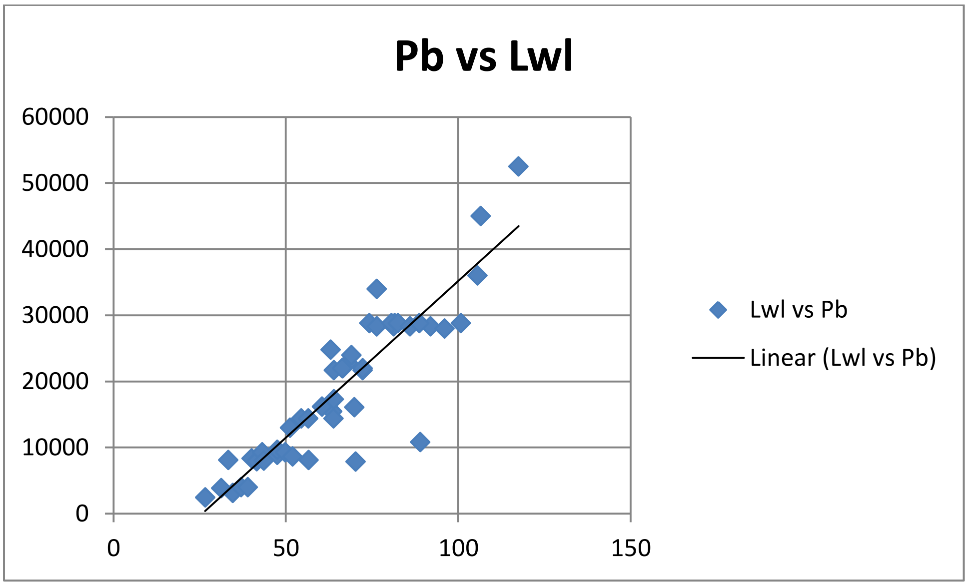


Figure 73, Trendline catamaran database, Pb vs lwl

XII Design hydrostatics report catamaran.

Design length	85.000	(m)	Midship location	42.500	(m)
Length over all	85.000	(m)	Relative water density	1.025	
Design beam	7.400	(m)	Mean shell thickness	0.0000	(m)
Maximum beam	24.323	(m)	Appendage coefficient	1.0000	
Design draught	6.000	(m)			

Volume properties			Waterplane properties		
Moulded volume	5141.2	(m^3)	Length on waterline	85.000	(m)
Total displaced volume	5141.2	(m^3)	Beam on waterline	24.294	(m)
Displacement	5269.7	(tonnes)	Entrance angle	0.000	(Degr.)
Block coefficient	1.3624		Waterplane area	1090.2	(m^2)
Prismatic coefficient	0.7429		Waterplane coefficient	1.7334	
Vert. prismatic coefficient	0.7860		Waterplane center of floatation	39.164	(m)
Wetted surface area	2547.1	(m^2)	Transverse moment of inertia	81901	(m^4)
Longitudinal center of buoyancy	41.529	(m)	Longitudinal moment of inertia	547110	(m^4)
Longitudinal center of buoyancy	-1.142	%			
Vertical center of buoyancy	3.415	(m)			

Midship properties			Initial stability		
Midship section area	81.416	(m^2)	Transverse metacentric height	19.345	(m)
Midship coefficient	1.8339		Longitudinal metacentric height	109.83	(m)

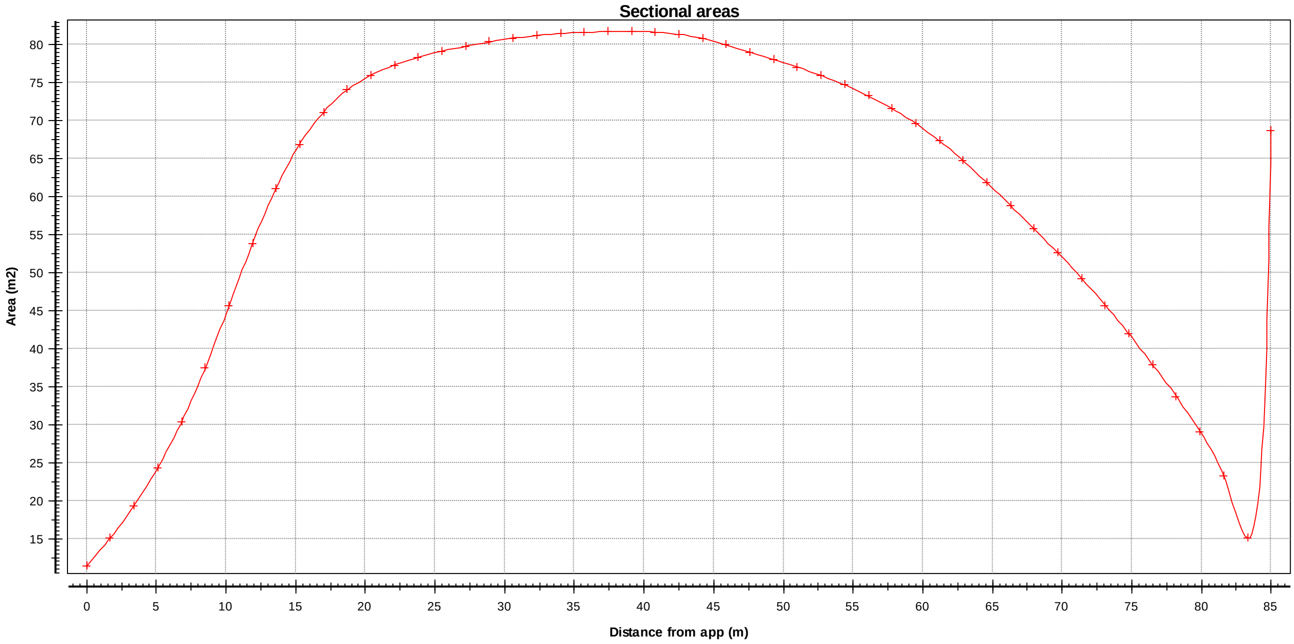
Lateral plane		
Lateral area	0.000	(m^2)
Longitudinal center of effort	0.000	(m)
Vertical center of effort	0.000	(m)

The following layer properties are calculated for both sides of the ship

Location	Area *(m^2)*	Thickness	Weight *(tonnes)*	VCG *(m)*	LCG *(m)*	TCG *(m)*
Layer 0	4456.1	0.000	0.000	4.842	42.803	0.000 (CL)

Sectional areas

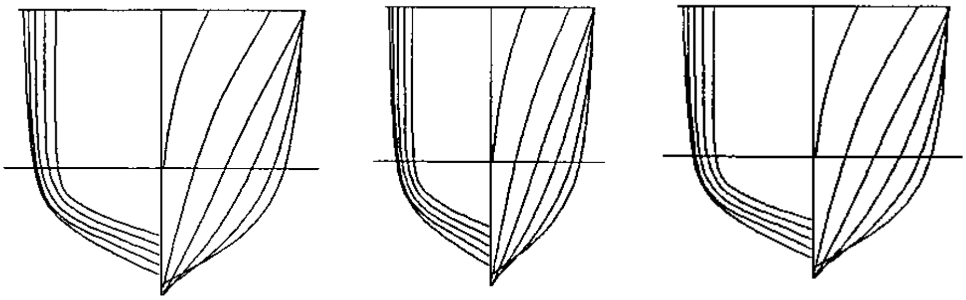
Location *(m)*	Area *(m^2)*	Location *(m)*	Area *(m^2)*	Location *(m)*	Area *(m^2)*	Location *(m)*	Area *(m^2)*	Location *(m)*	Area *(m^2)*
0.000	11.397	18.700	74.069	37.400	81.760	56.100	73.307	74.800	41.930
1.700	15.106	20.400	75.991	39.100	81.777	57.800	71.632	76.500	37.911
3.400	19.310	22.100	77.354	40.800	81.686	59.500	69.670	78.200	33.735
5.100	24.318	23.800	78.385	42.500	81.416	61.200	67.372	79.900	29.056
6.800	30.344	25.500	79.188	44.200	80.864	62.900	64.727	81.600	23.253
8.500	37.470	27.200	79.840	45.900	80.026	64.600	61.855	83.300	15.048
10.200	45.621	28.900	80.404	47.600	79.074	66.300	58.858	85.000	68.727
11.900	53.885	30.600	80.874	49.300	78.112	68.000	55.770		
13.600	61.123	32.300	81.232	51.000	77.084	69.700	52.586		
15.300	66.939	34.000	81.490	52.700	75.975	71.400	49.272		
17.000	71.164	35.700	81.664	54.400	74.761	73.100	45.726		



NOTE 1: Draught (and all other vertical heights) is measured above base Z=
NOTE 2: All calculated coefficients based on project length, draught and beam.

XIII Resistance prediction catamaran design

Molland



Model: 3b　　Model: 4a　　Model: 4b

Figure 74, Models for resistance prediction Molland

TABLE I: Notation and Main Parameters of Models

$L/\nabla^{\frac{1}{3}}$	B/T			C_P
	1.5	2.0	2.5	
6.3	—	3b*	—	0.693
7.4	4a	4b*	4c	0.693
8.5	5a	5b*	5c	0.693
9.5	6a	6b	6c	0.693

Figure 75, Notation and Main Parameters of Models, Molland

TABLE II: Details of the Models

Model	L[m]	L/B	B/T	$L/\nabla^{\frac{1}{3}}$	C_B	C_P	C_M	A[m^2]	LCB [% ⊗]
3b	1.6	7.0	2.0	6.27	0.397	0.693	0.565	0.434	-6.4
4a	1.6	10.4	1.5	7.40	0.397	0.693	0.565	0.348	-6.4
4b	1.6	9.0	2.0	7.41	0.397	0.693	0.565	0.338	-6.4
4c	1.6	8.0	2.5	7.39	0.397	0.693	0.565	0.340	-6.4
5a	1.6	12.8	1.5	8.51	0.397	0.693	0.565	0.282	-6.4
5b	1.6	11.0	2.0	8.50	0.397	0.693	0.565	0.276	-6.4
5c	1.6	9.9	2.5	8.49	0.397	0.693	0.565	0.277	-6.4
6a	1.6	15.1	1.5	9.50	0.397	0.693	·0.565	0.240	-6.4
6b	1.6	13.1	2.0	9.50	0.397	0.693	0.565	0.233	-6.4
6c	1.6	11.7	2.5	9.50	0.397	0.693	0.565	0.234	-6.4

Figure 76, Details of Models, Molland

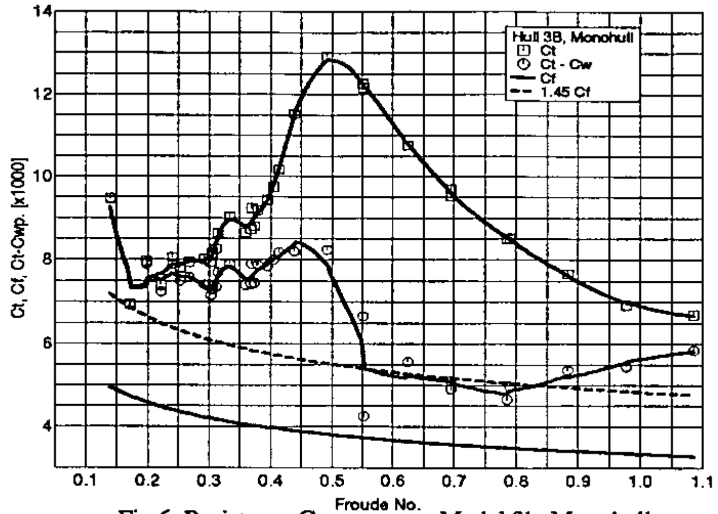


Fig 6. Resistance Components: Model 3b, Monohull

Figure 77, Resistance componants Model 3b, Mono-hull

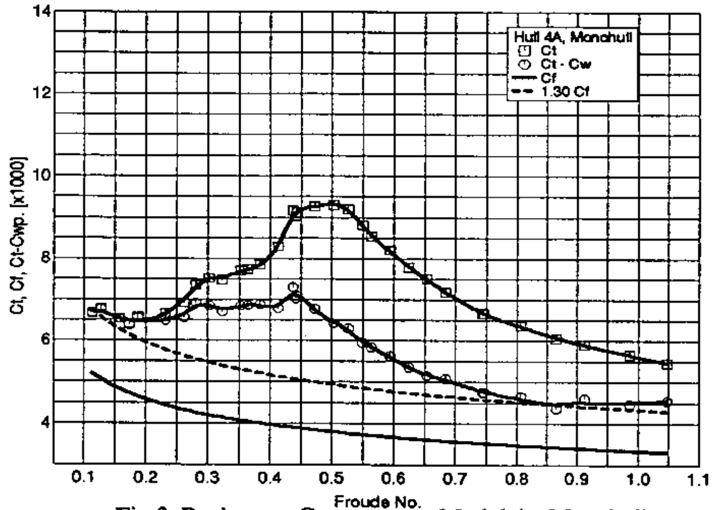


Fig 3. Resistance Components: Model 4a, Monohull

Figure 78, Resistance componants Model 4a, Mono-hull

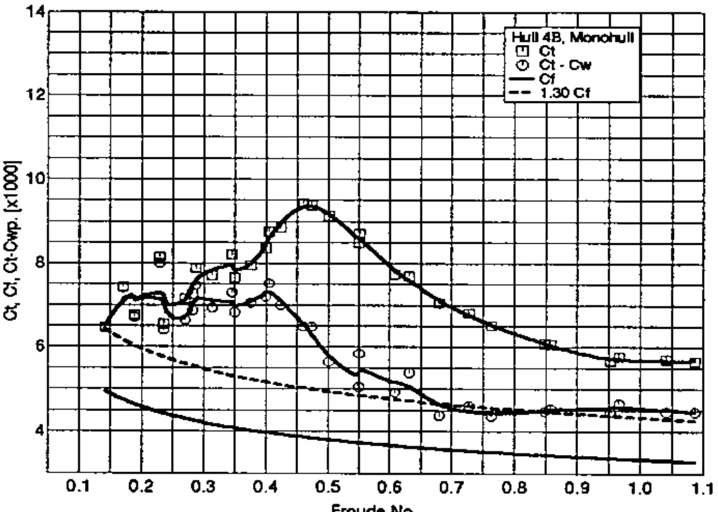


Fig 7. Resistance Components: Model 4b, Monohull

Figure 79, Resistance componants Model 4b, Mono-hull

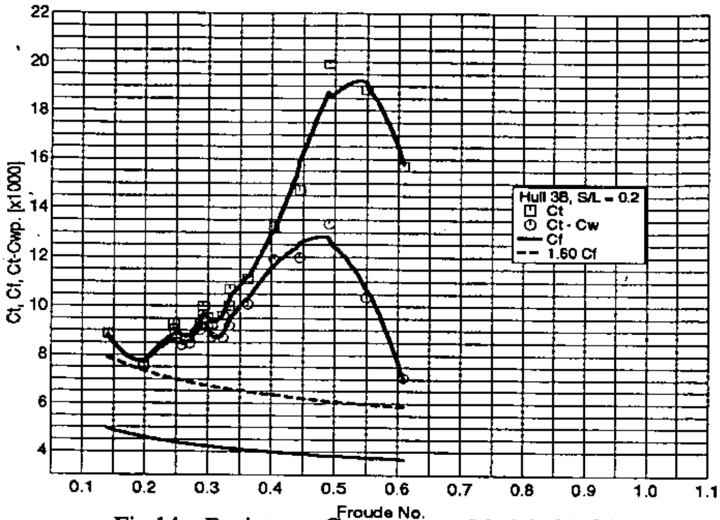


Fig 14a. Resistance Components: Models 3b, S/L = 0.2

Figure 80, Resistance componants Model 3b, S/L=0.2

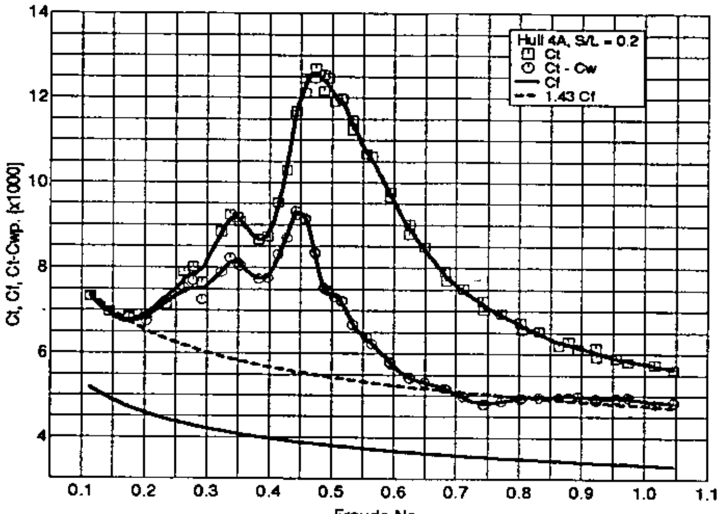


Fig 15a. Resistance Components: Models 4a, S/L = 0.2

Figure 81, Resistance componants Model 4a, S/L=0.2

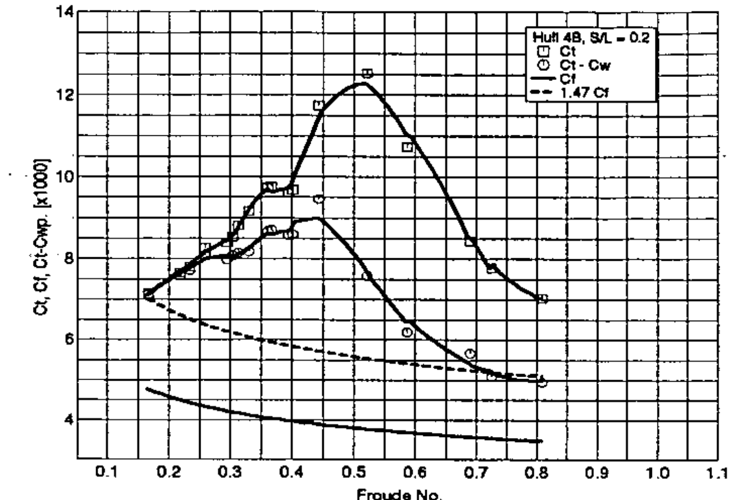


Fig 16a. Resistance Components: Models 4b, S/L = 0.2

Figure 82, Resistance componants Model 4b, S/L=0.2

XIV Weight calculation catamaran

XIV.A Weight of structure between demi-hulls

Total weight of the structure is the sum of the beams and a metal plate of 12mm thick. The problem is simplified by using a static approach of the situation and “Vergeet me nietjes”. The weight distribution is considered evenly over the length of the vessel, so the calculation is made for 1 section of the vessel of 1 meter.

Sketch 1

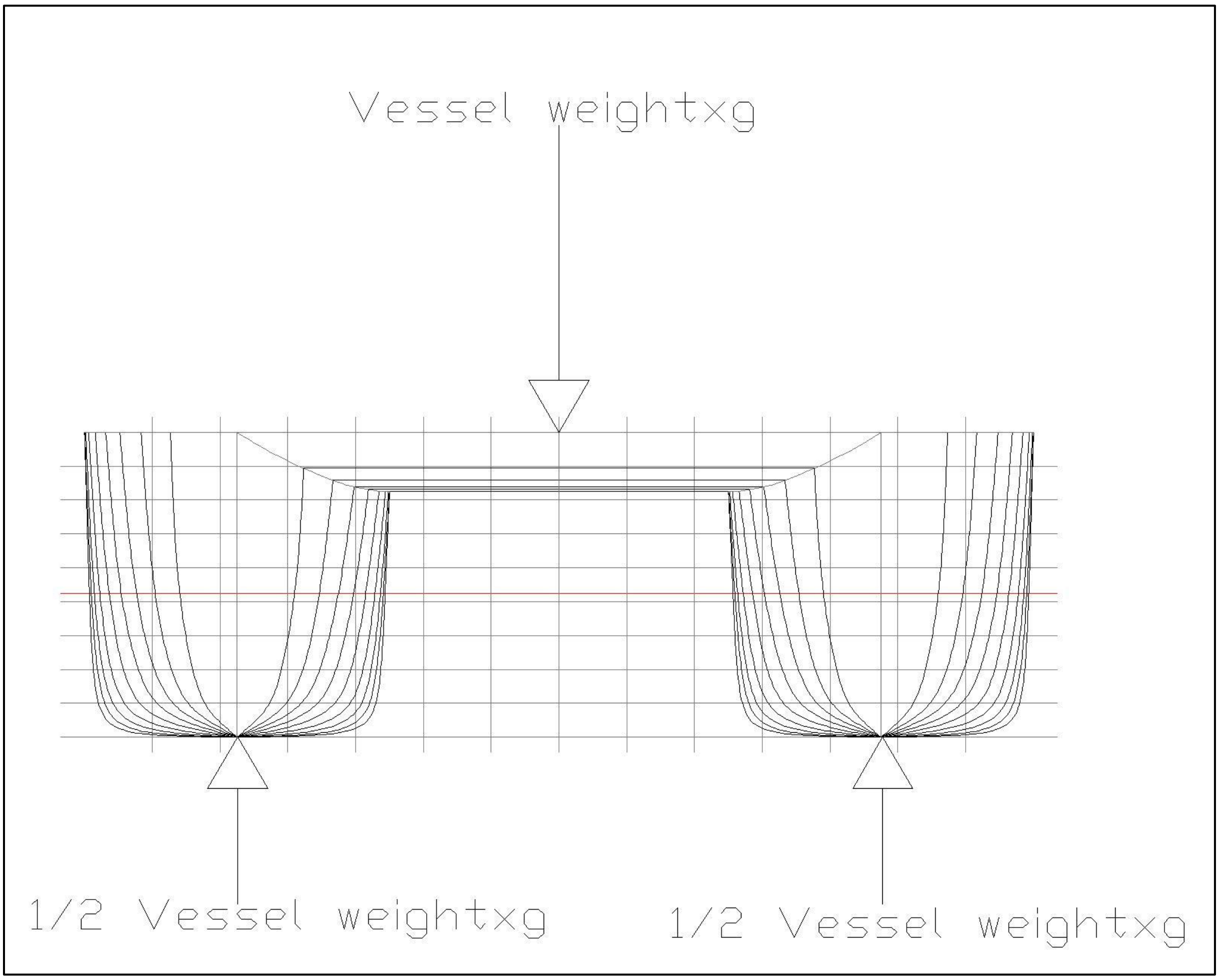


Figure 83, Equilibrium of forces on catamaran hull

Sketch 2

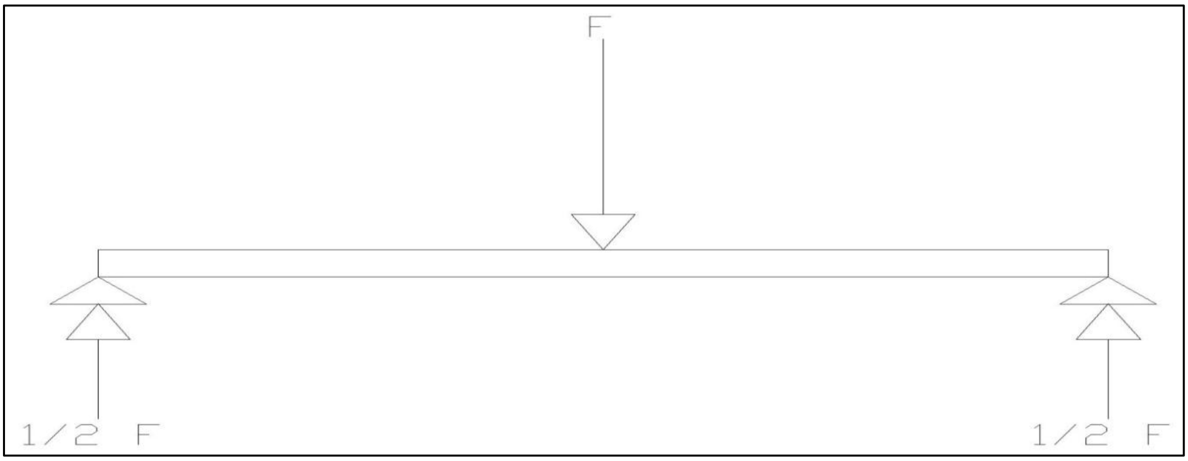


Figure 84, simplyfied equilibrium of forces on catamaran hull

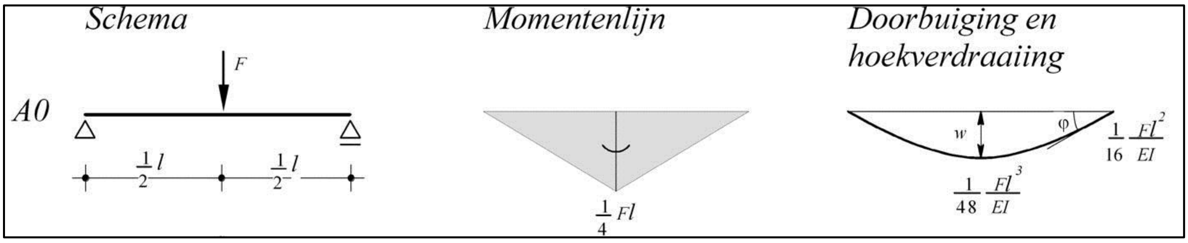


Figure 85, Vergeet me nietjes

For this calculation the deflection (w) is determined to be a maximum of 20 centimeters, this is a little over 2% of the length of the beam.

Moment of inertia of the beam:

$$I = \frac{1}{48}\frac{Fl^3}{wE} = \frac{1}{48}\frac{(36380 \cdot 9.81)\cdot(9^3)}{(0.2 \cdot 2E+11)} = 1.36E+08mm^4$$

Selected profile:

Profile nr.	HEA 1000	
G_g	277	kg/m
A	34685	mm^2
H	990	mm
B	300	mm
t_W	16.5	mm
t_f	31	mm
A_L	3.1	m^2/m
I_Y	553846	$x10^4mm^3$
W_y	11189	$x10^3mm^3$
I_Z	14004	$x10^4mm^3$
W_Z	934	$x10^3mm^3$

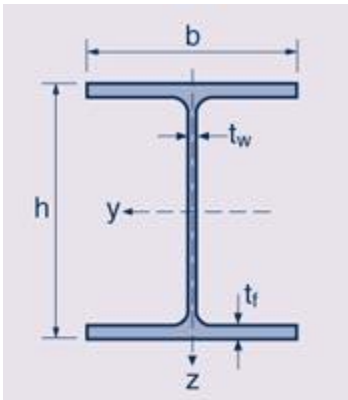


Table 60, H-profile parameters

Total weight beams:

$$1 \text{ beam} = 9 \cdot 277 = 2493kg$$

Weight of steel plate:

$$\text{Plate} = 9 \cdot 0.012 \cdot 7850 = 848kg/m$$

Total weight of the structure:

3340 kg/m

XIV.B Bare hull weight catamaran

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[m³]	[kg/m³]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
100	**Shipbuilding**							
110	Demi-hull SB		5967 m3	87 kg/m3	519,166	4.75	42.50	
110	Demi-hull PS		5967 m3	87 kg/m3	519,166	4.75	42.50	
110	MD-AD	Aluminium	2041 m3	30 kg/m3	61,236	10.90	63.75	
110	AD-BD	Aluminium	2041 m3	30 kg/m3	61,236	13.70	63.75	
110	BD-CD	Aluminium	1361 m3	30 kg/m3	40,824	16.50	58.75	
110	CD-Bridge deck	Aluminium	1361 m3	30 kg/m3	40,824	19.30	58.75	
	Total hull	Total volume	18739 m3					
		Factor	1242452 kg					
			66 kg/m3					
120	Structure between demi-hulls		85 m	3340 kg/m	283,900	9.00	42.50	
120	Wheelhouse		798 m3	48 kg/m3	38,304	22.30	63.75	
	Total superstructure	Total volume	883 m3					
		Factor	322204 kg					
			365 kg/m3					
130	Small steelwork		1564656	6.0%	93,879	7.23	45.53	
161	Paint		1658535	1.5%	24,878	7.23	45.53	
	Rolling margin & welding material		1658535	4.5%	74,634	7.23	45.53	
	Shipbuilding total				**1,758,047**	**7.23**	**45.53**	**0.00**

Table 61, Weight calculation catamaran 100

XV Extensive hydrostatics report catamaran

HYDROSTATIC PARTICULARS
FIRM Catamaran

Trim = 0.000 m 12 Jun 2013 13:42:06

Draft from base	4.000	4.100	4.200	4.300	4.400
Waterplane area	992.92	1000.95	1009.08	1017.16	1025.32
Centre of flotation	40.805	40.618	40.429	40.233	40.037
Mom. of inertia long.	431721	440547	449709	459258	469122
Mom. of inertia tran.	74455	75063	75662	76277	76894
Ton/cm immersion	10.18	10.26	10.34	10.43	10.51
Volume	3038.87	3138.51	3238.96	3340.23	3442.32
Volume & appendages	3038.87	3138.51	3238.96	3340.23	3442.32
Displacement	3114.84	3216.98	3319.94	3423.74	3528.38
Vert. Centre Buoyancy	2.304	2.359	2.415	2.470	2.526
Long. Centre Buoyancy	42.893	42.824	42.753	42.680	42.605
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	26.804	26.276	25.775	25.306	24.864
KM longitudinal	144.370	142.727	141.258	139.963	138.807
Mom change trim 1 cm	52.06	53.12	54.23	55.38	56.57
Wetted surface	1805.3	1842.4	1879.7	1917.4	1955.3
Block coefficient	0.3820	0.3849	0.3877	0.3905	0.3933
Hor.prism.coef	0.6791	0.6827	0.6862	0.6896	0.6931
Vert.prism.coef	0.7651	0.7648	0.7642	0.7637	0.7630
Midship coefficient	0.5624	0.5638	0.5651	0.5663	0.5675
Waterplane coef.	0.4992	0.5032	0.5073	0.5114	0.5155
Waterplane coef. fore	0.4643	0.4658	0.4672	0.4687	0.4701

Draft from base	4.500	4.600	4.700	4.800	4.900
Waterplane area	1033.08	1040.04	1046.39	1052.10	1057.13
Centre of flotation	39.861	39.704	39.577	39.457	39.374
Mom. of inertia long.	478937	487644	495853	503159	509738
Mom. of inertia tran.	77475	78003	78484	78920	79312
Ton/cm immersion	10.59	10.66	10.73	10.78	10.84
Volume	3545.21	3648.83	3753.13	3858.02	3963.46
Volume & appendages	3545.21	3648.83	3753.13	3858.02	3963.46
Displacement	3633.84	3740.05	3846.96	3954.47	4062.55
Vert. Centre Buoyancy	2.582	2.638	2.694	2.750	2.805
Long. Centre Buoyancy	42.528	42.450	42.372	42.294	42.218
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	24.435	24.015	23.605	23.206	22.816
KM longitudinal	137.676	136.282	134.811	133.169	131.415
Mom change trim 1 cm	57.75	58.80	59.79	60.68	61.47
Wetted surface	1993.0	2030.1	2066.7	2102.8	2138.4
Block coefficient	0.3961	0.3988	0.4015	0.4041	0.4067
Hor.prism.coef	0.6966	0.6999	0.7033	0.7066	0.7098
Vert.prism.coef	0.7626	0.7627	0.7631	0.7640	0.7652
Midship coefficient	0.5686	0.5698	0.5709	0.5719	0.5729
Waterplane coef.	0.5194	0.5229	0.5261	0.5290	0.5315
Waterplane coef. fore	0.4716	0.4729	0.4743	0.4756	0.4769

Draft from base	5.000	5.100	5.200	5.300	5.400
Waterplane area	1061.69	1065.58	1069.19	1072.51	1075.39
Centre of flotation	39.308	39.256	39.216	39.186	39.170
Mom. of inertia long.	515467	520387	524656	528420	531795
Mom. of inertia tran.	79658	79968	80245	80503	80737
Ton/cm immersion	10.88	10.92	10.96	10.99	11.02
Volume	4069.39	4175.74	4282.47	4389.55	4496.94
Volume & appendages	4069.39	4175.74	4282.47	4389.55	4496.94
Displacement	4171.12	4280.13	4389.53	4499.29	4609.37
Vert. Centre Buoyancy	2.861	2.917	2.973	3.028	3.084
Long. Centre Buoyancy	42.143	42.070	41.999	41.931	41.865
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	22.436	22.068	21.711	21.368	21.038
KM longitudinal	129.531	127.539	125.485	123.410	121.341
Mom change trim 1 cm	62.16	62.75	63.27	63.72	64.13
Wetted surface	2173.7	2208.7	2243.4	2277.9	2312.3
Block coefficient	0.4092	0.4117	0.4141	0.4164	0.4187
Hor.prism.coef	0.7130	0.7161	0.7191	0.7220	0.7249
Vert.prism.coef	0.7666	0.7684	0.7703	0.7722	0.7744
Midship coefficient	0.5739	0.5749	0.5758	0.5767	0.5776
Waterplane coef.	0.5338	0.5357	0.5376	0.5392	0.5407
Waterplane coef. fore	0.4783	0.4795	0.4809	0.4822	0.4834

Draft from base	5.500	5.600	5.700	5.800	5.900
Waterplane area	1078.42	1081.25	1083.30	1085.74	1088.13
Centre of flotation	39.151	39.147	39.148	39.152	39.144
Mom. of inertia long.	534757	537540	540095	542501	544712
Mom. of inertia tran.	80953	81155	81347	81530	81705
Ton/cm immersion	11.05	11.08	11.10	11.13	11.15
Volume	4604.63	4712.58	4820.80	4929.25	5037.94
Volume & appendages	4604.63	4712.58	4820.80	4929.25	5037.94
Displacement	4719.74	4830.40	4941.32	5052.48	5163.89
Vert. Centre Buoyancy	3.139	3.194	3.249	3.304	3.359
Long. Centre Buoyancy	41.802	41.741	41.683	41.627	41.574
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	20.720	20.415	20.124	19.844	19.577
KM longitudinal	119.274	117.259	115.284	113.362	111.481
Mom change trim 1 cm	64.49	64.82	65.13	65.42	65.69
Wetted surface	2346.6	2380.8	2414.9	2449.0	2483.1
Block coefficient	0.4209	0.4231	0.4252	0.4273	0.4293
Hor.prism.coef	0.7277	0.7304	0.7330	0.7356	0.7381
Vert.prism.coef	0.7763	0.7783	0.7807	0.7828	0.7847
Midship coefficient	0.5785	0.5793	0.5801	0.5809	0.5817
Waterplane coef.	0.5422	0.5436	0.5446	0.5459	0.5471
Waterplane coef. fore	0.4847	0.4859	0.4871	0.4885	0.4897

Draft from base	6.000	6.100	6.200	6.300	6.400
Waterplane area	1090.33	1092.43	1094.58	1096.53	1098.54
Centre of flotation	39.144	39.160	39.169	39.183	39.187
Mom. of inertia long.	546830	548959	550944	552925	554743
Mom. of inertia tran.	81870	82033	82190	82339	82487
Ton/cm immersion	11.18	11.20	11.22	11.24	11.26
Volume	5146.85	5255.98	5365.31	5474.85	5584.59
Volume & appendages	5146.85	5255.98	5365.31	5474.85	5584.59
Displacement	5275.52	5387.38	5499.45	5611.72	5724.20
Vert. Centre Buoyancy	3.414	3.469	3.524	3.578	3.633
Long. Centre Buoyancy	41.523	41.473	41.426	41.381	41.338
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	19.321	19.076	18.842	18.618	18.403
KM longitudinal	109.660	107.914	106.210	104.572	102.967
Mom change trim 1 cm	65.94	66.20	66.44	66.68	66.90
Wetted surface	2517.2	2551.3	2585.3	2619.3	2653.4
Block coefficient	0.4313	0.4332	0.4351	0.4369	0.4387
Hor.prism.coef	0.7404	0.7428	0.7450	0.7473	0.7494
Vert.prism.coef	0.7867	0.7887	0.7906	0.7925	0.7943
Midship coefficient	0.5825	0.5832	0.5840	0.5847	0.5854
Waterplane coef.	0.5482	0.5492	0.5503	0.5513	0.5523
Waterplane coef. fore	0.4909	0.4922	0.4933	0.4946	0.4959

Draft from base	6.500
Waterplane area	1100.29
Centre of flotation	39.200
Mom. of inertia long.	556571
Mom. of inertia tran.	82630
Ton/cm immersion	11.28
Volume	5694.52
Volume & appendages	5694.52
Displacement	5836.88
Vert. Centre Buoyancy	3.687
Long. Centre Buoyancy	41.297
Trans.Centre Buoyancy	0.000
KM transverse	18.197
KM longitudinal	101.425
Mom change trim 1 cm	67.12
Wetted surface	2687.4
Block coefficient	0.4405
Hor.prism.coef	0.7515
Vert.prism.coef	0.7962
Midship coefficient	0.5861
Waterplane coef.	0.5532
Waterplane coef. fore	0.4972

XVI Intact stability calculations catamaran

TRIM AND STABILITY CALCULATION
FIRM Catamaran

13 Jun 2013 15:30:46

Condition : crane operation + 650t deadweight + 250t deck load

Description	Weight	VCG	LCG	TCG	FSM
	ton	m	m	m	tonm
Empty ship	3769.000	7.600	41.711	0.000	0.000
Subtotals for group : Ballast water					
FP SB	124.939	3.400	78.851	8.446	32.356
FP PS	124.939	3.400	78.851	-8.446	32.356
SUBTOTAL	249.879	3.400	78.851	0.000	64.712
Subtotals for group : Crew and stores					
Crew and stores	17.000	14.000	60.000	0.000	0.000
SUBTOTAL	17.000	14.000	60.000	0.000	0.000
Subtotals for group : Deck load					
Deck load 250t	250.000	10.500	15.000	0.000	0.000
SUBTOTAL	250.000	10.500	15.000	0.000	0.000
Subtotals for group : Crane					
Crane load	100.000	28.500	15.000	-23.000	0.000
Crane boom	50.000	26.500	15.000	-15.000	0.000
SUBTOTAL	150.000	27.833	15.000	-20.333	0.000
Deadweight	650.000	4.000	42.500	0.000	0.000
TOTAL	**5085.879**	**7.694**	**41.597**	**-0.600**	**64.712**

Hydrostatics		
Volume	4962.121	m^3
LCF	39.152	m
Mom. change trim	65.504	tonm/cm
Ton/cm immersion	11.135	ton/cm
Specific weight	1.025	ton/m^3

Drafts and trim		
Drafts above base :		
Draft mean (Lpp/2)	5.830	m
Draft aft (App)	5.835	m
Draft fore (Fpp)	5.824	m
Trim	-0.011	m

Transverse stability		
KM transverse	19.762	m
VCG	7.694	m
GM solid	12.068	m
GG' correction	0.013	m
G'M liquid	12.055	m

VCG' 7.707 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(PS) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	5.830	-0.011	0.000	0.000	0.600	-0.600	0.000
2.00	5.829	-0.011	0.690	0.269	0.599	-0.178	0.000
5.00	5.823	-0.009	1.726	0.672	0.597	0.457	0.009
8.00	5.812	0.002	2.762	1.073	0.594	1.096	0.049
10.00	5.800	0.022	3.453	1.338	0.591	1.524	0.095
15.00	5.750	0.141	5.175	1.995	0.579	2.601	0.275
20.00	5.694	0.371	6.829	2.636	0.564	3.630	0.549
25.00	5.822	0.796	7.980	3.257	0.544	4.180	0.893
30.00	6.109	1.283	8.684	3.853	0.519	4.311	1.266
35.00	6.461	1.910	9.118	4.421	0.491	4.206	1.639
40.00	6.843	2.811	9.356	4.954	0.459	3.943	1.995
50.00	7.492	6.068	9.364	5.904	0.385	3.075	2.614
60.00	7.164	9.394	8.826	6.674	0.300	1.851	3.047
70.00	6.177	14.877	7.983	7.242	0.205	0.536	3.255

Statical angle of inclination is 2.845 degrees to portside

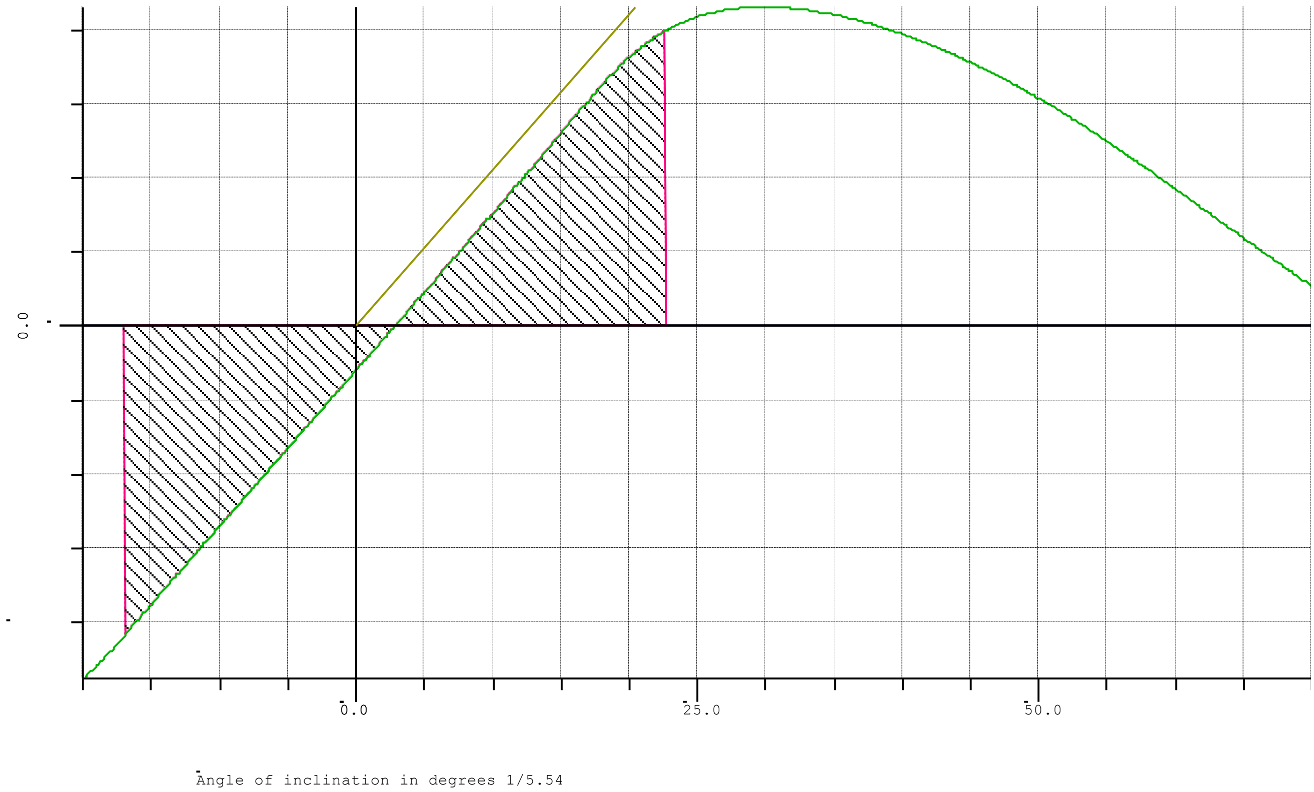
Summary

Hydrostatics	Criterion	Value
Draft mld.	6.000	5.830 m
Trim -0.011 m		
Statical angle of inclination 2.84 degrees PS		

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	12.055 meter
Maximum GZ at 30 degrees or more	0.200	4.311 meter
Top of the GZ curve at least at	15.000	29.800 degrees
Area under GZ curve up to top of the curve (Supply vessel criterion)	0.055	1.251
Area under the GZ curve between 30 and 40 degrees	0.030	0.730 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	22.649 degrees
Maximum statical angle due to wind	16.000	2.845 degrees
Maximum statical angle 80% of angle of deck immersion	13.753	2.845 degrees

VCG'

A non-zero statical angle of equilibrium occurs,
No maximum allowable VCG' is calculated.
Loading condition complies with the stated criteria.



0.0
0.0
25.0
50.0
Angle of inclination in degrees 1/5.54

XVII Design hydrostatics report final design.

Design length	120.00	(m)	Midship location	60.000	(m)
Length over all	120.00	(m)	Relative water density	1.025	
Design beam	21.000	(m)	Mean shell thickness	0.0000	(m)
Maximum beam	21.000	(m)	Appendage coefficient	1.0000	
Design draught	5.800	(m)			

Volume properties			Waterplane properties		
Moulded volume	6619.2	(m^3)	Length on waterline	120.00	(m)
Total displaced volume	6619.2	(m^3)	Beam on waterline	19.375	(m)
Displacement	6784.6	(tonnes)	Entrance angle	40.067	(Degr.)
Block coefficient	0.4529		Waterplane area	1781.5	(m^2)
Prismatic coefficient	0.6755		Waterplane coefficient	0.7069	
Vert. prismatic coefficient	0.6406		Waterplane center of floatation	49.701	(m)
Wetted surface area	2497.7	(m^2)	Transverse moment of inertia	43610	(m^4)
Longitudinal center of buoyancy	56.409	(m)	Longitudinal moment of inertia	1566398	(m^4)
Longitudinal center of buoyancy	-2.992	%			
Vertical center of buoyancy	3.509	(m)			

Midship properties			Initial stability		
Midship section area	81.656	(m^2)	Transverse metacentric height	10.097	(m)
Midship coefficient	0.6704		Longitudinal metacentric height	240.15	(m)

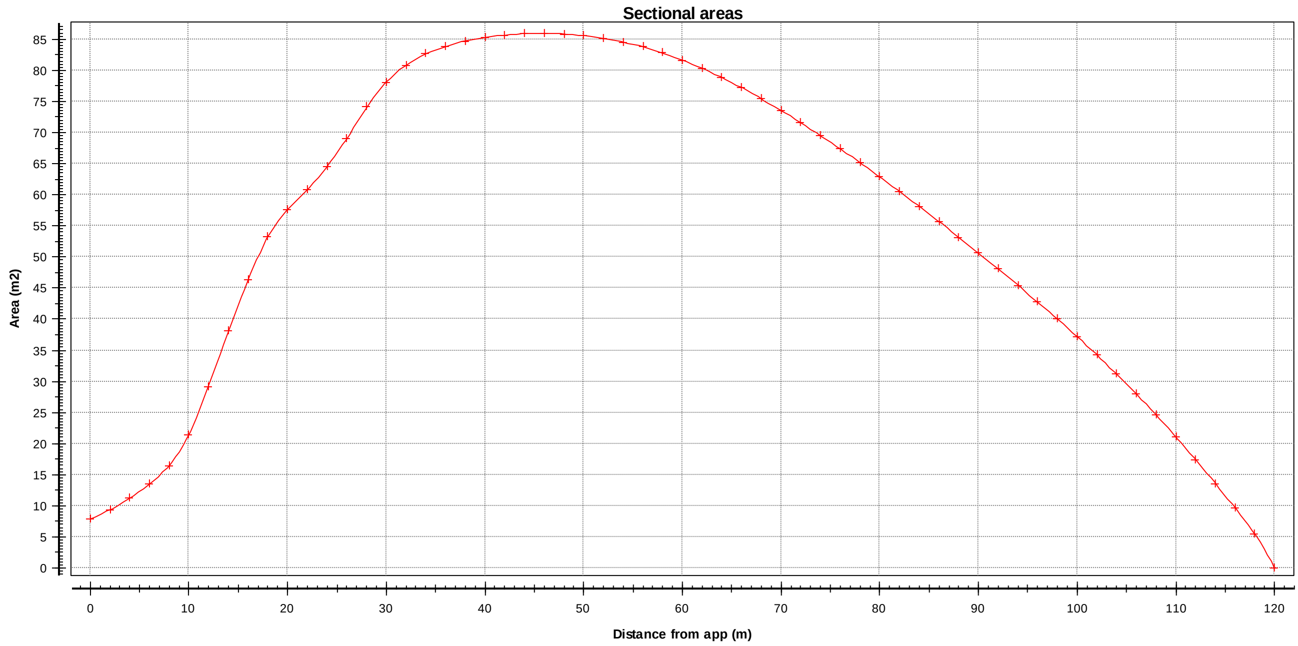
Lateral plane		
Lateral area	655.61	(m^2)
Longitudinal center of effort	63.321	(m)
Vertical center of effort	2.916	(m)

The following layer properties are calculated for both sides of the ship

Location	Area *(m^2)*	Thickness	Weight *(tonnes)*	VCG *(m)*	LCG *(m)*	TCG *(m)*
Layer 0	4295.0	0.000	0.000	5.439	59.983	0.000 (CL)

Sectional areas

Location *(m)*	Area *(m^2)*	Location *(m)*	Area *(m^2)*	Location *(m)*	Area *(m^2)*	Location *(m)*	Area *(m^2)*	Location *(m)*	Area *(m^2)*
0.000	7.814	26.000	69.115	52.000	85.141	78.000	65.153	104.000	31.167
2.000	9.370	28.000	74.110	54.000	84.552	80.000	62.869	106.000	27.950
4.000	11.200	30.000	78.085	56.000	83.780	82.000	60.522	108.000	24.600
6.000	13.484	32.000	80.823	58.000	82.813	84.000	58.109	110.000	21.071
8.000	16.448	34.000	82.640	60.000	81.656	86.000	55.653	112.000	17.400
10.000	21.424	36.000	83.872	62.000	80.324	88.000	53.157	114.000	13.584
12.000	29.133	38.000	84.722	64.000	78.832	90.000	50.624	116.000	9.615
14.000	38.118	40.000	85.299	66.000	77.196	92.000	48.049	118.000	5.454
16.000	46.336	42.000	85.679	68.000	75.432	94.000	45.428	120.000	0.000
18.000	53.212	44.000	85.886	70.000	73.551	96.000	42.754		
20.000	57.608	46.000	85.932	72.000	71.570	98.000	40.005		
22.000	60.837	48.000	85.824	74.000	69.507	100.000	37.167		
24.000	64.568	50.000	85.562	76.000	67.367	102.000	34.226		



NOTE 1: Draught (and all other vertical heights) is measured above base Z=
NOTE 2: All calculated coefficients based on project length, draught and beam.

XVIII Extensive hydrostatics report final design

HYDROSTATIC PARTICULARS
FIRM

Trim = 0.000 m

Draft from base	4.500	4.600	4.700	4.800	4.900
Waterplane area	1499.95	1522.95	1547.41	1575.34	1603.56
Centre of flotation	51.894	51.473	51.017	50.430	49.856
Mom. of inertia long.	1071093	1104254	1141854	1184899	1233486
Mom. of inertia tran.	31484	32266	33080	33930	34823
Ton/cm immersion	15.37	15.61	15.86	16.15	16.44
Volume	4477.94	4628.95	4782.34	4938.34	5097.17
Volume & appendages	4477.94	4628.95	4782.34	4938.34	5097.17
Displacement	4589.89	4744.67	4901.89	5061.80	5224.60
Vert. Centre Buoyancy	2.695	2.755	2.816	2.877	2.939
Long. Centre Buoyancy	55.710	55.580	55.441	55.293	55.133
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	9.726	9.726	9.733	9.748	9.771
KM longitudinal	241.888	241.309	241.581	242.816	244.933
Mom change trim 1 cm	93.84	96.74	100.03	103.81	108.06
Wetted surface	2015.3	2052.7	2092.4	2134.5	2177.6
Block coefficient	0.4050	0.4096	0.4141	0.4187	0.4234
Hor.prism.coef	0.6214	0.6238	0.6264	0.6290	0.6319
Vert.prism.coef	0.6634	0.6608	0.6576	0.6531	0.6487
Midship coefficient	0.6518	0.6565	0.6612	0.6657	0.6700
Waterplane coef.	0.6105	0.6198	0.6298	0.6412	0.6527
Waterplane coef. fore	0.4872	0.4903	0.4933	0.4962	0.4990

Draft from base	5.000	5.100	5.150	5.200	5.300
Waterplane area	1629.88	1654.98	1666.99	1678.17	1699.37
Centre of flotation	49.336	48.869	48.648	48.450	48.089
Mom. of inertia long.	1283376	1330067	1352087	1372970	1412078
Mom. of inertia tran.	35766	36750	37261	37774	38809
Ton/cm immersion	16.71	16.96	17.09	17.20	17.42
Volume	5258.73	5422.88	5505.87	5589.44	5758.23
Volume & appendages	5258.73	5422.88	5505.87	5589.44	5758.23
Displacement	5390.20	5558.45	5643.51	5729.17	5902.18
Vert. Centre Buoyancy	3.001	3.063	3.094	3.125	3.187
Long. Centre Buoyancy	54.964	54.787	54.696	54.604	54.419
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	9.802	9.839	9.861	9.883	9.927
KM longitudinal	247.047	248.332	248.666	248.761	248.415
Mom change trim 1 cm	112.43	116.52	118.45	120.28	123.71
Wetted surface	2219.3	2259.6	2279.3	2298.5	2335.5
Block coefficient	0.4281	0.4328	0.4351	0.4375	0.4422
Hor.prism.coef	0.6348	0.6378	0.6394	0.6410	0.6441
Vert.prism.coef	0.6453	0.6425	0.6413	0.6405	0.6393
Midship coefficient	0.6743	0.6785	0.6805	0.6826	0.6865
Waterplane coef.	0.6634	0.6736	0.6785	0.6830	0.6916
Waterplane coef. fore	0.5017	0.5045	0.5058	0.5070	0.5095

Draft from base	5.400	5.500	5.600	5.700	5.800
Waterplane area	1718.31	1735.01	1749.51	1763.77	1775.93
Centre of flotation	47.792	47.572	47.377	47.196	47.072
Mom. of inertia long.	1446869	1476746	1502389	1524745	1544233
Mom. of inertia tran.	39825	40796	41725	42617	43466
Ton/cm immersion	17.61	17.78	17.93	18.08	18.20
Volume	5929.03	6101.63	6275.82	6451.43	6628.35
Volume & appendages	5929.03	6101.63	6275.82	6451.43	6628.35
Displacement	6077.26	6254.17	6432.71	6612.72	6794.05
Vert. Centre Buoyancy	3.249	3.312	3.374	3.436	3.498
Long. Centre Buoyancy	54.233	54.047	53.865	53.686	53.511
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	9.966	9.998	10.022	10.042	10.055
KM longitudinal	247.281	245.337	242.767	239.778	236.472
Mom change trim 1 cm	126.76	129.37	131.62	133.58	135.29
Wetted surface	2370.4	2403.4	2434.7	2464.8	2493.8
Block coefficient	0.4469	0.4515	0.4561	0.4607	0.4651
Hor.prism.coef	0.6473	0.6504	0.6535	0.6566	0.6596
Vert.prism.coef	0.6390	0.6394	0.6406	0.6417	0.6435
Midship coefficient	0.6904	0.6942	0.6979	0.7016	0.7052
Waterplane coef.	0.6994	0.7061	0.7121	0.7179	0.7228
Waterplane coef. fore	0.5120	0.5144	0.5167	0.5189	0.5212

Draft from base	5.900	6.000	6.100	6.200	6.300
Waterplane area	1787.40	1797.80	1807.57	1817.38	1826.42
Centre of flotation	46.959	46.861	46.816	46.735	46.695
Mom. of inertia long.	1561180	1576227	1589735	1601926	1613256
Mom. of inertia tran.	44275	45052	45798	46521	47225
Ton/cm immersion	18.32	18.43	18.53	18.63	18.72
Volume	6806.45	6985.65	7165.87	7347.06	7529.18
Volume & appendages	6806.45	6985.65	7165.87	7347.06	7529.18
Displacement	6976.61	7160.29	7345.02	7530.74	7717.41
Vert. Centre Buoyancy	3.559	3.620	3.682	3.742	3.803
Long. Centre Buoyancy	53.341	53.177	53.017	52.864	52.715
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	10.064	10.070	10.073	10.074	10.075
KM longitudinal	232.927	229.258	225.530	221.779	218.070
Mom change trim 1 cm	136.77	138.09	139.27	140.34	141.33
Wetted surface	2521.9	2549.4	2576.3	2602.9	2629.2
Block coefficient	0.4695	0.4739	0.4781	0.4823	0.4864
Hor.prism.coef	0.6625	0.6654	0.6682	0.6709	0.6736
Vert.prism.coef	0.6454	0.6476	0.6499	0.6520	0.6543
Midship coefficient	0.7087	0.7121	0.7155	0.7189	0.7221
Waterplane coef.	0.7275	0.7317	0.7357	0.7397	0.7434
Waterplane coef. fore	0.5234	0.5256	0.5276	0.5298	0.5317

Draft from base	6.400	6.500	6.600	6.700	6.800
Waterplane area	1834.47	1843.65	1851.81	1859.57	1867.68
Centre of flotation	46.659	46.594	46.577	46.541	46.517
Mom. of inertia long.	1622776	1633661	1642177	1651169	1659943
Mom. of inertia tran.	47911	48585	49257	49909	50561
Ton/cm immersion	18.80	18.90	18.98	19.06	19.14
Volume	7712.19	7896.05	8080.75	8266.27	8452.58
Volume & appendages	7712.19	7896.05	8080.75	8266.27	8452.58
Displacement	7905.00	8093.45	8282.77	8472.93	8663.89
Vert. Centre Buoyancy	3.864	3.924	3.984	4.044	4.103
Long. Centre Buoyancy	52.572	52.433	52.300	52.171	52.047
Trans.Centre Buoyancy	0.000	0.000	0.000	0.000	0.000
KM transverse	10.076	10.077	10.079	10.081	10.085
KM longitudinal	214.281	210.820	207.205	203.791	200.486
Mom change trim 1 cm	142.17	143.12	143.87	144.65	145.42
Wetted surface	2655.2	2681.1	2706.9	2732.5	2758.0
Block coefficient	0.4904	0.4944	0.4983	0.5021	0.5059
Hor.prism.coef	0.6761	0.6786	0.6810	0.6834	0.6856
Vert.prism.coef	0.6569	0.6589	0.6612	0.6635	0.6655
Midship coefficient	0.7254	0.7286	0.7317	0.7348	0.7379
Waterplane coef.	0.7466	0.7504	0.7537	0.7568	0.7601
Waterplane coef. fore	0.5339	0.5359	0.5379	0.5399	0.5418

Draft from base	6.900	7.000
Waterplane area	1876.07	1882.62
Centre of flotation	46.469	46.467
Mom. of inertia long.	1668172	1676704
Mom. of inertia tran.	51211	51855
Ton/cm immersion	19.23	19.30
Volume	8639.68	8827.56
Volume & appendages	8639.68	8827.56
Displacement	8855.67	9048.25
Vert. Centre Buoyancy	4.163	4.222
Long. Centre Buoyancy	51.927	51.811
Trans.Centre Buoyancy	0.000	0.000
KM transverse	10.090	10.096
KM longitudinal	197.245	194.162
Mom change trim 1 cm	146.14	146.89
Wetted surface	2783.5	2808.8
Block coefficient	0.5096	0.5133
Hor.prism.coef	0.6878	0.6899
Vert.prism.coef	0.6674	0.6699
Midship coefficient	0.7409	0.7439
Waterplane coef.	0.7636	0.7662
Waterplane coef. fore	0.5440	0.5459

XIX Weight calculation final design

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg/m3]	[kg]	[m]	[m]	[m]
			[m3]			AB	fr 0	SB = +
100	**Shipbuilding**							
110	Hull		21600 m3	87 kg/m3	1,879,200	5.50	56.00	
110	Skeg		2 m3	7850 kg/m3	14,036	2.25	14.50	
110	MD-AD		4645 m3	50 kg/m3	232,260	10.50	71.00	
110	AD-BD		4704 m3	50 kg/m3	235,200	13.30	71.00	
	Total hull	Total volume	30951 m3					
		Factor	2360696 kg					
			76 kg/m3					
120	BD-CD	Aluminium	2352 m3	30 kg/m3	70,560	16.10	71.00	
120	CD-Bridge deck	Aluminium	1882 m3	30 kg/m3	56,448	18.90	67.00	
120	Wheelhouse	Aluminium	798 m3	48 kg/m3	38,304	23.50	61.00	
120	Funnel		0 m3		0			
	Total superstructure	Total volume	5032 m3					
		Factor	165312 kg					
			33 kg/m3					
130	Small steelwork		2526008	6.0%	151,560	7.54	59.29	
161	Paint		2677568	1.5%	40,164	7.54	59.29	
161	Rolling margin & welding material		2677568	4.5%	120,491	7.54	59.29	
	Shipbuilding total				**2,838,222**	**7.54**	**59.29**	**0.0**

Table 62, Weight calculation final design 100

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
200	**Main machinery**							
211	Main engines	Wärtsila 8L38	4	63000	252,000	4.00	38.00	
212	Gearboxes	Single in twin out	2	32000	64,000	3.50	30.00	
213	Propellers	5350mm CPP	2	14500	29,000	0.50	1.60	
213	Shafts & stern tubes		2	40000	80,000	2.00	13.00	
213	Seals & bearings		2	2500	5,000	2.00	13.00	
221	Rudders		2	15000	30,000	1.80	0.00	
222	Steering gear		2	5000	10,000	6.00	0.00	
223	Bow thruster - 1	1500 kW	1	10600	10,600	1.50	107.00	
223	Bow thruster - 2	1500 kW	1	10600	10,600	1.50	103.50	
223	Sternthruster - 1	1500 kW	1	10600	10,600	2.00	16.50	
223	Stern thruster - 2	1500 kW	1	10600	10,600	2.00	13.00	
223	E motor bow thruster - 1	1500 kW	1	8000	8,000	3.50	107.00	
223	E motor bow thruster - 2	1500 kW	1	8000	8,000	3.50	103.50	
223	E motor sternthruster - 1	1500 kW	1	8000	8,000	4.00	16.50	
223	E motor stern thruster - 2	1500 kW	1	8000	8,000	4.00	13.00	
223	Drive bow thruster - 1		1	2000	2,000	3.50	107.00	
223	Drive bow thruster - 2		1	2000	2,000	3.50	103.50	
223	Drive sternthruster - 1		1	2000	2,000	4.00	16.50	
223	Drive stern thruster - 2		1	2000	2,000	4.00	13.00	
256	Bottom doors	Incl 110	0	15000	0	2.00	46.90	
	Main machinery total				**552.400**	**3.18**	**31.85**	**0.00**

Table 63, Weight calculation final design 200

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
300	**Primary ship systems**							
310	Bilge ballast piping		1	25000	25,000	4.50	55.00	
310	Fifi piping		1	7500	7,500	9.50	58.00	
320	Fuel oil piping		1	10000	10,000	4.00	45.00	
330	Cooling water piping		1	20000	20,000	3.00	48.00	
340	Fresh water piping		1	2000	2,000	12.50	75.00	
340	Sewage piping		1	8000	8,000	12.50	75.00	
340	Deck scupper piping		1	5000	5,000	12.00	58.00	
350	Tank sounding/filling piping		1	17500	17,500	7.00	58.00	
360	Lub oil piping		1	8000	8,000	4.00	47.00	
380	Exhaust piping ER		2	4000	8,000	12.00	50.00	
380	Exhaust piping PR		4	3500	14,000	15.00	57.00	
390	Miscellaneous piping		1	20000	20,000	5.50	58.00	
300	System fillings		145,000	20%	29,000	7.17	55.23	
300	Appendages		145,000	20%	29,000	7.17	55.23	0.00
					0			0.00
310	Bilge ballast equipment		1	2000	2,000	4.50	55.00	
310	Fifi equipment		1	1000	1,000	9.50	58.00	
320	Fuel oil equipment		1	3000	3,000	4.00	45.00	
330	Cooling water equipment		1	12000	12,000	3.00	48.00	
340	Fresh water equipment		1	3000	3,000	12.50	75.00	
340	Sewage plant		1	6000	6,000	4.00	75.00	
340	Other sewage equipment		1	1000	1,000	4.50	83.00	
350	Tank sounding/filling equipment		1	1000	1,000	7.00	58.00	
360	Lub oil equipment		1	2500	2,500	4.00	47.00	
370	HVAC piping (spiro)		1	10000	10,000	15.00	75.00	
370	HVAC unit		1	6500	6,500	15.00	55.00	
370	Other HVAC equipment		1	3000	3,000	15.00	95.00	
380	Exhaust equipment		6	2500	15,000	13.00	48.00	
390	Remaining primary ship systems		1	15000	15,000	5.50	58.00	
	Primary ship systems total				**284,000**	**7.66**	**56.36**	

Table 64, Weight calculation final design 300

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
400	**Electrical system**							
410	Generator set	Wartsila 8L20	2	20700	41,400	4.50	56.00	
410	Generator set	Wartsila 8L26	2	45000	90,000	4.50	56.00	
410	Emergency set	Cat C18	1	1905	1,905	19.00	54.00	
420	Cables & cable trays below main deck		1	32000	32,000	6.00	55.00	
420	Cables & cable trays above maindeck		1	22000	22,000	14.00	55.00	
430	Main switchboard		4	5500	22,000	7.50	65.00	
430	Other switchboards		1	10000	10,000	7.50	65.00	
450	Lighting		1	3000	3,000	15.00	70.00	
490	Remaining items		1	15000	15,000	9.50	58.00	
	Electrical system total				**237,305**	**6.55**	**57.27**	

Table 65, Weight calculation final design 400

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
500	**Deck equipment**							
510	Anchor winch		1	5000	5,000	13.50	108.00	
510	Anchors		2	3000	6,000	11.50	113.00	
510	Chain		1	25000	25,000	7.50	110.00	
510	Chain stoppers		2	650	1,300	12.50	111.00	
510	Mooring winches aft		2	6000	12,000	10.00	2.00	
520	Capstans aft		2	1200	2,400	10.00	2.00	
540	Deck crane (subsea execution)		1	275000	275,000	18.20	20.00	-5.50
540	Deck crane Pedestal	Incl			0			
540	Deck crane counter ballast		1	189000	189,000	6.00	20.00	8.00
540	Store crane		1	5000	5,000	15.50	94.50	
550	Tugger winches		2	4000	8,000	10.00	38.50	
560	ROV Davit		1	15000	15,000	12.50	56.00	
570	Fast rescue boat + davit		1	8000	8,000	13.50	49.70	
570	Life boat + davits		2	10000	20,000	16.50	66.50	
570	MOB boat + davit		1	2000	2,000	12.50	42.00	
570	life rafts		6	500	3,000	9.50	41.00	
590	Remaining items		1	15000	15,000	9.00	58.00	
	Deck equipment total				**591,700**	**12.84**	**30.16**	

Table 66, Weight calculation final design 500

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
600	**Secondary ship systems**							
610	Hydraulic piping		1	5000	5,000	10.00	40.00	
620	Compressed air piping		6	2000	12,000	8.50	45.00	
660	Pre-wetting piping	Local protection	1	3000	3,000	4.50	45.00	
670	CO2 piping		1	1000	1,000	10.00	45.00	
680	Cold & freeze piping		1	1000	1,000	10.50	64.50	
680	Remaining systems		1	10000	10,000	5.00	50.00	0.00
600	System fillings		22,000	20%	4,400	8.45	44.75	0.00
600	Appendages		22,000	20%	4,400	8.45	44.75	
					0			
610	Hydraulic equipment		1	5000	5,000	10.50	45.50	
620	Compressed air equipment		1	3000	3,000	7.50	40.00	
670	CO2 equipment		1	1000	1,000	11.00	42.00	
680	Cold & freeze equipment		1	1500	1,500	10.50	64.50	
	Secondary ship systems total				51,300	8.03	46.09	

Table 67, Weight calculation final design 600

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[m2]	[kg/m2]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
700	**Joinery and arrangement of accommodation**							
710	Joinery main deck		650 m2	150	97,500	10.00	77.00	
710	Joinery A - deck		650 m2	150	97,500	12.80	75.00	
710	Joinery B - deck		450 m2	120	54,000	15.60	75.00	
710	Joinery C - deck		450 m2	120	54,000	18.40	72.50	
710	Joinery bridge deck		190 m2	100	19,000	22.50	59.50	
730	Floor plates	Steel	250 m2	43	10,750	4.00	58.00	
	Joinery and arrangement of accommodation total				**332.750**	**13,61**	**73,75**	

Table 68, Weight calculation final design 700

Code	Description		Number	Weight	Weight	VCG	LCG	TCG
			[-]	[kg]	[kg]	[m]	[m]	[m]
						AB	fr 0	SB = +
800	**Nautical, navigation and communication equipment**							
			1	3000	3,000	22.50	60.00	
	Nautical, navigation and communication equipment total				**3,000**	**22.50**	**60.00**	

Table 69, Weight calculation final design 800

TRIM AND STABILITY CALCULATION
FIRM

14 Jun 2013 15:18:44

Condition : 1.1 Light service draft, Departure 100t deckload

Description		Weight	VCG	LCG	TCG	FSM
		ton	m	m	m	tonm
Empty ship		5135.000	8.370	53.241	0.000	0.000
Subtotals for group : Ballast water						
BW FP	155-fwd	0.000	0.002	110.300	0.000	0.000
BW DB CT	133-145	0.000	-0.000	97.190	0.000	0.000
BW DB SB	124-133	0.000	-0.000	89.889	0.106	0.000
BW DB PS	124-133	0.000	-0.000	89.889	-0.106	0.000
BW WT SB	124-133	0.000	2.500	90.007	3.360	0.000
BW WT PS	124-133	0.000	2.500	90.007	-3.360	0.000
BW DB SB	112-124	0.000	-0.000	82.495	0.118	0.000
BW DB PS	112-124	0.000	-0.000	82.495	-0.118	0.000
BW WT SB	112-124	0.000	2.500	82.749	4.281	0.000
BW WT PS	112-124	0.000	2.500	82.749	-4.281	0.000
BW DB SB	100-112	0.000	-0.000	74.152	0.131	0.000
BW DB PS	100-112	0.000	-0.000	74.152	-0.131	0.000
BW WT SB	100-112	0.000	2.500	73.849	5.053	0.000
BW WT PS	100-112	0.000	2.500	73.849	-5.053	0.000
BW DB SB	88-100	0.000	-0.000	65.835	0.137	0.000
BW DB PS	88-100	0.000	-0.000	65.835	-0.137	0.000
BW WT SB	88-100	0.000	2.500	65.579	5.452	0.000
BW WT PS	88-100	0.000	2.500	65.579	-5.452	0.000
BW DB SB	73-88	0.000	-0.000	56.254	0.136	0.000
BW DB PS	73-88	0.000	-0.000	56.254	-0.136	0.000
BW WT SB	73-88	0.000	2.500	56.485	7.076	0.000
BW WT PS	73-88	0.000	2.500	56.485	-7.076	0.000
BW DB SB	61-73	0.000	-0.000	48.739	0.137	0.000
BW DB PS	61-73	0.000	-0.000	48.739	-0.137	0.000
BW WT SB	61-73	0.000	2.500	46.740	7.419	0.000
BW WT PS	61-73	0.000	2.500	46.740	-7.419	0.000
BW DB SB	49-61	0.000	0.015	42.024	0.203	0.000
BW DB PS	49-61	0.000	0.015	42.024	-0.203	0.000
BW WT SB	49-61	0.000	2.500	38.458	7.466	0.000
BW WT PS	49-61	0.000	2.500	38.458	-7.466	0.000
BW DB SB	37-49	0.000	0.123	34.063	0.144	0.000
BW DB PS	37-49	0.000	0.123	34.063	-0.144	0.000
BW WT SB	37-49	0.000	2.500	30.454	7.408	0.000
BW WT PS	37-49	0.000	2.500	30.454	-7.408	0.000
BW SB	4-19	0.000	5.750	8.540	8.034	0.000
BW PS	4-19	0.000	5.750	8.540	-8.034	0.000
BW SB	-4-4	0.000	4.761	-1.533	0.033	0.000
BW PS	-4-4	0.000	4.761	-1.533	-0.033	0.000
SUBTOTAL		0.000	0.000	0.000	0.000	0.000

Subtotals for group : Fuel oil

FO CT	124-133	84.241	4.092	89.765	0.000	0.000	!
FO CT	112-124	0.000	2.500	82.367	0.000	0.000	
FO CT	100-112	185.000	4.092	74.200	0.000	341.545	!
FO CT	88-100	0.000	2.500	65.800	0.000	0.000	
FO SB	4-19	0.000	5.750	8.050	5.600	0.000	
FO PS	4-19	0.000	5.750	8.050	-5.600	0.000	
SUBTOTAL		269.241	4.092	79.070	0.000	341.545	

Subtotals for group : Fresh water

FW WT SB	133-145	24.788	3.254	97.303	2.544	15.764	!
FW WT PS	133-145	24.788	3.254	97.303	-2.544	15.764	!
SUBTOTAL		49.576	3.254	97.303	-0.000	31.528	

Subtotals for group : Crew and stores

Crew and stores		17.000	13.500	75.000	0.000	0.000
SUBTOTAL		17.000	13.500	75.000	0.000	0.000

Subtotals for group : Deck load

Deckload 100t		100.000	10.000	23.000	0.000	0.000
SUBTOTAL		100.000	10.000	23.000	0.000	0.000
TOTAL		**5570.817**	**8.163**	**54.405**	**-0.000**	**373.073**

For FSM's marked with ! one of the following methods has been chosen : 1. FSM is set to zero, 2. FSM is set to the maximum, 3. FSM is set to zero if filling percentage > 98%

Hydrostatics			Drafts and trim		
Volume	5434.946	m^3	Drafts above base :		
LCF	48.486	m	Draft mean (Lpp/2)	5.093	m
Mom. change trim	118.834	tonm/cm	Draft aft (App)	5.178	m
Ton/cm immersion	17.087	ton/cm	Draft fore (Fpp)	5.008	m
Specific weight	1.025	ton/m^3	Trim	-0.171	m

Transverse stability					
KM transverse	9.913	m			
VCG	8.163	m			
GM solid	1.751	m			
GG' correction	0.067	m			
G'M liquid	1.684	m	VCG'	8.230	m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	5.093	-0.171	0.000	0.000	-0.000	0.000	0.000
2.00	5.090	-0.157	0.346	0.287	-0.000	0.059	0.001
5.00	5.077	-0.091	0.864	0.717	-0.000	0.147	0.006
7.00	5.062	-0.022	1.208	1.003	-0.000	0.205	0.013
10.00	5.030	0.115	1.721	1.429	-0.000	0.292	0.026
15.00	4.948	0.417	2.562	2.130	-0.000	0.432	0.057
20.00	4.826	0.814	3.376	2.815	-0.000	0.562	0.101
25.00	4.658	1.295	4.142	3.478	-0.000	0.664	0.155
30.00	4.447	1.784	4.827	4.115	-0.000	0.712	0.215
35.00	4.187	2.254	5.435	4.720	-0.000	0.715	0.277
40.00	3.860	2.730	5.991	5.290	-0.000	0.701	0.339
50.00	2.890	3.788	7.025	6.304	-0.000	0.721	0.462
60.00	1.261	5.098	7.873	7.127	-0.000	0.746	0.591

Statical angle of inclination is 0.000 degrees to starboard
Contour : FIRM

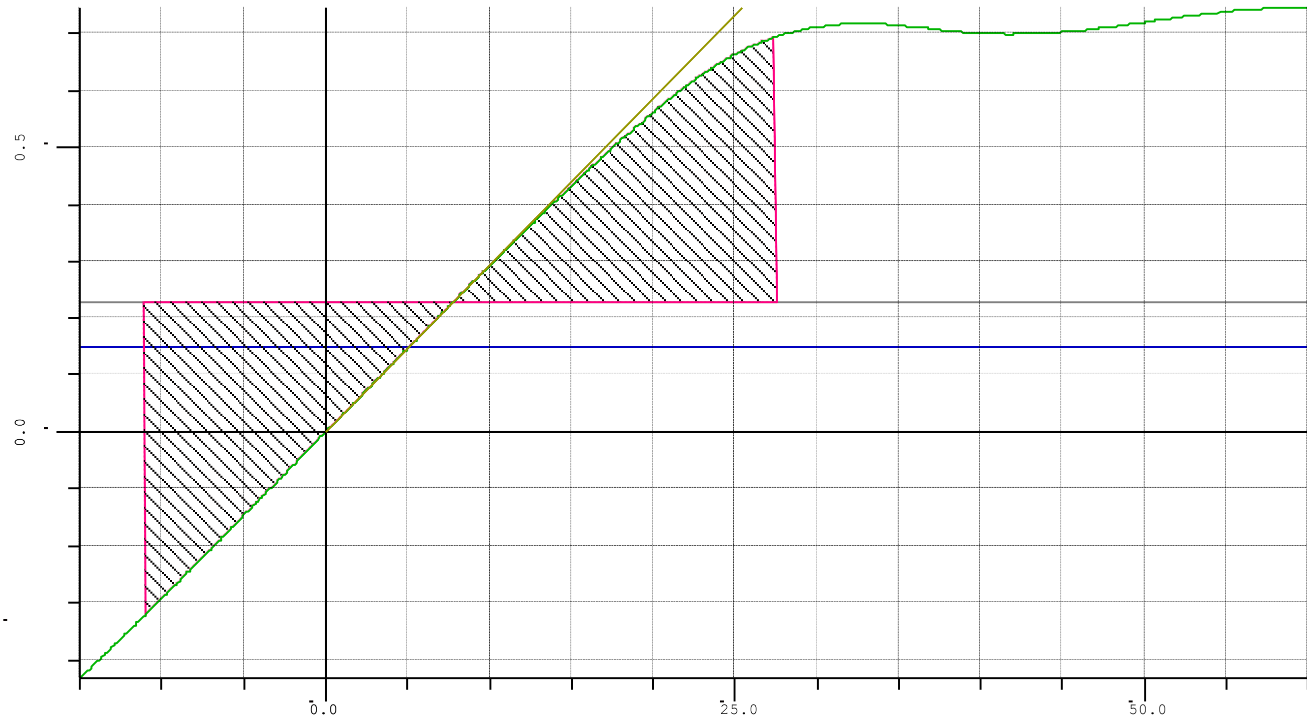
Summary

Hydrostatics		Criterion	Value
Draft mld.		6.600	5.093 m
Trim	-0.171 m		
Statical angle of inclination	0.00 degrees SB		
Flooding angle	60.00 degrees		

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	1.684 meter
Maximum GZ at 30 degrees or more	0.200	0.746 meter
Top of the GZ curve at least at	15.000	59.390 degrees
Area under the GZ curve up to 30 degrees	0.055	0.215 mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.124 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	27.473 degrees
Maximum statical angle due to wind	16.000	5.150 degrees
Maximum statical angle 80% of angle of deck immersion	18.511	5.150 degrees

VCG'	
Actual	8.230 m
Maximum allowable	8.894 m

Loading condition complies with the stated criteria.



Angle of inclination in degrees 1/4.62

TRIM AND STABILITY CALCULATION
FIRM

14 Jun 2013 15:19:20

Condition : 1.2 Light service draft, Arrival 100t deckload

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm	
Empty ship		5135.000	8.370	53.241	0.000	0.000	
Subtotals for group : Ballast water							
BW FP	155-fwd	0.000	0.002	110.300	0.000	0.000	
BW DB CT	133-145	89.028	1.430	97.069	0.000	157.940	
BW DB SB	124-133	0.000	-0.000	89.889	0.106	0.000	
BW DB PS	124-133	0.000	-0.000	89.889	-0.106	0.000	
BW WT SB	124-133	0.000	2.500	90.007	3.360	0.000	
BW WT PS	124-133	0.000	2.500	90.007	-3.360	0.000	
BW DB SB	112-124	0.000	-0.000	82.495	0.118	0.000	
BW DB PS	112-124	0.000	-0.000	82.495	-0.118	0.000	
BW WT SB	112-124	0.000	2.500	82.749	4.281	0.000	
BW WT PS	112-124	0.000	2.500	82.749	-4.281	0.000	
BW DB SB	100-112	0.000	-0.000	74.152	0.131	0.000	
BW DB PS	100-112	0.000	-0.000	74.152	-0.131	0.000	
BW WT SB	100-112	0.000	2.500	73.849	5.053	0.000	
BW WT PS	100-112	0.000	2.500	73.849	-5.053	0.000	
BW DB SB	88-100	0.000	-0.000	65.835	0.137	0.000	
BW DB PS	88-100	0.000	-0.000	65.835	-0.137	0.000	
BW WT SB	88-100	0.000	2.500	65.579	5.452	0.000	
BW WT PS	88-100	0.000	2.500	65.579	-5.452	0.000	
BW DB SB	73-88	0.000	-0.000	56.254	0.136	0.000	
BW DB PS	73-88	0.000	-0.000	56.254	-0.136	0.000	
BW WT SB	73-88	0.000	2.500	56.485	7.076	0.000	
BW WT PS	73-88	0.000	2.500	56.485	-7.076	0.000	
BW DB SB	61-73	0.000	-0.000	48.739	0.137	0.000	
BW DB PS	61-73	0.000	-0.000	48.739	-0.137	0.000	
BW WT SB	61-73	0.000	2.500	46.740	7.419	0.000	
BW WT PS	61-73	0.000	2.500	46.740	-7.419	0.000	
BW DB SB	49-61	0.000	0.015	42.024	0.203	0.000	
BW DB PS	49-61	0.000	0.015	42.024	-0.203	0.000	
BW WT SB	49-61	0.000	2.500	38.458	7.466	0.000	
BW WT PS	49-61	0.000	2.500	38.458	-7.466	0.000	
BW DB SB	37-49	0.000	0.123	34.063	0.144	0.000	
BW DB PS	37-49	0.000	0.123	34.063	-0.144	0.000	
BW WT SB	37-49	0.000	2.500	30.454	7.408	0.000	
BW WT PS	37-49	0.000	2.500	30.454	-7.408	0.000	
BW SB	4-19	0.000	5.750	8.540	8.034	0.000	
BW PS	4-19	0.000	5.750	8.540	-8.034	0.000	
BW SB	-4-4	0.000	4.761	-1.533	0.033	0.000	
BW PS	-4-4	0.000	4.761	-1.533	-0.033	0.000	
SUBTOTAL		89.028	1.430	97.069	0.000	157.940	
Subtotals for group : Fuel oil							
FO CT	124-133	8.596	2.662	89.765	0.000	0.000	!
FO CT	112-124	0.000	2.500	82.367	0.000	0.000	
FO CT	100-112	18.878	2.662	74.200	0.000	341.545	!
FO CT	88-100	0.000	2.500	65.800	0.000	0.000	
FO SB	4-19	0.000	5.750	8.050	5.600	0.000	
FO PS	4-19	0.000	5.750	8.050	-5.600	0.000	
SUBTOTAL		27.474	2.662	79.070	0.000	341.545	

Subtotals for group : Fresh water

FW WT SB	133-145	24.788	3.254	97.303	2.544	15.764	!
FW WT PS	133-145	24.788	3.254	97.303	-2.544	15.764	!
SUBTOTAL		49.576	3.254	97.303	-0.000	31.528	

Subtotals for group : Crew and stores

Crew and stores	17.000	13.500	75.000	0.000	0.000
SUBTOTAL	17.000	13.500	75.000	0.000	0.000

Subtotals for group : Deck load

Deckload 100t	100.000	10.000	23.000	0.000	0.000
SUBTOTAL	100.000	10.000	23.000	0.000	0.000
TOTAL	**5418.078**	**8.226**	**54.005**	**-0.000**	**531.013**

For FSM's marked with ! one of the following methods has been chosen : 1. FSM is set to zero, 2. FSM is set to the maximum, 3. FSM is set to zero if filling percentage > 98%

Hydrostatics

Volume	5285.932	m^3
LCF	48.343	m
Mom. change trim	118.387	tonm/cm
Ton/cm immersion	17.020	ton/cm
Specific weight	1.025	ton/m^3

Drafts and trim

Drafts above base :		
Draft mean (Lpp/2)	4.981	m
Draft aft (App)	5.194	m
Draft fore (Fpp)	4.769	m
Trim	-0.426	m

Transverse stability

KM transverse	9.985	m
VCG	8.226	m
GM solid	1.758	m
GG' correction	0.098	m
G'M liquid	1.660	m

VCG' 8.324 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	4.981	-0.426	0.000	0.000	-0.000	0.000	0.000
2.00	4.979	-0.412	0.348	0.291	-0.000	0.058	0.001
5.00	4.965	-0.345	0.870	0.726	-0.000	0.145	0.006
7.00	4.950	-0.275	1.216	1.014	-0.000	0.202	0.012
10.00	4.917	-0.139	1.732	1.446	-0.000	0.286	0.025
15.00	4.835	0.162	2.576	2.155	-0.000	0.422	0.056
20.00	4.711	0.559	3.392	2.847	-0.000	0.545	0.098
25.00	4.539	1.040	4.159	3.518	-0.000	0.641	0.151
30.00	4.324	1.535	4.845	4.162	-0.000	0.683	0.209
35.00	4.059	2.009	5.452	4.775	-0.000	0.677	0.268
40.00	3.725	2.486	6.005	5.351	-0.000	0.654	0.326
50.00	2.737	3.541	7.033	6.377	-0.000	0.656	0.440
60.00	1.061	4.842	7.895	7.209	-0.000	0.686	0.557

Statical angle of inclination is 0.000 degrees to starboard
Contour : FIRM

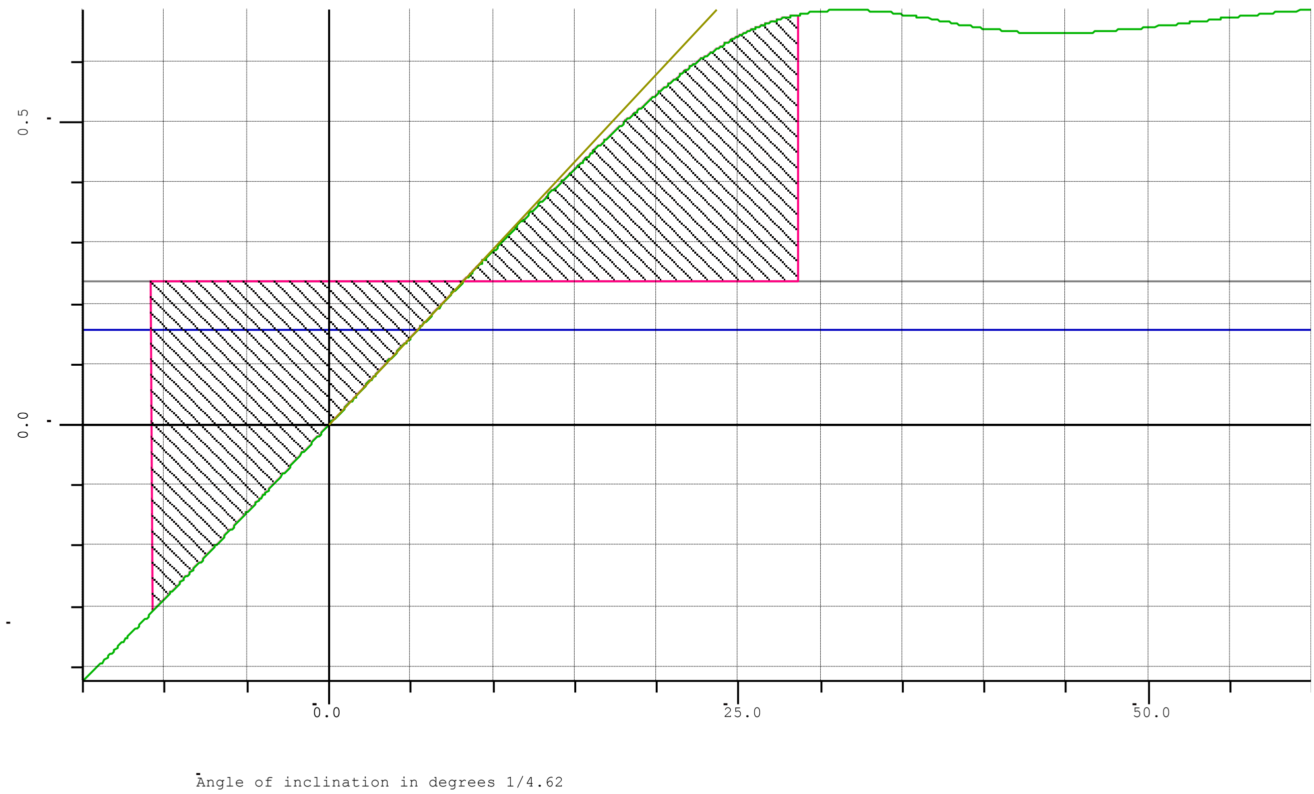
Summary

Hydrostatics		Criterion	Value
Draft mld.		6.600	4.981 m
Trim	-0.426 m		
Statical angle of inclination	0.00 degrees SB		
Flooding angle	60.00 degrees		

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	1.660 meter
Maximum GZ at 30 degrees or more	0.200	0.686 meter
Top of the GZ curve at least at	15.000	60.000 degrees
Area under the GZ curve up to 30 degrees	0.055	0.209 mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.118 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	28.637 degrees
Maximum statical angle due to wind	16.000	5.459 degrees
Maximum statical angle 80% of angle of deck immersion	18.850	5.459 degrees

VCG'	
Actual	8.324 m
Maximum allowable	8.887 m

Loading condition complies with the stated criteria.



TRIM AND STABILITY CALCULATION
FIRM

14 Jun 2013 15:19:58

Condition : 2.1 Design draft, Departure 100% consumables 600t deckload

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm	
Empty ship		5135.000	8.370	53.241	0.000	0.000	
Subtotals for group : Ballast water							
BW FP	155-fwd	0.000	0.002	110.300	0.000	0.000	
BW DB CT	133-145	95.217	1.498	97.069	0.000	0.000	
BW DB SB	124-133	45.511	1.499	89.857	1.626	0.000	
BW DB PS	124-133	45.511	1.499	89.857	-1.626	0.000	
BW WT SB	124-133	0.000	2.500	90.007	3.360	0.000	
BW WT PS	124-133	0.000	2.500	90.007	-3.360	0.000	
BW DB SB	112-124	0.000	-0.000	82.495	0.118	0.000	
BW DB PS	112-124	0.000	-0.000	82.495	-0.118	0.000	
BW WT SB	112-124	0.000	2.500	82.749	4.281	0.000	
BW WT PS	112-124	0.000	2.500	82.749	-4.281	0.000	
BW DB SB	100-112	0.000	-0.000	74.152	0.131	0.000	
BW DB PS	100-112	0.000	-0.000	74.152	-0.131	0.000	
BW WT SB	100-112	0.000	2.500	73.849	5.053	0.000	
BW WT PS	100-112	0.000	2.500	73.849	-5.053	0.000	
BW DB SB	88-100	0.000	-0.000	65.835	0.137	0.000	
BW DB PS	88-100	0.000	-0.000	65.835	-0.137	0.000	
BW WT SB	88-100	0.000	2.500	65.579	5.452	0.000	
BW WT PS	88-100	0.000	2.500	65.579	-5.452	0.000	
BW DB SB	73-88	0.000	-0.000	56.254	0.136	0.000	
BW DB PS	73-88	0.000	-0.000	56.254	-0.136	0.000	
BW WT SB	73-88	0.000	2.500	56.485	7.076	0.000	
BW WT PS	73-88	0.000	2.500	56.485	-7.076	0.000	
BW DB SB	61-73	0.000	-0.000	48.739	0.137	0.000	
BW DB PS	61-73	0.000	-0.000	48.739	-0.137	0.000	
BW WT SB	61-73	0.000	2.500	46.740	7.419	0.000	
BW WT PS	61-73	0.000	2.500	46.740	-7.419	0.000	
BW DB SB	49-61	0.000	0.015	42.024	0.203	0.000	
BW DB PS	49-61	0.000	0.015	42.024	-0.203	0.000	
BW WT SB	49-61	0.000	2.500	38.458	7.466	0.000	
BW WT PS	49-61	0.000	2.500	38.458	-7.466	0.000	
BW DB SB	37-49	0.000	0.123	34.063	0.144	0.000	
BW DB PS	37-49	0.000	0.123	34.063	-0.144	0.000	
BW WT SB	37-49	0.000	2.500	30.454	7.408	0.000	
BW WT PS	37-49	0.000	2.500	30.454	-7.408	0.000	
BW SB	4-19	0.000	5.750	8.540	8.034	0.000	
BW PS	4-19	0.000	5.750	8.540	-8.034	0.000	
BW SB	-4-4	0.000	4.761	-1.533	0.033	0.000	
BW PS	-4-4	0.000	4.761	-1.533	-0.033	0.000	
SUBTOTAL		186.240	1.498	93.544	-0.000	0.000	
Subtotals for group : Fuel oil							
FO CT	124-133	84.241	4.092	89.765	0.000	0.000	!
FO CT	112-124	158.571	4.092	82.367	0.000	0.000	!
FO CT	100-112	185.000	4.092	74.200	0.000	341.545	!
FO CT	88-100	185.000	4.092	65.800	0.000	0.000	!
FO SB	4-19	77.084	7.342	8.050	5.600	0.000	!
FO PS	4-19	77.084	7.342	8.050	-5.600	0.000	!
SUBTOTAL		766.980	4.746	62.275	0.000	341.545	

Subtotals for group : Fresh water

FW WT SB	133-145	47.216	3.848	97.285	2.648	15.764 !
FW WT PS	133-145	47.216	3.848	97.285	-2.648	15.764 !
SUBTOTAL		94.431	3.848	97.285	0.000	31.528

Subtotals for group : Crew and stores

Crew and stores		17.000	13.500	75.000	0.000	0.000
SUBTOTAL		17.000	13.500	75.000	0.000	0.000

Subtotals for group : Deck load

Deckload 600t		600.000	10.000	23.000	0.000	0.000
SUBTOTAL		600.000	10.000	23.000	0.000	0.000
TOTAL		**6799.650**	**7.867**	**53.362**	**0.000**	**373.073**

For FSM's marked with ! one of the following methods has been chosen :
1. FSM is set to zero, 2. FSM is set to the maximum, 3. FSM is set to zero if filling percentage > 98%

Hydrostatics		Drafts and trim	
Volume	6634.102 m^3	Drafts above base :	
LCF	47.006 m	Draft mean (Lpp/2)	5.796 m
Mom. change trim	135.574 tonm/cm	Draft aft (App)	5.832 m
Ton/cm immersion	18.220 ton/cm	Draft fore (Fpp)	5.760 m
Specific weight	1.025 ton/m^3	Trim	-0.073 m

Transverse stability			
KM transverse	10.072 m		
VCG	7.867 m		
GM solid	2.206 m		
GG' correction	0.055 m		
G'M liquid	2.151 m	VCG'	7.922 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	5.796	-0.073	0.000	0.000	-0.000	0.000	0.000
2.00	5.794	-0.064	0.351	0.276	-0.000	0.075	0.001
5.00	5.783	-0.021	0.876	0.690	-0.000	0.185	0.008
7.00	5.771	0.029	1.222	0.965	-0.000	0.257	0.016
10.00	5.743	0.136	1.738	1.376	-0.000	0.363	0.032
15.00	5.673	0.387	2.587	2.050	-0.000	0.537	0.071
20.00	5.571	0.704	3.404	2.709	-0.000	0.694	0.125
25.00	5.448	0.991	4.138	3.348	-0.000	0.790	0.191
30.00	5.298	1.215	4.794	3.961	-0.000	0.833	0.262
35.00	5.107	1.417	5.396	4.544	-0.000	0.852	0.335
40.00	4.857	1.621	5.958	5.092	-0.000	0.866	0.410
50.00	4.096	2.076	6.988	6.068	-0.000	0.920	0.566
60.00	2.906	2.534	7.702	6.860	-0.000	0.842	0.724

Statical angle of inclination is 0.000 degrees to starboard
Contour : FIRM

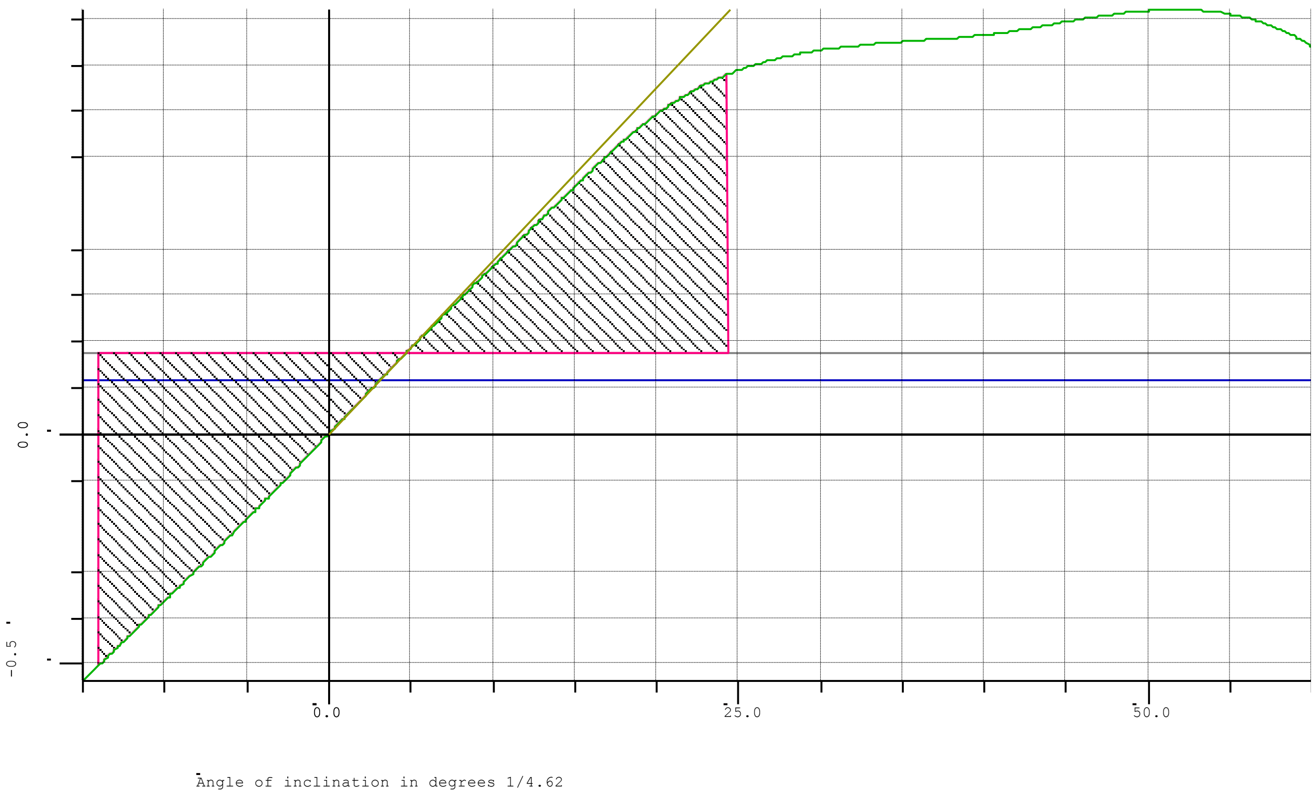
Summary

Hydrostatics		Criterion	Value
User defined draft		5.900	5.796 m
Trim	-0.073 m		
Statical angle of inclination	0.00 degrees SB		
Flooding angle	60.00 degrees		

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	2.151 meter
Maximum GZ at 30 degrees or more	0.200	0.922 meter
Top of the GZ curve at least at	15.000	51.726 degrees
Area under the GZ curve up to 30 degrees	0.055	0.262 mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.149 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	24.291 degrees
Maximum statical angle due to wind	16.000	3.144 degrees
Maximum statical angle 80% of angle of deck immersion	14.794	3.144 degrees

VCG'	
Actual	7.922 m
Maximum allowable	9.005 m

Loading condition complies with the stated criteria.



TRIM AND STABILITY CALCULATION
FIRM

14 Jun 2013 15:20:31

Condition : 2.2 Design draft, Arrival 10% consumables 600t deckload

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm	
Empty ship		5135.000	8.370	53.241	0.000	0.000	
Subtotals for group : Ballast water							
BW FP	155-fwd	199.539	6.137	111.550	0.000	0.000	
BW DB CT	133-145	95.217	1.498	97.069	0.000	0.000	
BW DB SB	124-133	45.511	1.499	89.857	1.626	0.000	
BW DB PS	124-133	45.511	1.499	89.857	-1.626	0.000	
BW WT SB	124-133	0.000	2.500	90.007	3.360	0.000	
BW WT PS	124-133	0.000	2.500	90.007	-3.360	0.000	
BW DB SB	112-124	0.000	-0.000	82.495	0.118	0.000	
BW DB PS	112-124	0.000	-0.000	82.495	-0.118	0.000	
BW WT SB	112-124	0.000	2.500	82.749	4.281	0.000	
BW WT PS	112-124	0.000	2.500	82.749	-4.281	0.000	
BW DB SB	100-112	0.000	-0.000	74.152	0.131	0.000	
BW DB PS	100-112	0.000	-0.000	74.152	-0.131	0.000	
BW WT SB	100-112	0.000	2.500	73.849	5.053	0.000	
BW WT PS	100-112	0.000	2.500	73.849	-5.053	0.000	
BW DB SB	88-100	0.000	-0.000	65.835	0.137	0.000	
BW DB PS	88-100	0.000	-0.000	65.835	-0.137	0.000	
BW WT SB	88-100	0.000	2.500	65.579	5.452	0.000	
BW WT PS	88-100	0.000	2.500	65.579	-5.452	0.000	
BW DB SB	73-88	0.000	-0.000	56.254	0.136	0.000	
BW DB PS	73-88	0.000	-0.000	56.254	-0.136	0.000	
BW WT SB	73-88	0.000	2.500	56.485	7.076	0.000	
BW WT PS	73-88	0.000	2.500	56.485	-7.076	0.000	
BW DB SB	61-73	0.000	-0.000	48.739	0.137	0.000	
BW DB PS	61-73	0.000	-0.000	48.739	-0.137	0.000	
BW WT SB	61-73	0.000	2.500	46.740	7.419	0.000	
BW WT PS	61-73	0.000	2.500	46.740	-7.419	0.000	
BW DB SB	49-61	0.000	0.015	42.024	0.203	0.000	
BW DB PS	49-61	0.000	0.015	42.024	-0.203	0.000	
BW WT SB	49-61	0.000	2.500	38.458	7.466	0.000	
BW WT PS	49-61	0.000	2.500	38.458	-7.466	0.000	
BW DB SB	37-49	0.000	0.123	34.063	0.144	0.000	
BW DB PS	37-49	0.000	0.123	34.063	-0.144	0.000	
BW WT SB	37-49	0.000	2.500	30.454	7.408	0.000	
BW WT PS	37-49	0.000	2.500	30.454	-7.408	0.000	
BW SB	4-19	0.000	5.750	8.540	8.034	0.000	
BW PS	4-19	0.000	5.750	8.540	-8.034	0.000	
BW SB	-4-4	0.000	4.761	-1.533	0.033	0.000	
BW PS	-4-4	0.000	4.761	-1.533	-0.033	0.000	
SUBTOTAL		385.779	3.898	102.858	-0.000	0.000	
Subtotals for group : Fuel oil							
FO CT	124-133	8.596	2.662	89.765	0.000	0.000	!
FO CT	112-124	16.181	2.662	82.367	0.000	0.000	!
FO CT	100-112	18.878	2.662	74.200	0.000	341.545	!
FO CT	88-100	18.878	2.662	65.800	0.000	341.541	
FO SB	4-19	7.866	5.912	8.050	5.600	0.000	!
FO PS	4-19	7.866	5.912	8.050	-5.600	0.000	!
SUBTOTAL		78.263	3.316	62.275	0.000	683.086	

Subtotals for group : Fresh water							
FW WT SB	133-145	5.902	2.693	97.329	2.432	15.764	!
FW WT PS	133-145	5.902	2.693	97.329	-2.432	15.764	!
SUBTOTAL		11.804	2.693	97.329	-0.000	31.528	
Subtotals for group : Crew and stores							
Crew and stores		17.000	13.500	75.000	0.000	0.000	
SUBTOTAL		17.000	13.500	75.000	0.000	0.000	
Subtotals for group : Deck load							
Deckload 600t		600.000	10.000	23.000	0.000	0.000	
SUBTOTAL		600.000	10.000	23.000	0.000	0.000	
TOTAL		**6227.846**	**8.190**	**53.657**	**-0.000**	**714.614**	

For FSM's marked with ! one of the following methods has been chosen :
1. FSM is set to zero, 2. FSM is set to the maximum, 3. FSM is set to zero if filling percentage > 98%

Hydrostatics		Drafts and trim	
Volume	6075.947 m^3	Drafts above base :	
LCF	47.364 m	Draft mean (Lpp/2)	5.466 m
Mom. change trim	130.251 tonm/cm	Draft aft (App)	5.566 m
Ton/cm immersion	17.819 ton/cm	Draft fore (Fpp)	5.367 m
Specific weight	1.025 ton/m^3	Trim	-0.199 m

Transverse stability			
KM transverse	10.058 m		
VCG	8.190 m		
GM solid	1.869 m		
GG' correction	0.115 m		
G'M liquid	1.754 m	VCG'	8.304 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	5.466	-0.199	0.000	0.000	-0.000	0.000	0.000
2.00	5.464	-0.188	0.351	0.290	-0.000	0.061	0.001
5.00	5.452	-0.133	0.874	0.724	-0.000	0.150	0.007
7.00	5.439	-0.074	1.220	1.012	-0.000	0.208	0.013
10.00	5.409	0.046	1.735	1.442	-0.000	0.293	0.026
15.00	5.334	0.320	2.582	2.149	-0.000	0.432	0.058
20.00	5.223	0.674	3.400	2.840	-0.000	0.560	0.101
25.00	5.077	1.061	4.155	3.510	-0.000	0.645	0.154
30.00	4.900	1.402	4.821	4.152	-0.000	0.669	0.212
35.00	4.678	1.722	5.423	4.763	-0.000	0.659	0.270
40.00	4.394	2.045	5.979	5.338	-0.000	0.641	0.327
50.00	3.533	2.765	7.013	6.362	-0.000	0.652	0.439
60.00	2.141	3.572	7.781	7.192	-0.000	0.589	0.550

Statical angle of inclination is 0.000 degrees to starboard
Contour : FIRM

Summary

Hydrostatics		Criterion	Value
User defined draft		5.900	5.466 m
Trim	-0.199 m		
Statical angle of inclination	0.00 degrees SB		
Flooding angle	60.00 degrees		

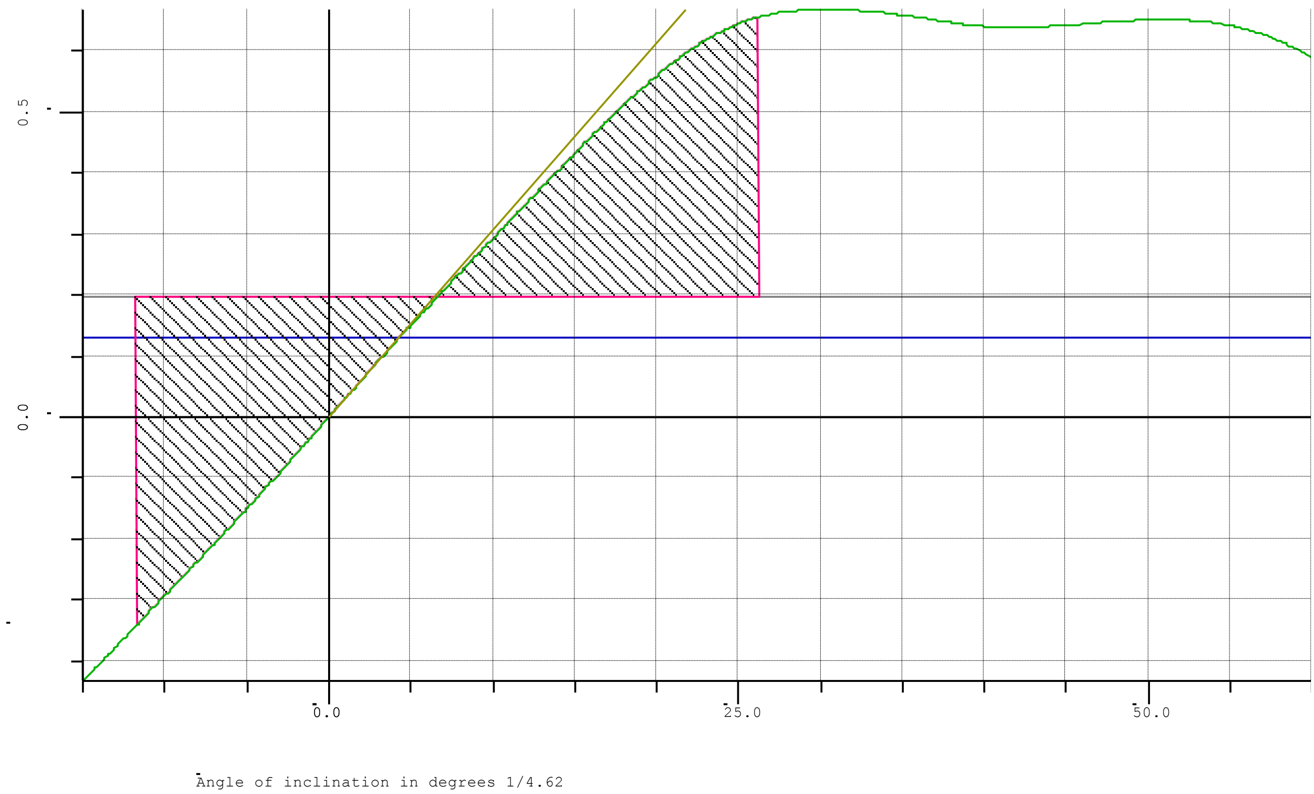
Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	1.754 meter
Maximum GZ at 30 degrees or more	0.200	0.669 meter
Top of the GZ curve at least at	15.000	30.363 degrees
Area under the GZ curve up to 30 degrees	0.055	0.212 mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.115 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	26.183 degrees
Maximum statical angle due to wind	16.000	4.371 degrees
Maximum statical angle 80% of angle of deck immersion	16.406	4.371 degrees

VCG'

Actual 8.304 m

Maximum allowable 8.977 m

Loading condition complies with the stated criteria.



TRIM AND STABILITY CALCULATION
FIRM

14 Jun 2013 15:21:03

Condition : 3.1 DP draft, Departure 100% consumables 600t deckload

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm	
Empty ship		5135.000	8.370	53.241	0.000	0.000	
Subtotals for group : Ballast water							
BW FP	155-fwd	0.000	0.002	110.300	0.000	0.000	
BW DB CT	133-145	95.217	1.498	97.069	0.000	0.000	
BW DB SB	124-133	45.511	1.499	89.857	1.626	0.000	
BW DB PS	124-133	45.511	1.499	89.857	-1.626	0.000	
BW WT SB	124-133	0.000	2.500	90.007	3.360	0.000	
BW WT PS	124-133	0.000	2.500	90.007	-3.360	0.000	
BW DB SB	112-124	73.001	1.494	82.466	1.951	0.000	
BW DB PS	112-124	73.001	1.494	82.466	-1.951	0.000	
BW WT SB	112-124	0.000	2.500	82.749	4.281	0.000	
BW WT PS	112-124	0.000	2.500	82.749	-4.281	0.000	
BW DB SB	100-112	86.731	1.487	74.092	2.301	0.000	
BW DB PS	100-112	86.731	1.487	74.092	-2.301	0.000	
BW WT SB	100-112	0.000	2.500	73.849	5.053	0.000	
BW WT PS	100-112	0.000	2.500	73.849	-5.053	0.000	
BW DB SB	88-100	99.317	1.484	65.718	2.627	0.000	
BW DB PS	88-100	99.317	1.484	65.718	-2.627	0.000	
BW WT SB	88-100	0.000	2.500	65.579	5.452	0.000	
BW WT PS	88-100	0.000	2.500	65.579	-5.452	0.000	
BW DB SB	73-88	137.750	1.489	56.277	2.926	0.000	
BW DB PS	73-88	137.750	1.489	56.277	-2.926	0.000	
BW WT SB	73-88	0.000	2.500	56.485	7.076	0.000	
BW WT PS	73-88	0.000	2.500	56.485	-7.076	0.000	
BW DB SB	61-73	114.709	1.499	46.898	3.070	0.000	
BW DB PS	61-73	114.709	1.499	46.898	-3.070	0.000	
BW WT SB	61-73	0.000	2.500	46.740	7.419	0.000	
BW WT PS	61-73	0.000	2.500	46.740	-7.419	0.000	
BW DB SB	49-61	0.000	0.015	42.024	0.203	0.000	
BW DB PS	49-61	0.000	0.015	42.024	-0.203	0.000	
BW WT SB	49-61	0.000	2.500	38.458	7.466	0.000	
BW WT PS	49-61	0.000	2.500	38.458	-7.466	0.000	
BW DB SB	37-49	93.743	1.659	30.346	2.994	0.000	
BW DB PS	37-49	93.743	1.659	30.346	-2.994	0.000	
BW WT SB	37-49	0.000	2.500	30.454	7.408	0.000	
BW WT PS	37-49	0.000	2.500	30.454	-7.408	0.000	
BW SB	4-19	104.916	7.507	8.120	8.566	0.000	
BW PS	4-19	104.916	7.507	8.120	-8.566	0.000	
BW SB	-4-4	0.000	4.761	-1.533	0.033	0.000	
BW PS	-4-4	0.000	4.761	-1.533	-0.033	0.000	
SUBTOTAL		1606.574	2.297	55.413	0.000	0.000	
Subtotals for group : Fuel oil							
FO CT	124-133	84.241	4.092	89.765	0.000	0.000	!
FO CT	112-124	158.571	4.092	82.367	0.000	0.000	!
FO CT	100-112	185.000	4.092	74.200	0.000	341.545	!
FO CT	88-100	185.000	4.092	65.800	0.000	0.000	!
FO SB	4-19	77.084	7.342	8.050	5.600	0.000	!
FO PS	4-19	77.084	7.342	8.050	-5.600	0.000	!
SUBTOTAL		766.980	4.746	62.275	0.000	341.545	

Subtotals for group : Fresh water						
FW WT SB	133-145	47.216	3.848	97.285	2.648	15.423
FW WT PS	133-145	47.216	3.848	97.285	-2.648	15.423
SUBTOTAL		94.431	3.848	97.285	0.000	30.846
Subtotals for group : Crew and stores						
Crew and stores		17.000	13.500	75.000	0.000	0.000
SUBTOTAL		17.000	13.500	75.000	0.000	0.000
Subtotals for group : Deck load						
Deckload 600t		600.000	10.000	23.000	0.000	0.000
SUBTOTAL		600.000	10.000	23.000	0.000	0.000
TOTAL		**8219.984**	**6.922**	**52.852**	**0.000**	**372.391**

For FSM's marked with ! one of the following methods has been chosen :
1. FSM is set to zero, 2. FSM is set to the maximum, 3. FSM is set to zero if filling percentage > 98%

Hydrostatics		Drafts and trim	
Volume	8019.525 m^3	Drafts above base :	
LCF	46.694 m	Draft mean (Lpp/2)	6.596 m
Mom. change trim	143.435 tonm/cm	Draft aft (App)	6.451 m
Ton/cm immersion	18.934 ton/cm	Draft fore (Fpp)	6.742 m
Specific weight	1.025 ton/m^3	Trim	0.291 m

Transverse stability			
KM transverse	10.046 m		
VCG	6.922 m		
GM solid	3.123 m		
GG' correction	0.045 m		
G'M liquid	3.078 m	VCG'	6.968 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	6.596	0.291	0.000	0.000	0.000	-0.000	0.000
2.00	6.595	0.296	0.351	0.243	0.000	0.107	0.002
5.00	6.585	0.322	0.876	0.607	0.000	0.269	0.012
7.00	6.574	0.355	1.225	0.849	0.000	0.376	0.023
10.00	6.551	0.429	1.745	1.210	0.000	0.535	0.047
15.00	6.493	0.610	2.590	1.803	0.000	0.787	0.105
20.00	6.430	0.731	3.358	2.383	0.000	0.975	0.182
25.00	6.361	0.750	4.052	2.945	0.000	1.107	0.273
30.00	6.274	0.705	4.698	3.484	0.000	1.214	0.375
35.00	6.154	0.629	5.309	3.997	0.000	1.312	0.485
40.00	5.987	0.535	5.895	4.479	0.000	1.416	0.604
50.00	5.515	0.243	6.885	5.338	0.000	1.548	0.865
60.00	4.847	-0.237	7.520	6.034	0.000	1.485	1.133

Statical angle of inclination is 0.000 degrees to starboard
Contour : FIRM

Opening	is submerged at [degrees]
ER Vent in	56.02

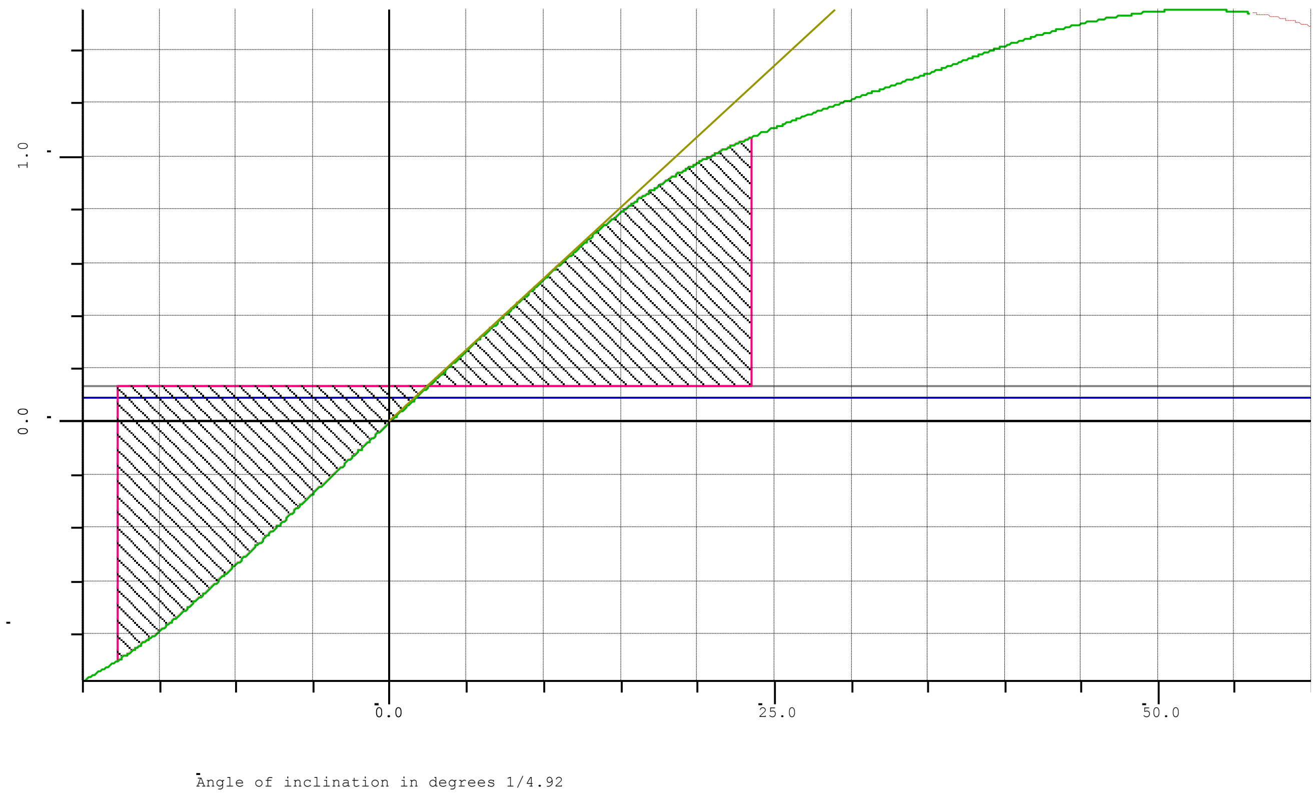
Summary

Hydrostatics	Criterion	Value
Draft mld.	6.600	6.596 m

Trim 0.291 m
Statical angle of inclination 0.00 degrees SB
Flooding angle 56.02 degrees

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	3.078 meter
Maximum GZ at 30 degrees or more	0.200	1.554 meter
Top of the GZ curve at least at	15.000	52.453 degrees
Area under the GZ curve up to 30 degrees	0.055	0.375 mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.229 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	23.484 degrees
Maximum statical angle due to wind	16.000	1.684 degrees
Maximum statical angle 80% of angle of deck immersion	11.143	1.684 degrees

VCG'
Actual 6.968 m
Maximum allowable 8.886 m
Loading condition complies with the stated criteria.



TRIM AND STABILITY CALCULATION
FIRM

14 Jun 2013 15:21:30

Condition : 3.2 DP draft, Arrival 10% consumables 600t deckload

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm	
Empty ship		5135.000	8.370	53.241	0.000	0.000	
Subtotals for group : Ballast water							
BW FP	155-fwd	0.000	0.002	110.300	0.000	0.000	
BW DB CT	133-145	95.217	1.498	97.069	0.000	0.000	
BW DB SB	124-133	45.511	1.499	89.857	1.626	0.000	
BW DB PS	124-133	45.511	1.499	89.857	-1.626	0.000	
BW WT SB	124-133	0.000	2.500	90.007	3.360	0.000	
BW WT PS	124-133	0.000	2.500	90.007	-3.360	0.000	
BW DB SB	112-124	73.001	1.494	82.466	1.951	0.000	
BW DB PS	112-124	73.001	1.494	82.466	-1.951	0.000	
BW WT SB	112-124	0.000	2.500	82.749	4.281	0.000	
BW WT PS	112-124	0.000	2.500	82.749	-4.281	0.000	
BW DB SB	100-112	86.731	1.487	74.092	2.301	0.000	
BW DB PS	100-112	86.731	1.487	74.092	-2.301	0.000	
BW WT SB	100-112	0.000	2.500	73.849	5.053	0.000	
BW WT PS	100-112	0.000	2.500	73.849	-5.053	0.000	
BW DB SB	88-100	99.317	1.484	65.718	2.627	0.000	
BW DB PS	88-100	99.317	1.484	65.718	-2.627	0.000	
BW WT SB	88-100	0.000	2.500	65.579	5.452	0.000	
BW WT PS	88-100	0.000	2.500	65.579	-5.452	0.000	
BW DB SB	73-88	137.750	1.489	56.277	2.926	0.000	
BW DB PS	73-88	137.750	1.489	56.277	-2.926	0.000	
BW WT SB	73-88	0.000	2.500	56.485	7.076	0.000	
BW WT PS	73-88	0.000	2.500	56.485	-7.076	0.000	
BW DB SB	61-73	114.709	1.499	46.898	3.070	0.000	
BW DB PS	61-73	114.709	1.499	46.898	-3.070	0.000	
BW WT SB	61-73	0.000	2.500	46.740	7.419	0.000	
BW WT PS	61-73	0.000	2.500	46.740	-7.419	0.000	
BW DB SB	49-61	111.381	1.533	38.547	3.077	0.000	
BW DB PS	49-61	111.381	1.533	38.547	-3.077	0.000	
BW WT SB	49-61	0.000	2.500	38.458	7.466	0.000	
BW WT PS	49-61	0.000	2.500	38.458	-7.466	0.000	
BW DB SB	37-49	93.743	1.659	30.346	2.994	0.000	
BW DB PS	37-49	93.743	1.659	30.346	-2.994	0.000	
BW WT SB	37-49	0.000	2.500	30.454	7.408	0.000	
BW WT PS	37-49	0.000	2.500	30.454	-7.408	0.000	
BW SB	4-19	0.000	5.750	8.540	8.034	0.000	
BW PS	4-19	0.000	5.750	8.540	-8.034	0.000	
BW SB	-4-4	0.000	4.761	-1.533	0.033	0.000	
BW PS	-4-4	0.000	4.761	-1.533	-0.033	0.000	
SUBTOTAL		1619.504	1.517	59.220	0.000	0.000	
Subtotals for group : Fuel oil							
FO CT	124-133	8.596	2.662	89.765	0.000	0.000	!
FO CT	112-124	16.181	2.662	82.367	0.000	0.000	!
FO CT	100-112	18.878	2.662	74.200	0.000	341.545	!
FO CT	88-100	18.878	2.662	65.800	0.000	0.000	!
FO SB	4-19	7.866	5.912	8.050	5.600	0.000	!
FO PS	4-19	7.866	5.912	8.050	-5.600	0.000	!
SUBTOTAL		78.263	3.316	62.275	0.000	341.545	

Subtotals for group : Fresh water						
FW WT SB	133-145	5.902	2.693	97.329	2.432	7.420
FW WT PS	133-145	5.902	2.693	97.329	-2.432	7.420
SUBTOTAL		11.804	2.693	97.329	-0.000	14.840
Subtotals for group : Crew and stores						
Crew and stores		17.000	13.500	75.000	0.000	0.000
SUBTOTAL		17.000	13.500	75.000	0.000	0.000
Subtotals for group : Deck load						
Deckload 600t		600.000	10.000	23.000	0.000	0.000
SUBTOTAL		600.000	10.000	23.000	0.000	0.000
TOTAL		**7461.571**	**6.963**	**52.321**	**0.000**	**356.385**

For FSM's marked with ! one of the following methods has been chosen :
1. FSM is set to zero, 2. FSM is set to the maximum, 3. FSM is set to zero if filling percentage > 98%

Hydrostatics		Drafts and trim	
Volume	7279.650 m^3	Drafts above base :	
LCF	46.594 m	Draft mean (Lpp/2)	6.131 m
Mom. change trim	140.384 tonm/cm	Draft aft (App)	6.290 m
Ton/cm immersion	18.616 ton/cm	Draft fore (Fpp)	5.972 m
Specific weight	1.025 ton/m^3	Trim	-0.318 m

Transverse stability			
KM transverse	10.122 m		
VCG	6.963 m		
GM solid	3.158 m		
GG' correction	0.048 m		
G'M liquid	3.111 m	VCG'	7.011 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	6.131	-0.318	0.000	0.000	0.000	-0.000	0.000
2.00	6.129	-0.313	0.353	0.245	0.000	0.109	0.002
5.00	6.119	-0.283	0.882	0.611	0.000	0.271	0.012
7.00	6.108	-0.247	1.233	0.854	0.000	0.378	0.023
10.00	6.083	-0.164	1.755	1.217	0.000	0.538	0.047
15.00	6.020	0.040	2.607	1.815	0.000	0.793	0.105
20.00	5.937	0.249	3.402	2.398	0.000	1.004	0.184
25.00	5.846	0.354	4.108	2.963	0.000	1.145	0.278
30.00	5.731	0.401	4.754	3.506	0.000	1.249	0.383
35.00	5.580	0.415	5.357	4.021	0.000	1.336	0.496
40.00	5.376	0.418	5.929	4.507	0.000	1.422	0.616
50.00	4.758	0.384	6.943	5.371	0.000	1.572	0.879
60.00	3.821	0.207	7.608	6.072	0.000	1.536	1.154

Statical angle of inclination is 0.000 degrees to starboard
Contour : FIRM

Opening	is submerged at [degrees]
ER Vent in	58.48

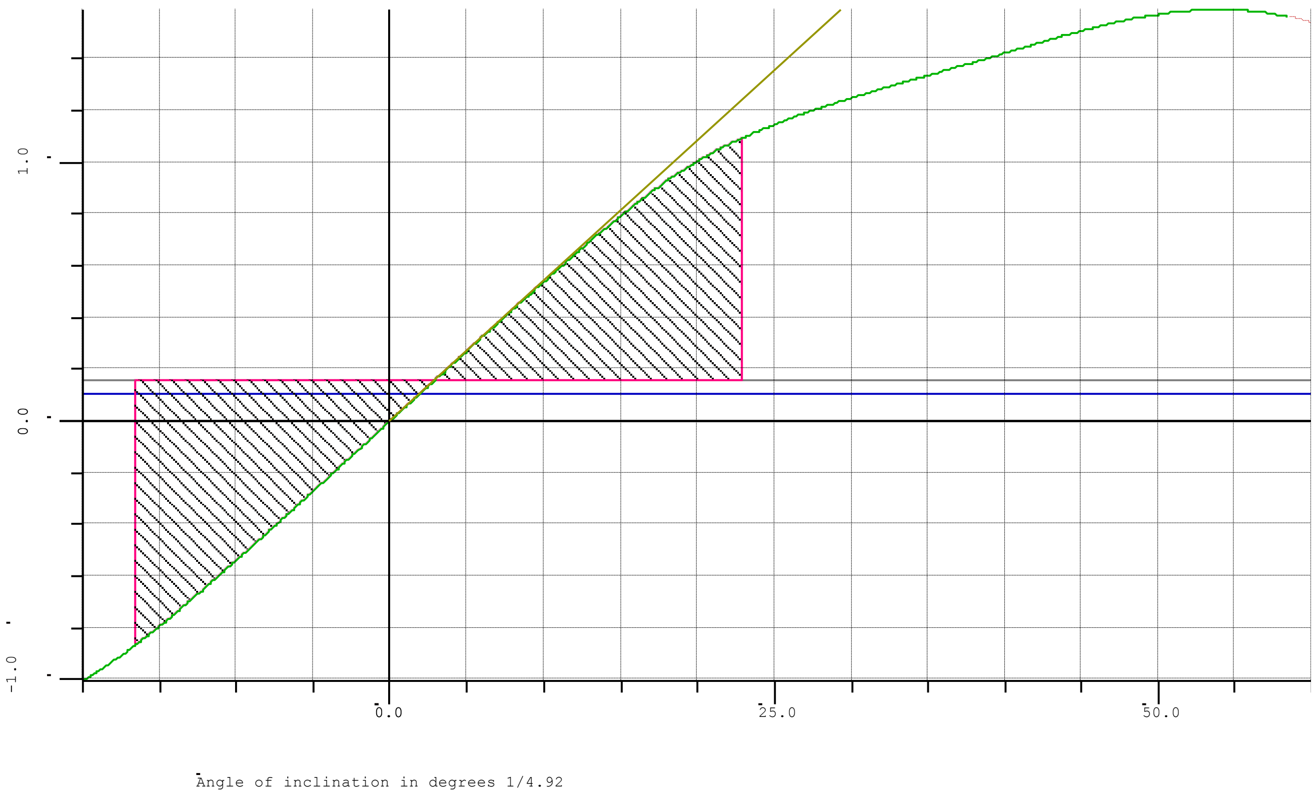
Summary

Hydrostatics		Criterion	Value
Draft mld.		6.600	6.131 m
Trim	-0.318 m		
Statical angle of inclination	0.00 degrees SB		
Flooding angle	58.48 degrees		

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	3.111 meter
Maximum GZ at 30 degrees or more	0.200	1.591 meter
Top of the GZ curve at least at	15.000	54.002 degrees
Area under the GZ curve up to 30 degrees	0.055	0.383 mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.233 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	22.915 degrees
Maximum statical angle due to wind	16.000	1.933 degrees
Maximum statical angle 80% of angle of deck immersion	12.805	1.933 degrees

VCG'	
Actual	7.011 m
Maximum allowable	8.989 m

Loading condition complies with the stated criteria.



TRIM AND STABILITY CALCULATION
FIRM

14 Jun 2013 15:33:32

Condition : 4.1 Crane operation 100t@15m 100% consumables 500t deckload

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm	
Empty ship		5135.000	8.370	53.241	0.000	0.000	
Subtotals for group : Ballast water							
BW FP	155-fwd	0.000	0.002	110.300	0.000	0.000	
BW DB CT	133-145	11.426	0.290	97.137	0.000	63.317	
BW DB SB	124-133	45.511	1.499	89.857	1.626	0.000	
BW DB PS	124-133	45.511	1.499	89.857	-1.626	0.000	
BW WT SB	124-133	0.000	2.500	90.007	3.360	0.000	
BW WT PS	124-133	0.000	2.500	90.007	-3.360	0.000	
BW DB SB	112-124	73.001	1.494	82.466	1.951	0.000	
BW DB PS	112-124	73.001	1.494	82.466	-1.951	0.000	
BW WT SB	112-124	0.000	2.500	82.749	4.281	0.000	
BW WT PS	112-124	0.000	2.500	82.749	-4.281	0.000	
BW DB SB	100-112	86.731	1.487	74.092	2.301	0.000	
BW DB PS	100-112	86.731	1.487	74.092	-2.301	0.000	
BW WT SB	100-112	0.000	2.500	73.849	5.053	0.000	
BW WT PS	100-112	0.000	2.500	73.849	-5.053	0.000	
BW DB SB	88-100	99.317	1.484	65.718	2.627	0.000	
BW DB PS	88-100	99.317	1.484	65.718	-2.627	0.000	
BW WT SB	88-100	0.000	2.500	65.579	5.452	0.000	
BW WT PS	88-100	0.000	2.500	65.579	-5.452	0.000	
BW DB SB	73-88	137.750	1.489	56.277	2.926	0.000	
BW DB PS	73-88	137.750	1.489	56.277	-2.926	0.000	
BW WT SB	73-88	0.000	2.500	56.485	7.076	0.000	
BW WT PS	73-88	0.000	2.500	56.485	-7.076	0.000	
BW DB SB	61-73	114.709	1.499	46.898	3.070	0.000	
BW DB PS	61-73	114.709	1.499	46.898	-3.070	0.000	
BW WT SB	61-73	0.000	2.500	46.740	7.419	0.000	
BW WT PS	61-73	0.000	2.500	46.740	-7.419	0.000	
BW DB SB	49-61	0.000	0.015	42.024	0.203	0.000	
BW DB PS	49-61	0.000	0.015	42.024	-0.203	0.000	
BW WT SB	49-61	100.510	5.847	38.458	8.622	5.681	
BW WT PS	49-61	0.000	2.500	38.458	-7.466	0.000	
BW DB SB	37-49	93.743	1.659	30.346	2.994	0.000	
BW DB PS	37-49	93.743	1.659	30.346	-2.994	0.000	
BW WT SB	37-49	102.194	5.899	30.116	8.658	0.000	
BW WT PS	37-49	0.000	2.500	30.454	-7.408	0.000	
BW SB	4-19	104.916	7.507	8.120	8.566	0.000	
BW PS	4-19	0.000	5.750	8.540	-8.034	0.000	
BW SB	-4-4	0.000	4.761	-1.533	0.033	0.000	
BW PS	-4-4	0.000	4.761	-1.533	-0.033	0.000	
SUBTOTAL		1620.571	2.440	53.674	1.635	68.998	
Subtotals for group : Fuel oil							
FO CT	124-133	84.241	4.092	89.765	0.000	0.000	!
FO CT	112-124	158.571	4.092	82.367	0.000	0.000	!
FO CT	100-112	185.000	4.092	74.200	0.000	341.545	!
FO CT	88-100	185.000	4.092	65.800	0.000	0.000	!
FO SB	4-19	77.084	7.342	8.050	5.600	0.000	!
FO PS	4-19	77.084	7.342	8.050	-5.600	0.000	!
SUBTOTAL		766.980	4.746	62.275	0.000	341.545	

Subtotals for group : Fresh water						
FW WT SB	133-145	47.216	3.848	97.285	2.648	15.423
FW WT PS	133-145	47.216	3.848	97.285	-2.648	15.423
SUBTOTAL		94.431	3.848	97.285	0.000	30.846
Subtotals for group : Crew and stores						
Crew and stores		17.000	13.500	75.000	0.000	0.000
SUBTOTAL		17.000	13.500	75.000	0.000	0.000
Subtotals for group : Crane						
Crane load		100.000	27.000	20.000	-20.500	0.000
Crane boom		50.000	25.000	20.000	-12.000	0.000
SUBTOTAL		150.000	26.333	20.000	-17.667	0.000
Deckload 500t		500.000	10.000	23.000	0.000	0.000
TOTAL		**8283.981**	**7.257**	**52.282**	**0.000**	**441.389**

For FSM's marked with ! one of the following methods has been chosen :
1. FSM is set to zero, 2. FSM is set to the maximum, 3. FSM is set to zero if filling percentage > 98%

Hydrostatics		Drafts and trim	
Volume	8081.957 m^3	Drafts above base :	
LCF	46.582 m	Draft mean (Lpp/2)	6.600 m
Mom. change trim	143.887 tonm/cm	Draft aft (App)	6.605 m
Ton/cm immersion	18.976 ton/cm	Draft fore (Fpp)	6.595 m
Specific weight	1.025 ton/m^3	Trim	-0.010 m

Transverse stability			
KM transverse	10.080 m		
VCG	7.257 m		
GM solid	2.823 m		
GG' correction	0.053 m		
G'M liquid	2.770 m	VCG'	7.310 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	6.600	-0.010	0.000	0.000	0.000	-0.000	0.000
2.00	6.598	-0.005	0.352	0.255	0.000	0.097	0.002
5.00	6.589	0.019	0.879	0.637	0.000	0.242	0.011
7.00	6.578	0.049	1.230	0.891	0.000	0.339	0.021
10.00	6.555	0.116	1.753	1.269	0.000	0.483	0.042
15.00	6.500	0.275	2.598	1.892	0.000	0.706	0.094
20.00	6.443	0.343	3.355	2.500	0.000	0.854	0.163
25.00	6.381	0.309	4.044	3.089	0.000	0.954	0.242
30.00	6.301	0.212	4.688	3.655	0.000	1.033	0.329
35.00	6.189	0.080	5.298	4.193	0.000	1.105	0.422
40.00	6.030	-0.074	5.885	4.699	0.000	1.187	0.522
50.00	5.586	-0.527	6.871	5.600	0.000	1.271	0.739
60.00	4.959	-1.255	7.504	6.331	0.000	1.173	0.955

Statical angle of inclination is 0.000 degrees to starboard
Contour : FIRM

Opening	is submerged at [degrees]
ER Vent in	55.57

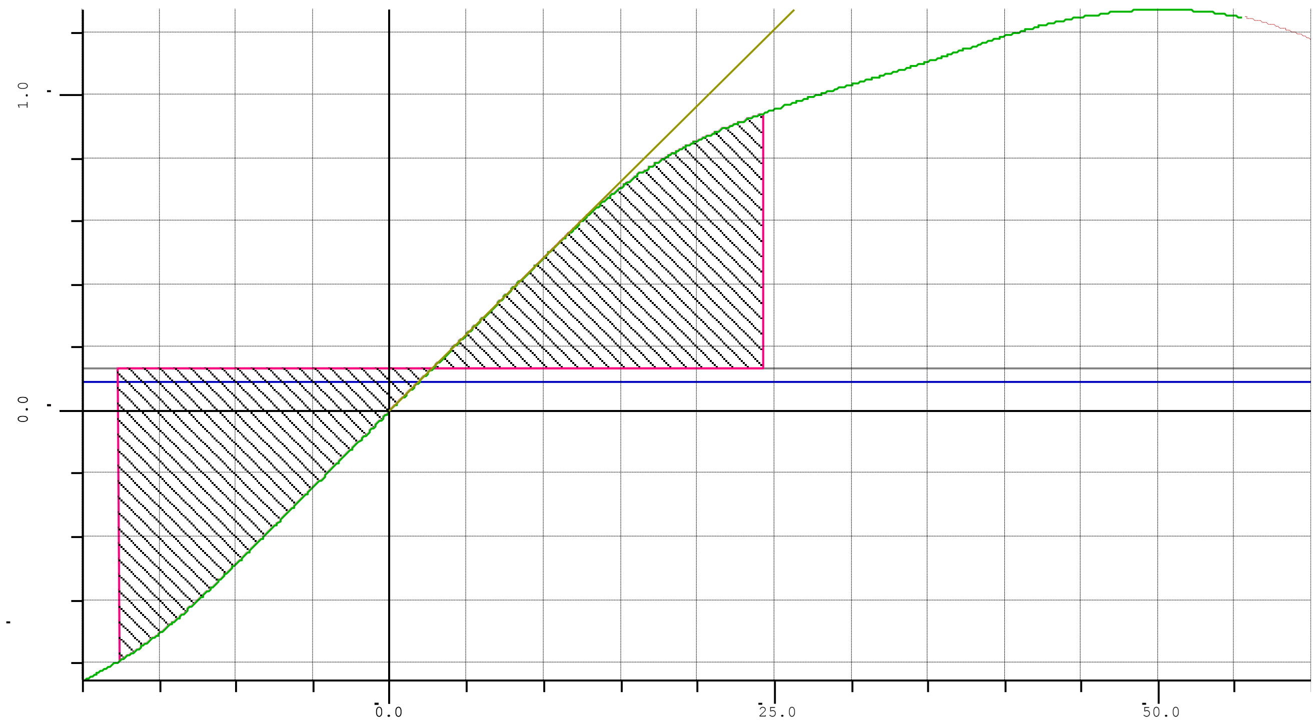
Summary

Hydrostatics		Criterion	Value	
Draft mld.		6.600	6.600	m
Trim	-0.010 m			
Statical angle of inclination	0.00 degrees SB			
Flooding angle	55.57 degrees			

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value	
Minimum metacentric height G'M	0.150	2.770	meter
Maximum GZ at 30 degrees or more	0.200	1.271	meter
Top of the GZ curve at least at	15.000	50.310	degrees
Area under the GZ curve up to 30 degrees	0.055	0.329	mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.193	mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	24.236	degrees
Maximum statical angle due to wind	15.932	1.870	degrees
Maximum statical angle 80% of angle of deck immersion	10.831	1.870	degrees

VCG'	
Actual	7.310 m
Maximum allowable	8.838 m

Loading condition complies with the stated criteria.



Angle of inclination in degrees 1/4.92

TRIM AND STABILITY CALCULATION
FIRM

14 Jun 2013 15:36:38

Condition : 4.2 Crane operation 100t@15m 50% consumables 500t deckload

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm	
Empty ship		5135.000	8.370	53.241	0.000	0.000	
Subtotals for group : Ballast water							
BW FP	155-fwd	0.000	0.002	110.300	0.000	0.000	
BW DB CT	133-145	95.217	1.498	97.069	0.000	0.000	
BW DB SB	124-133	45.511	1.499	89.857	1.626	0.000	
BW DB PS	124-133	45.511	1.499	89.857	-1.626	0.000	
BW WT SB	124-133	0.000	2.500	90.007	3.360	0.000	
BW WT PS	124-133	0.000	2.500	90.007	-3.360	0.000	
BW DB SB	112-124	73.001	1.494	82.466	1.951	0.000	
BW DB PS	112-124	73.001	1.494	82.466	-1.951	0.000	
BW WT SB	112-124	0.000	2.500	82.749	4.281	0.000	
BW WT PS	112-124	0.000	2.500	82.749	-4.281	0.000	
BW DB SB	100-112	86.731	1.487	74.092	2.301	0.000	
BW DB PS	100-112	86.731	1.487	74.092	-2.301	0.000	
BW WT SB	100-112	0.000	2.500	73.849	5.053	0.000	
BW WT PS	100-112	0.000	2.500	73.849	-5.053	0.000	
BW DB SB	88-100	99.317	1.484	65.718	2.627	0.000	
BW DB PS	88-100	99.317	1.484	65.718	-2.627	0.000	
BW WT SB	88-100	0.000	2.500	65.579	5.452	0.000	
BW WT PS	88-100	0.000	2.500	65.579	-5.452	0.000	
BW DB SB	73-88	137.750	1.489	56.277	2.926	0.000	
BW DB PS	73-88	137.750	1.489	56.277	-2.926	0.000	
BW WT SB	73-88	0.000	2.500	56.485	7.076	0.000	
BW WT PS	73-88	0.000	2.500	56.485	-7.076	0.000	
BW DB SB	61-73	114.709	1.499	46.898	3.070	0.000	
BW DB PS	61-73	114.709	1.499	46.898	-3.070	0.000	
BW WT SB	61-73	0.000	2.500	46.740	7.419	0.000	
BW WT PS	61-73	0.000	2.500	46.740	-7.419	0.000	
BW DB SB	49-61	111.381	1.533	38.547	3.077	0.000	
BW DB PS	49-61	111.381	1.533	38.547	-3.077	0.000	
BW WT SB	49-61	100.510	5.847	38.458	8.622	5.681	
BW WT PS	49-61	0.000	2.500	38.458	-7.466	0.000	
BW DB SB	37-49	93.743	1.659	30.346	2.994	0.000	
BW DB PS	37-49	93.743	1.659	30.346	-2.994	0.000	
BW WT SB	37-49	102.194	5.899	30.116	8.658	0.000	
BW WT PS	37-49	0.000	2.500	30.454	-7.408	0.000	
BW SB	4-19	104.916	7.507	8.120	8.566	0.000	
BW PS	4-19	0.000	5.750	8.540	-8.034	0.000	
BW SB	-4-4	0.000	4.761	-1.533	0.033	0.000	
BW PS	-4-4	0.000	4.761	-1.533	-0.033	0.000	
SUBTOTAL		1927.124	2.301	53.812	1.375	5.681	
Subtotals for group : Fuel oil							
FO CT	124-133	8.596	2.662	89.765	0.000	0.000	!
FO CT	112-124	16.181	2.662	82.367	0.000	0.000	!
FO CT	100-112	18.878	2.662	74.200	0.000	341.545	!
FO CT	88-100	18.878	2.662	65.800	0.000	0.000	!
FO SB	4-19	7.866	5.912	8.050	5.600	0.000	!
FO PS	4-19	7.866	5.912	8.050	-5.600	0.000	!
SUBTOTAL		78.263	3.316	62.275	0.000	341.545	

Subtotals for group : Fresh water						
FW WT SB	133-145	5.902	2.693	97.329	2.432	7.420
FW WT PS	133-145	5.902	2.693	97.329	-2.432	7.420
SUBTOTAL		11.804	2.693	97.329	-0.000	14.840
Subtotals for group : Crew and stores						
Crew and stores		17.000	13.500	75.000	0.000	0.000
SUBTOTAL		17.000	13.500	75.000	0.000	0.000
Subtotals for group : Crane						
Crane load		100.000	27.000	20.000	-20.500	0.000
Crane boom		50.000	25.000	20.000	-12.000	0.000
SUBTOTAL		150.000	26.333	20.000	-17.667	0.000
Deckload 500t		500.000	10.000	23.000	0.000	0.000
TOTAL		**7819.191**	**7.275**	**51.015**	**0.000**	**362.066**

For FSM's marked with ! one of the following methods has been chosen :
1. FSM is set to zero, 2. FSM is set to the maximum, 3. FSM is set to zero if filling percentage > 98%

Hydrostatics		
Volume	7628.518	m^3
LCF	46.268	m
Mom. change trim	142.469	tonm/cm
Ton/cm immersion	18.815	ton/cm
Specific weight	1.025	ton/m^3

Drafts and trim		
Drafts above base :		
Draft mean (Lpp/2)	6.263	m
Draft aft (App)	6.708	m
Draft fore (Fpp)	5.817	m
Trim	-0.891	m

Transverse stability		
KM transverse	10.187	m
VCG	7.275	m
GM solid	2.912	m
GG' correction	0.046	m
G'M liquid	2.865	m

VCG' 7.321 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(SB) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	6.263	-0.891	0.000	0.000	0.000	-0.000	0.000
2.00	6.261	-0.887	0.356	0.256	0.000	0.100	0.002
5.00	6.252	-0.863	0.889	0.638	0.000	0.251	0.011
7.00	6.241	-0.835	1.244	0.892	0.000	0.351	0.021
10.00	6.218	-0.772	1.772	1.271	0.000	0.501	0.044
15.00	6.161	-0.620	2.627	1.895	0.000	0.732	0.098
20.00	6.099	-0.563	3.389	2.504	0.000	0.885	0.169
25.00	6.030	-0.604	4.078	3.094	0.000	0.983	0.251
30.00	5.941	-0.717	4.718	3.661	0.000	1.057	0.340
35.00	5.817	-0.865	5.322	4.199	0.000	1.123	0.435
40.00	5.643	-1.036	5.901	4.706	0.000	1.195	0.536
50.00	5.126	-1.529	6.901	5.609	0.000	1.292	0.755
60.00	4.356	-2.377	7.550	6.341	0.000	1.210	0.977

Statical angle of inclination is 0.000 degrees to starboard
Contour : FIRM

Opening	is submerged at [degrees]
ER Vent in	56.71

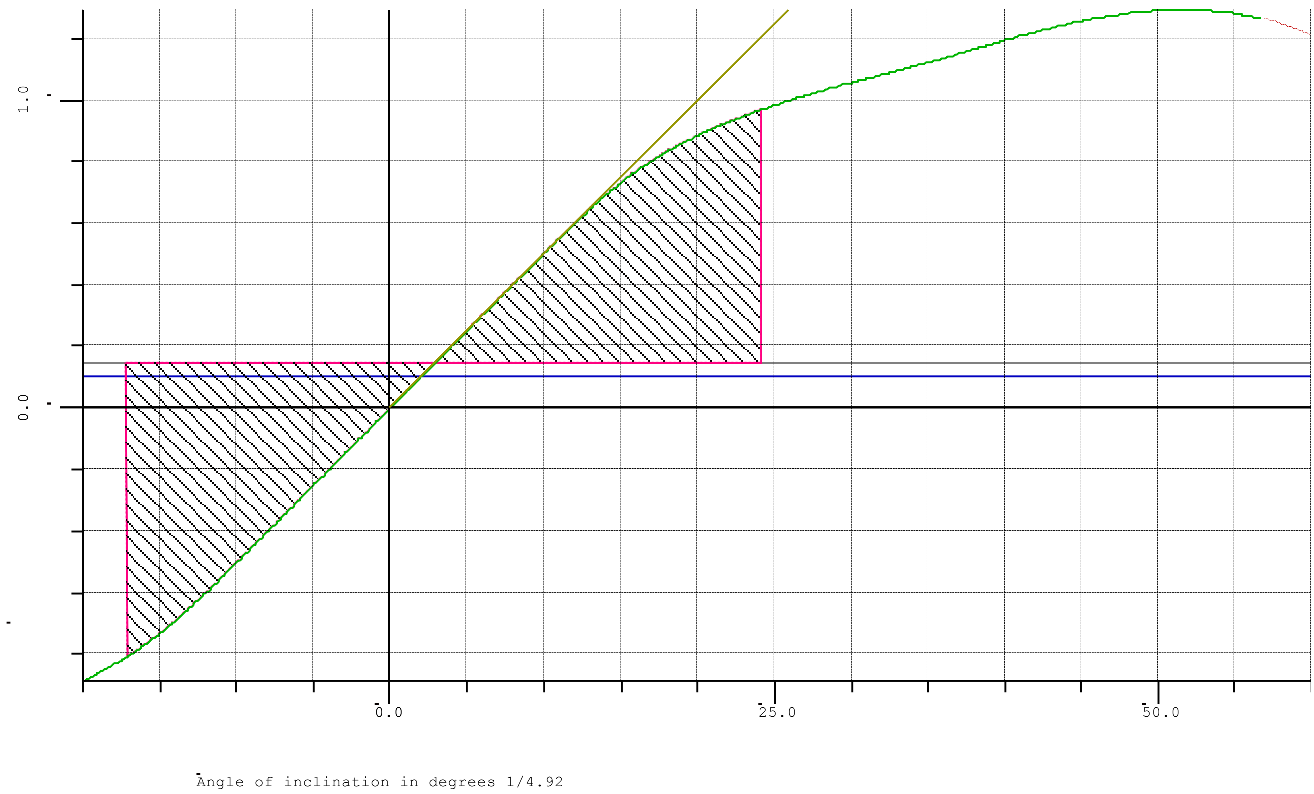
Summary

Hydrostatics		Criterion	Value
Draft mld.		6.600	6.263 m
Trim	-0.891 m		
Statical angle of inclination	0.00 degrees SB		
Flooding angle	56.71 degrees		

Intact Stability Code for vessels with a large B/H ratio	Criterion	Value
Minimum metacentric height G'M	0.150	2.865 meter
Maximum GZ at 30 degrees or more	0.200	1.295 meter
Top of the GZ curve at least at	15.000	51.573 degrees
Area under the GZ curve up to 30 degrees	0.055	0.340 mrad
Area under the GZ curve between 30 and 40 degrees	0.030	0.196 mrad
Maximum angle of inclination acc. to IMO's A.562 weathercriterion	50.000	24.173 degrees
Maximum statical angle due to wind	15.698	2.009 degrees
Maximum statical angle 80% of angle of deck immersion	10.589	2.009 degrees

VCG'	
Actual	7.321 m
Maximum allowable	8.915 m

Loading condition complies with the stated criteria.



XXI Loss of load calculation final design

TRIM AND STABILITY CALCULATION
FIRM

14 Jun 2013 16:20:30

Condition : 5.1 Crane operation LoL calculation 100% consumables

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm	
Empty ship		5135.000	8.370	53.241	0.000	0.000	
Subtotals for group : Ballast water							
BW FP	155-fwd	0.000	0.002	110.300	0.000	0.000	
BW DB CT	133-145	11.426	0.290	97.137	0.000	63.317	
BW DB SB	124-133	45.511	1.499	89.857	1.626	0.000	
BW DB PS	124-133	45.511	1.499	89.857	-1.626	0.000	
BW WT SB	124-133	0.000	2.500	90.007	3.360	0.000	
BW WT PS	124-133	0.000	2.500	90.007	-3.360	0.000	
BW DB SB	112-124	73.001	1.494	82.466	1.951	0.000	
BW DB PS	112-124	73.001	1.494	82.466	-1.951	0.000	
BW WT SB	112-124	0.000	2.500	82.749	4.281	0.000	
BW WT PS	112-124	0.000	2.500	82.749	-4.281	0.000	
BW DB SB	100-112	86.731	1.487	74.092	2.301	0.000	
BW DB PS	100-112	86.731	1.487	74.092	-2.301	0.000	
BW WT SB	100-112	0.000	2.500	73.849	5.053	0.000	
BW WT PS	100-112	0.000	2.500	73.849	-5.053	0.000	
BW DB SB	88-100	99.317	1.484	65.718	2.627	0.000	
BW DB PS	88-100	99.317	1.484	65.718	-2.627	0.000	
BW WT SB	88-100	0.000	2.500	65.579	5.452	0.000	
BW WT PS	88-100	0.000	2.500	65.579	-5.452	0.000	
BW DB SB	73-88	137.750	1.489	56.277	2.926	0.000	
BW DB PS	73-88	137.750	1.489	56.277	-2.926	0.000	
BW WT SB	73-88	0.000	2.500	56.485	7.076	0.000	
BW WT PS	73-88	0.000	2.500	56.485	-7.076	0.000	
BW DB SB	61-73	114.709	1.499	46.898	3.070	0.000	
BW DB PS	61-73	114.709	1.499	46.898	-3.070	0.000	
BW WT SB	61-73	0.000	2.500	46.740	7.419	0.000	
BW WT PS	61-73	0.000	2.500	46.740	-7.419	0.000	
BW DB SB	49-61	0.000	0.015	42.024	0.203	0.000	
BW DB PS	49-61	0.000	0.015	42.024	-0.203	0.000	
BW WT SB	49-61	0.000	2.500	38.458	7.466	0.000	
BW WT PS	49-61	0.000	2.500	38.458	-7.466	0.000	
BW DB SB	37-49	93.743	1.659	30.346	2.994	0.000	
BW DB PS	37-49	93.743	1.659	30.346	-2.994	0.000	
BW WT SB	37-49	0.000	2.500	30.454	7.408	0.000	
BW WT PS	37-49	0.000	2.500	30.454	-7.408	0.000	
BW SB	4-19	0.000	5.750	8.540	8.034	0.000	
BW PS	4-19	0.000	5.750	8.540	-8.034	0.000	
BW SB	-4-4	0.000	4.761	-1.533	0.033	0.000	
BW PS	-4-4	0.000	4.761	-1.533	-0.033	0.000	
SUBTOTAL		1312.951	1.505	60.313	0.000	63.317	
Subtotals for group : Fuel oil							
FO CT	124-133	84.241	4.092	89.765	0.000	0.000	!
FO CT	112-124	158.571	4.092	82.367	0.000	0.000	!
FO CT	100-112	185.000	4.092	74.200	0.000	341.545	!
FO CT	88-100	185.000	4.092	65.800	0.000	0.000	!
FO SB	4-19	77.084	7.342	8.050	5.600	0.000	!
FO PS	4-19	77.084	7.342	8.050	-5.600	0.000	!
SUBTOTAL		766.980	4.746	62.275	0.000	341.545	

Subtotals for group : Fresh water						
FW WT SB	133-145	47.216	3.848	97.285	2.648	15.423
FW WT PS	133-145	47.216	3.848	97.285	-2.648	15.423
SUBTOTAL		94.431	3.848	97.285	0.000	30.846
Subtotals for group : Crew and stores						
Crew and stores		17.000	13.500	75.000	0.000	0.000
SUBTOTAL		17.000	13.500	75.000	0.000	0.000
Subtotals for group : Crane						
Crane boom		50.000	25.000	20.000	-12.000	0.000
SUBTOTAL		50.000	25.000	20.000	-12.000	0.000
Deckload 500t		500.000	10.000	23.000	0.000	0.000
TOTAL		**7876.361**	**7.039**	**53.744**	**-0.076**	**435.708**

For FSM's marked with ! one of the following methods has been chosen :
1. FSM is set to zero, 2. FSM is set to the maximum, 3. FSM is set to zero if filling percentage > 98%

Hydrostatics			Drafts and trim		
Volume	7684.337	m^3	Drafts above base :		
LCF	46.964	m	Draft mean (Lpp/2)	6.449	m
Mom. change trim	141.238	tonm/cm	Draft aft (App)	6.129	m
Ton/cm immersion	18.743	ton/cm	Draft fore (Fpp)	6.768	m
Specific weight	1.025	ton/m^3	Trim	0.638	m

Transverse stability					
KM transverse	9.991	m			
VCG	7.039	m			
GM solid	2.953	m			
GG' correction	0.055	m			
G'M liquid	2.897	m	VCG'	7.094	m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(PS) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	6.449	0.638	0.000	0.000	0.076	-0.076	0.000
2.00	6.447	0.644	0.349	0.248	0.076	0.025	0.000
5.00	6.437	0.677	0.870	0.618	0.076	0.176	0.005
7.00	6.425	0.717	1.216	0.865	0.076	0.276	0.013
10.00	6.400	0.806	1.732	1.232	0.075	0.425	0.032
15.00	6.338	1.021	2.575	1.836	0.074	0.665	0.079
20.00	6.258	1.254	3.366	2.426	0.072	0.868	0.147
25.00	6.170	1.390	4.075	2.998	0.069	1.008	0.229
30.00	6.062	1.467	4.726	3.547	0.066	1.113	0.322
35.00	5.920	1.516	5.335	4.069	0.062	1.204	0.423
40.00	5.727	1.557	5.915	4.560	0.058	1.297	0.532
50.00	5.162	1.621	6.923	5.434	0.049	1.440	0.772
60.00	4.343	1.642	7.572	6.143	0.038	1.390	1.023

Statical angle of inclination is 1.506 degrees to portside

Opening	is submerged at [degrees]
Er vent out	57.57

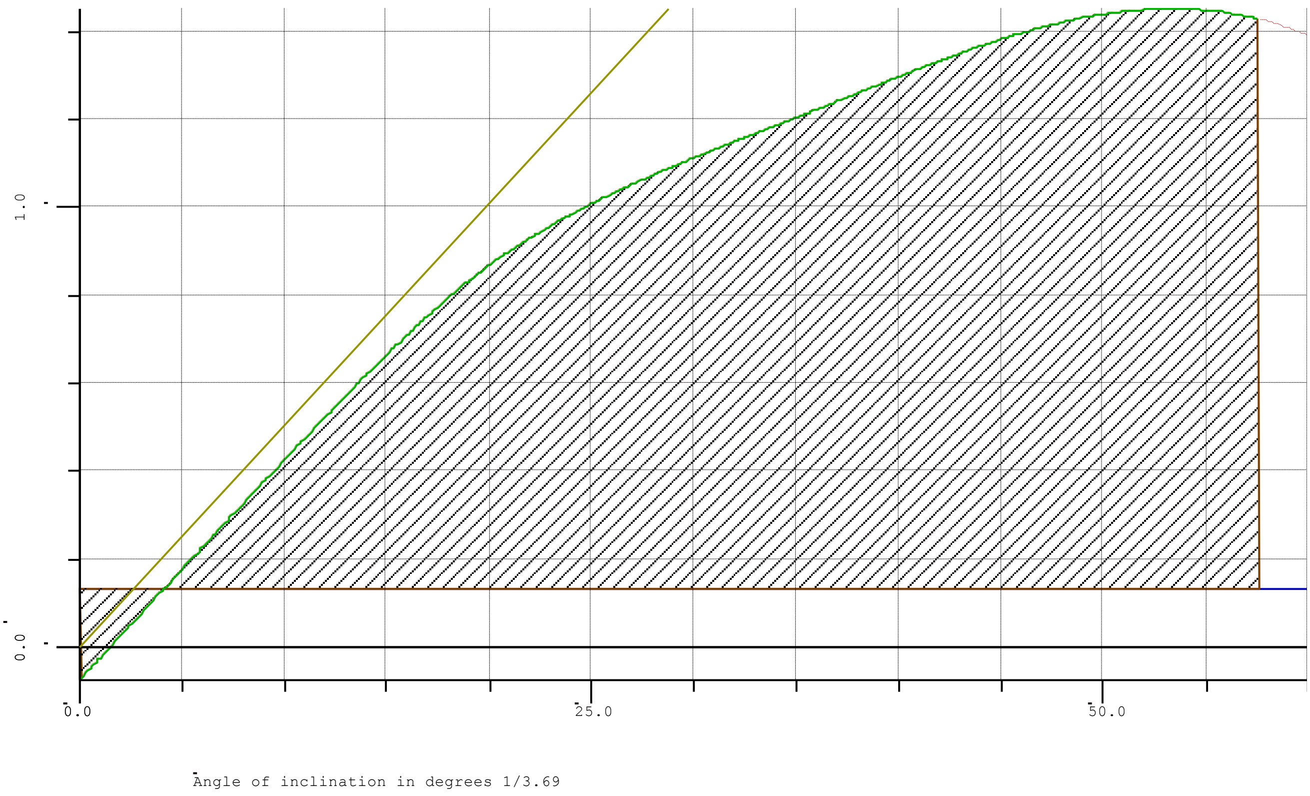
Summary

Hydrostatics		Criterion	Value	
Draft mld.		6.600	6.449	m
Trim	0.638 m			
Statical angle of inclination	1.51 degrees PS			
Flooding angle	57.57 degrees			

DNV loss load	Criterion	Value	
DNV Loss of Load (Pt. 5 Ch. 7 Sec 17 D) Area A2> 1,4 A1	1.400	114.106	-
DNV Loss of Load, angle max 15 degrees	15.000	4.086	degrees

VCG'	
Actual	7.094 m
Maximum allowable	8.941 m

Loading condition complies with the stated criteria.



TRIM AND STABILITY CALCULATION
FIRM

14 Jun 2013 16:21:28

Condition : 5.2 Crane operation LoL calculation 10% consumables

Description		Weight ton	VCG m	LCG m	TCG m	FSM tonm	
Empty ship		5135.000	8.370	53.241	0.000	0.000	
Subtotals for group : Ballast water							
BW FP	155-fwd	0.000	0.002	110.300	0.000	0.000	
BW DB CT	133-145	11.426	0.290	97.137	0.000	63.317	
BW DB SB	124-133	45.511	1.499	89.857	1.626	0.000	
BW DB PS	124-133	45.511	1.499	89.857	-1.626	0.000	
BW WT SB	124-133	0.000	2.500	90.007	3.360	0.000	
BW WT PS	124-133	0.000	2.500	90.007	-3.360	0.000	
BW DB SB	112-124	73.001	1.494	82.466	1.951	0.000	
BW DB PS	112-124	73.001	1.494	82.466	-1.951	0.000	
BW WT SB	112-124	0.000	2.500	82.749	4.281	0.000	
BW WT PS	112-124	0.000	2.500	82.749	-4.281	0.000	
BW DB SB	100-112	86.731	1.487	74.092	2.301	0.000	
BW DB PS	100-112	86.731	1.487	74.092	-2.301	0.000	
BW WT SB	100-112	0.000	2.500	73.849	5.053	0.000	
BW WT PS	100-112	0.000	2.500	73.849	-5.053	0.000	
BW DB SB	88-100	99.317	1.484	65.718	2.627	0.000	
BW DB PS	88-100	99.317	1.484	65.718	-2.627	0.000	
BW WT SB	88-100	0.000	2.500	65.579	5.452	0.000	
BW WT PS	88-100	0.000	2.500	65.579	-5.452	0.000	
BW DB SB	73-88	137.750	1.489	56.277	2.926	0.000	
BW DB PS	73-88	137.750	1.489	56.277	-2.926	0.000	
BW WT SB	73-88	0.000	2.500	56.485	7.076	0.000	
BW WT PS	73-88	0.000	2.500	56.485	-7.076	0.000	
BW DB SB	61-73	114.709	1.499	46.898	3.070	0.000	
BW DB PS	61-73	114.709	1.499	46.898	-3.070	0.000	
BW WT SB	61-73	0.000	2.500	46.740	7.419	0.000	
BW WT PS	61-73	0.000	2.500	46.740	-7.419	0.000	
BW DB SB	49-61	0.000	0.015	42.024	0.203	0.000	
BW DB PS	49-61	0.000	0.015	42.024	-0.203	0.000	
BW WT SB	49-61	0.000	2.500	38.458	7.466	0.000	
BW WT PS	49-61	0.000	2.500	38.458	-7.466	0.000	
BW DB SB	37-49	93.743	1.659	30.346	2.994	0.000	
BW DB PS	37-49	93.743	1.659	30.346	-2.994	0.000	
BW WT SB	37-49	0.000	2.500	30.454	7.408	0.000	
BW WT PS	37-49	0.000	2.500	30.454	-7.408	0.000	
BW SB	4-19	0.000	5.750	8.540	8.034	0.000	
BW PS	4-19	0.000	5.750	8.540	-8.034	0.000	
BW SB	-4-4	0.000	4.761	-1.533	0.033	0.000	
BW PS	-4-4	0.000	4.761	-1.533	-0.033	0.000	
SUBTOTAL		1312.951	1.505	60.313	0.000	63.317	
Subtotals for group : Fuel oil							
FO CT	124-133	8.596	2.662	89.765	0.000	0.000	!
FO CT	112-124	16.181	2.662	82.367	0.000	0.000	!
FO CT	100-112	18.878	2.662	74.200	0.000	341.545	!
FO CT	88-100	18.878	2.662	65.800	0.000	0.000	!
FO SB	4-19	7.866	5.912	8.050	5.600	0.000	!
FO PS	4-19	7.866	5.912	8.050	-5.600	0.000	!
SUBTOTAL		78.263	3.316	62.275	0.000	341.545	

Subtotals for group : Fresh water						
FW WT SB	133-145	5.902	2.693	97.329	2.432	7.420
FW WT PS	133-145	5.902	2.693	97.329	-2.432	7.420
SUBTOTAL		11.804	2.693	97.329	-0.000	14.840
Subtotals for group : Crew and stores						
Crew and stores		17.000	13.500	75.000	0.000	0.000
SUBTOTAL		17.000	13.500	75.000	0.000	0.000
Subtotals for group : Crane						
Crane boom		50.000	25.000	20.000	-12.000	0.000
SUBTOTAL		50.000	25.000	20.000	-12.000	0.000
Deckload 500t		500.000	10.000	23.000	0.000	0.000
TOTAL		**7105.018**	**7.280**	**52.411**	**-0.084**	**419.702**

For FSM's marked with ! one of the following methods has been chosen : 1. FSM is set to zero, 2. FSM is set to the maximum, 3. FSM is set to zero if filling percentage > 98%

Hydrostatics		Drafts and trim	
Volume	6931.880 m^3	Drafts above base :	
LCF	46.645 m	Draft mean (Lpp/2)	5.928 m
Mom. change trim	138.515 tonm/cm	Draft aft (App)	6.137 m
Ton/cm immersion	18.445 ton/cm	Draft fore (Fpp)	5.719 m
Specific weight	1.025 ton/m^3	Trim	-0.418 m

Transverse stability			
KM transverse	10.144 m		
VCG	7.280 m		
GM solid	2.864 m		
GG' correction	0.059 m		
G'M liquid	2.805 m	VCG'	7.339 m

The stability values are calculated for the actual trim.

Statical and dynamical stability, calculated with constant LCB :

Angle(PS) degrees	Draft mld. m	Trim m	KNsinφ m	VCG'sinφ m	TCGcosφ m	G'Nsinφ m	Area mrad
0.00	5.928	-0.418	0.000	0.000	0.084	-0.084	0.000
2.00	5.926	-0.412	0.354	0.256	0.084	0.013	0.000
5.00	5.916	-0.378	0.883	0.640	0.084	0.159	0.005
7.00	5.905	-0.338	1.234	0.894	0.084	0.255	0.012
10.00	5.878	-0.246	1.755	1.274	0.083	0.397	0.029
15.00	5.812	-0.025	2.608	1.900	0.082	0.627	0.074
20.00	5.720	0.232	3.417	2.510	0.079	0.828	0.138
25.00	5.615	0.407	4.133	3.102	0.077	0.955	0.216
30.00	5.484	0.519	4.782	3.670	0.073	1.039	0.303
35.00	5.315	0.603	5.382	4.210	0.069	1.103	0.397
40.00	5.091	0.680	5.948	4.718	0.065	1.166	0.496
50.00	4.401	0.834	6.969	5.622	0.054	1.292	0.711
60.00	3.334	0.883	7.655	6.356	0.042	1.257	0.937

Statical angle of inclination is 1.726 degrees to portside

Opening	is submerged at [degrees]
Er vent out	59.74

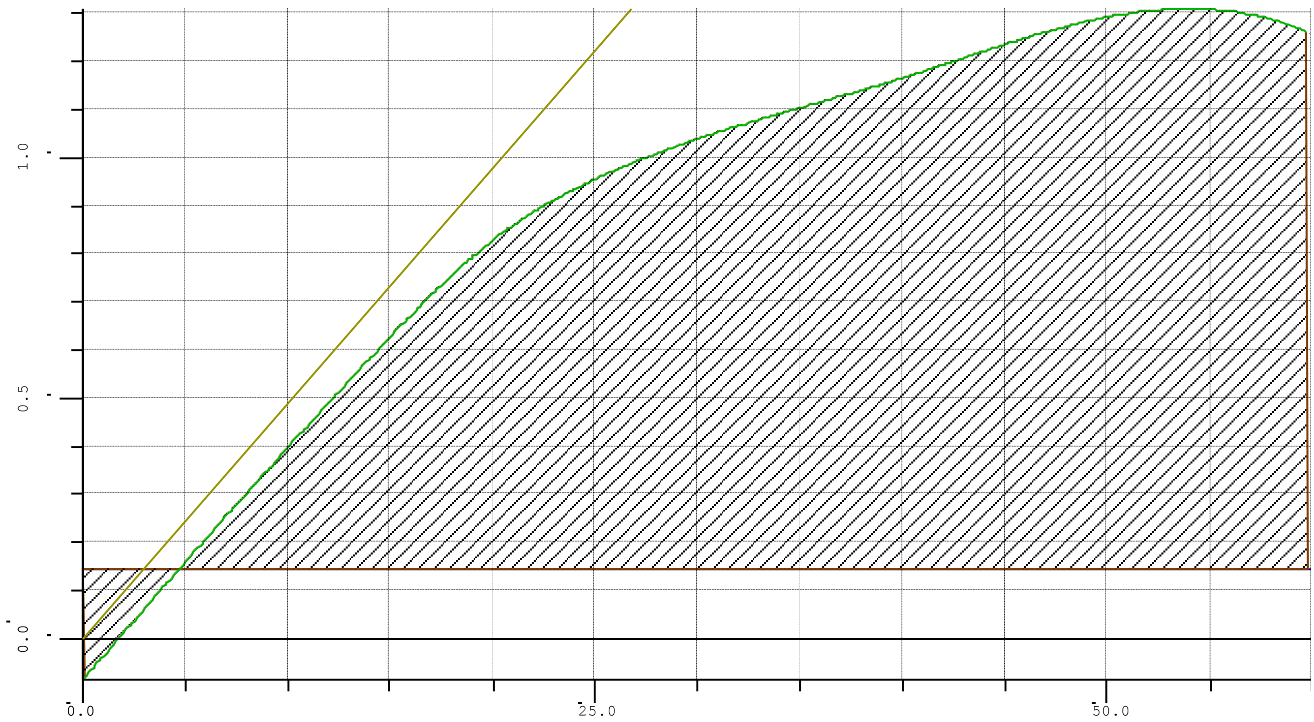
Summary

Hydrostatics		Criterion	Value
Draft mld.		6.600	5.928 m
Trim	-0.418 m		
Statical angle of inclination	1.73 degrees PS		
Flooding angle	59.74 degrees		

DNV loss load	Criterion	Value
DNV Loss of Load (Pt. 5 Ch. 7 Sec 17 D) Area A2> 1,4 A1	1.400	84.485 -
DNV Loss of Load, angle max 15 degrees	15.000	4.689 degrees

VCG'	
Actual	7.339 m
Maximum allowable	8.987 m

Loading condition complies with the stated criteria.



Angle of inclination in degrees 1/3.69

XXII Dynamic positioning calculations final design

Section	Shape	T	2T	B	Re	B/2T	Cd	dX [m]	x wrt L/2 [m]	dF keel [kN]	M keel [kNm]
1	Ellipse	0.97	1.94	17.65	14242	9.10	0.31	5	-57.5	0.82	-47.37
2	Ellipse	1.35	2.7	18.21	14694	6.74	0.25	5	-52.5	0.91	-47.58
3	Ellipse	2.02	4.04	18.38	14831	4.55	0.33	5	-47.5	23.16	-1100.3
4	Ellipse	2.94	5.88	18.46	14895	3.14	0.42	5	-42.5	19.76	-839.92
5	Ellipse	3.86	7.72	18.5	14928	2.40	0.52	5	-37.5	16.98	-636.89
6	Ellipse	4.61	9.22	18.51	14936	2.01	0.62	5	-32.5	15.26	-496.07
7	Ellipse	5.14	10.3	18.51	14936	1.80	0.70	5	-27.5	9.70	-266.69
8	Ellipse	5.44	10.9	18.5	14928	1.70	0.74	5	-22.5	10.87	-244.48
9	Ellipse	5.6	11.2	18.49	14919	1.65	0.76	5	-17.5	11.52	-201.52
10	Ellipse	5.72	11.4	18.46	14895	1.61	0.78	5	-12.5	12.03	-150.34
11	Ellipse	5.85	11.7	18.35	14807	1.57	0.80	5	-7.5	12.64	-94.83
12	Ellipse	5.92	11.8	18.22	14702	1.54	0.81	5	-2.5	13.03	-32.58
13	Ellipse	5.97	11.9	17.93	14468	1.50	0.83	5	2.5	13.45	33.63
14	Ellipse	5.99	12	17.46	14088	1.46	0.85	5	7.5	13.88	104.10
15	Ellipse	6	12	16.76	13524	1.40	0.89	5	12.5	14.46	180.76
16	Ellipse	6	12	15.77	12725	1.31	0.94	5	17.5	15.27	267.26
17	Ellipse	6	12	14.48	11684	1.21	1.01	5	22.5	16.43	369.71
18	Ellipse	6	12	12.94	10441	1.08	1.10	5	27.5	17.98	494.47
19	Ellipse	6	12	11.26	9086	0.94	1.22	5	32.5	19.90	646.66
20	Ellipse	6	12	9.48	7649	0.79	1.36	5	37.5	22.21	833.04
21	Ellipse	6	12	7.63	6157	0.64	1.53	5	42.5	24.97	1061.30
22	Ellipse	6	12	5.69	4591	0.47	1.74	5	47.5	28.29	1343.84
23	Ellipse	5.99	12	3.57	2881	0.30	1.99	5	52.5	32.41	1701.76
24	Ellipse	2.16	4.32	0.92	742	0.21	2.13	5	57.5	12.50	718.60
SUM							**0.94**			**378.45**	**3596.59**

Table 70, Current forces and moments final design

TECHNICAL TENDER Page 1 of 10 CARGOTEC

TECHNICAL TENDER DOCUMENT

Equipment:

HMC 3568 LKO 250-32 (1000-15) AHC 2500m

1		11.11.11	TSS	LMA	
A	Issued for IDC	19.09.11	PUB		
Rev.	Reason for issue:	Date	Auth.	Check.	

Title:

OFFSHORE KNUCKLE JIB CRANE

Customer: **Damen Shipyard**	Project name.: 237 034
Cargotec Quote no.: ST5802	Customer Ref: **Mark Couwenberg**

Cargotec doc. no.:	Customer doc. no.:	No.of attachments:	No. of pages:
			10

Cargotec Norway AS
Andøyveien 23
N-4623
Tel +47 91 68 60 00
Fax +47 38 01 87 01
www.cargotec.com

Domicile
Kristiansand, Norway
Business Identity code
NO914246965
Registered office
Andøyveien 23
N-4623, Kristiansand, Norway

Lloyd's Register Quality Assurance certifies that the Quality Management System for Cargotec Corporation's business area MacGregor is ISO 9001 compliant.

HIAB · KALMAR · MACGREGOR

1 SCOPE OF SUPPLY AND PRICES

The work to be performed includes all management, engineering, supervision, equipment and materials necessary to perform the work as outlined below.

1.1 Project management:

a Provision of overall project management for the completion of the required work.
b Establishment of schedule and quality documentation
c Overall administration of the work

1.2 Engineering:

a Preparation of manufacturing procedures.
b Detail design.
c Preparing user manual and data book.
d As built documentation.

1.3 Procurement:

a Provision of materials and equipment for completion of the work.

1.4 Manufacturing:

a Manufacturing and assembly of units as described in technical section.
b Manufacturing follow up by Cargotec and eventual class.

1.5 Testing:

a FAT test at Cargotec's facilities for offshore load handling.

1.6 Installation (NB! Optional):

a Installation to vessel at Cargotec's facilities
b HAT (quayside) Harbour Acceptance Test (Overload test onboard)(Option)
c SAT (Sea test) Test of crane at sea (Option)

A 100T OFFSHORE KNUCKLE JIB CRANE WITH AHC

Pos:	Qty:	Description:
A1	1	**El. hydraulic Self-contained Offshore Knuckle Jib Crane:** **Type: HMC 3568 LKO 250-32 (1000-15) AHC 2500m**

Complete Active Heave Compensated electro-hydraulic driven knuckle jib MacGregor crane for efficient general offshore/subsea load handling, with integrated electro-hydraulic power unit, delivered as a complete unit ready for installation to vessels.

The crane is equipped with a circular foundation for welding/bolting to deck with a height of 5000 mm, a fully equipped operator cabin, a hydraulic driven Active Heave Compensated winch system with SWL 100 tons single line winch, hydraulic cylinder operated luffing and knuckle jibs and a hydraulic driven slew system.

Knuckle jib cranes were originally designed to keep the jib end, including load, as low as possible to reduce pendulum motion caused by vessel movement. However, when these cranes are used to lift large and heavy objects, it is sometimes necessary to have more free-hook height to provide increased space for lifting arrangements, slings etc.
All our knuckle jib cranes are designed to lift high loads with an extended knuckle jib. This includes sufficient strength in the structure and cylinder system to deal with these forces. This feature provides operators with great flexibility during planning of lifting operations.

When the crane is in the over-side working position, with active heave-compensation (AHC) activated and the crane hook in the water, it is still possible to operate jib and slew crane functions. This makes load positioning possible and optimizes other crane functions without shutting down the AHC mode or moving the vessel.

On all larger MacGregor cranes the slew drive system components, including drive gears and motors, are located inside the crane's king. This simplifies maintenance and inspections throughout the entire lifetime of the crane and protects the components from the aggressive environment/surroundings.

The crane is fully tested and adjusted ready for installation by welding/bolting to deck and connection of el. supply to integrated el. slip rings.

Main winch Data:

Hook travel length:	2500 meters
Wire type and dimension:	OD Ø64mm, galvanized, non rotating type.
Hoisting speed, single line, 0-33t:	0-60 m/min stepless var. on mid lay
Hoisting speed, single line, 33-66t:	0-60-30 m/min stepless var. on mid lay
Hoisting speed, single line, 66-100t:	0-30-20 m/min stepless var. on mid lay

(Hoisting speeds are automatic a function of load, therefore speeds are approximate values)

Main Crane Data

Slewing speed, R=15/35m:	0-1/0-0.5 rpm
Minimum working radius:	~6.5 m
Dynamic factor:	ψ= 1.3 (2.0 on pedestal/slew system)

(Hoisting speeds are automatic a function of load, therefore speeds are approximate values)

El.supply data

Power supply connection location:	To terminals inside pedestal
Power supply:	690V/60Hz/3ph, 440V/60Hz
Required power, main motors:	3x300 kW + 1x550 kW
Required power, aux motors:	141 kW
Required power, emergency:	50 kW
Required power, aux power:	15 kW (230V/60Hz/3ph)
Required power, controlsystem, UPS:	5 kW (230V/60Hz/1ph)

Weight Data

Total weight of crane ex. whip line winch:	Approximate 270t
Weight of whip line winch system:	According to selected option

Main hook lifting capacity,

Crane lifting capacity is an automatic step less function of the crane outreach with the following main capacities: (Lifting capacity on outer drum layer, full drum)

a.	Lifting capacity, single line arr.	SWL 250 kN (25t) at 32m outreach
b.	Lifting capacity, single line arr:	SWL 1000 kN (100t) at 15m outreach
c.	Ship to ship capacity:	Derating curves will be issued
d.	Subsea lift capacity:	Reduce above SWL with weight of submerged rope and DAF due to hydrodynamic forces and add buoyancy of the load

Auto tension system:	High speed auto-tension function included
Auto tension force setting:	0-100t, set from operators cabin
Emergency pay out function:	MOPS and AOPS

Table 1: Remaining lifting capacity vs. depth

Capacity	Deck	Wire	Weight dry/wet	1000m	2000m	3000m	3500m
Max SWL=100t	100t	Ø64mm	19.9/17.9kg/m	93t	76t	59t	50t
Max SWL=150t	150t	Ø77mm	29.8/25.0kg/m	141t	116t	91t	79t

Hydrodynamic forces etc. are not considered in this table

In the buoyancy calculation the volume is calculated from massive steel with a density of steel = 7850 kg/m^3 and the density of seawater = 1025 kg/m^3.

A2 1 **Active Heave compensation system (AHC/AT):**

By using the finest and most reliable motion sensors, position sensors and control system components, MacGregor cranes provide the best possible active heave-compensation performance on the market. Accuracy measured to a few centimetres is achievable even under extreme heave conditions.

Max top wire tension, single line during AHC: 1000 kN (100t single line)

Performance case AHC/AT, 0-50t:

Heave period: 10 sec
Nominal displacement: +/- 3.2 m (6.4 m total motion)
Max. displacement: +/- 4.2 m (8.4 m total motion)
Max compensation speed: 2.0 m/s
Reference system: MRU in crane control system

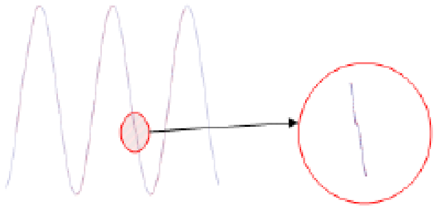
Performance case AHC/AT, 50-100t:

Heave period: 12 sec
Nominal displacement: +/- 3.9 m (7.8 m total motion)
Max compensation speed: 2.0 m/s
Reference system: MRU in crane control system

Dual sensor system (important safety function):

In our expert opinion, all regulation sensors used in AHC/AT mode are of critical importance and are therefore, specifically focused on during the product design stage. A fail-safe sensor system with dual sensors has been developed, tested and implemented in our products. This system with auto-takeover ensures unique winch function reliability when operating in AHC/AT mode. The **load cell** is one of these sensors which have a dual output (two channels). This enables the AHC/AT to continue (without stop) in case of a failure in one of these channels. Another sensor is the winch position encoder which is original a Profibus sensor, while a secondary independent analog sensor operates without the Profibus system. If a failure in the default sensor occurs, the secondary sensor takes over immediately, without any stop in AHC/AT mode. These new features significantly increase the system reliability. The crane jib system is also equipped with dual-sensors giving important feedback to the system in AHC/AT mode. The control system will automatically switch to the second sensor if there is a failure in the primary one. All dual sensors will generate alarms if there is deviation between them. This is to warn the operator at an early stage that one of the sensors is not sending a correct value. The operator can easily switch between the sensors, unless one of them has totally failed.

Logging from the verification test when switching from one position encoder to another during AHC



The AHC winch is following a simulated compensating motion (sinus curve), when at this spot the default encoder suddenly fails! → The control system respond immediately by switch to the second encoder, with an almost invisible deviation form the reference/motion curve.

Crane design: The crane is categorized as an offshore crane according to DNV "Standard for Certification No.2.22, Lifting Appliances, October 2008" with all operational and safety features included.

A3 1 Electro hydraulic power unit:

Complete electro hydraulic power unit of sufficient capacity, totally enclosed unit mounted in the crane king. Hydraulic oil tank is built-in in the crane king structure.

A4 1 Surface treatment / Paint spec.:

- The external surfaces are sandblasted to Sa 2,5
- International Interspec System 1, or equivalent for general purpose.
- International Interspec System 6, for application on non-ferrous metals.
- International Interspec for Hydraulic Tank, for oil reservoir on inside.
- Top coat color: RAL9010 White

Pipe / Fittings material

Pipes and pipe fittings conforms to ISO 8434-1 (DIN 2353) standards.
Pipes, Nuts and locking rings in stainless steel AISI 316.
All other fittings in el. zn coated steel,

Hoses conforms to EN 856 (SAR R13/12) / EN 857 (SAE R2T)
Hose couplings are in regular steel and coated with "Tuff Coat".

Fitting system <Ø38 mm pipes:	"Walform" DIN 2353. Body in yellow chromate steel
Fitting system >Ø38 mm pipes:	Flange sys. SAE J518 and ISO6164 in yellow chrome. steel
Pipe materials, external	OD up to OD Ø50mm, AISI 316 stainless steel.
	OD above Ø50mm, Mild steel

All couplings/fittings are covered with "Denso Tape" to ensure a NON CORROSIVE environment

A5	1	**DNV approval of crane pedestal:** Design review and manufacturing control of crane pedestal
A6	1	**FAT:** FAT test carried out at Cargotec's facilities for offshore load handling. Client invited for attendance.
A7	3	**User manual:** Contains all required user information as, installation, first start up, operation, maintenance and preservation. All required drawings, diagrams and certificates are included here. English language.
A10	1	**Operators Cabin:** The crane is equipped with a well dimensioned operator cabin representing a comfortable work place for the crane operator. The operator cabin is equipped with an ergonomic and dampened operator chair with all main operation handles of joy stick type located in armrests at side of the operators chair. The cabin is fully insulated equipped air condition system, Window wipers, Signal horn, window sun-blinds, FM radio/CD player, VHF / UHF radio and general instrumentation. The size and comfort of our operator cabins are among the best in the market. The ergonomic control consoles and the screen-based control system provide the operator with a clear view of the crane's status and performance.
A11	4	**El. motor starter starter system of Star/Delta type:** This item is included and fitted inside the crane king. Electrical termination of supply cables from crane pedestal mounted main slip ring and to all electrical motors fitted in crane king. Starter cabinet is of Star/Delta type with sequence start of each motor. Starter is separated in two sections for redundant supply from two separate power tables.
A12	1	**Fully integrated Automatic Grease lubrication system:** Two sectioned fully automatic crane grease system for automatic lubrication of all grease points on the MacGregor crane. This system simplifies the maintenance of the crane significantly. The advantage of a central lubrication system is that it releases "a little grease frequently" as opposed to "too much grease infrequently", which is often the case with manual lubrication.
A13	1	**EPS; emergency power system:** An emergency power system, consisting of a totally-independent pump/motor system with a separate remote control panel, ensures the safe operation of the crane, even if the main power

supply (and aux. 230V power supply) fails. All crane and winch functions (not AHC/AT mode) can be operated at full load at reduced speed. The hook-up of the emergency system is done with a cable from the bottom of the pedestal, giving power to the system independent of the slip rings. It is a great advantage that crane operations can continue even if such situation occurs.

A14	1	**Main Hook / Block:** Subsea swivel hook swivel for single line lift – SWL 100t
A15	2	**Flood light:** The crane jib is fitted with a pendulum suspended 400W, Marine floodlight in marine enclosures.
A16	2	**Helicopter Warning Lights:** The crane is fitted with a helicopter warning light, in marine enclosure, on top of main winch and in front of main jib.
A17	1	**Extra slip rings:** 6 off extra slip rings for ROV monitors and communication system.
A18	1	**Winch camera monitoring system:** Complete camera monitoring system for all crane winches. LCD flat screen monitor in crane cabin.
A19	1	**SPM nipples in electric main motors:** All main electric motors are fitted with SPM nipples for condition control.
A20	1	**Crane load diagrams:** The crane will be delivered with a set of load diagrams covering normal offshore operation modes, including internal lifting on vessel, ship to ship and ship to seabed operations. The diagrams will be calculated and included in crane user manual. The diagrams will also be used as basis for programming the crane compute in cabin.
A21	1	**Derating table – ship to ship operation:** Derating table for ship to ship lifting is included in scope. The table specifies the crane capacity during loading / offloading operations between mother vessel and another vessel in a specified seastate condition. The key element in these calculations is expected max relative speed between crane hook and load, at time of pick up.

OPTIONS:

AO820T150 **Whip line winch:**
Complete whip line winch mounted on the main jib. Separate wire sheave bracket on knuckle jib.
Whip line hook lifting capacity:

Safe working load (SWL):	100kN (10t)
Hook travel:	150 m
Hoisting speed:	30 m/min
Weight, incl. wire sheaves and wire:	Approximate 3t

AO10.1 1 **Remote diagnostic (Satellite based system) control system:**
Satellite based remote diagnostic system (yearly fee will apply).

AO11.1 1 **Power Management System:**
Crane control system with interface for bridge monitoring / control of power management.

AO12.2 1 **Bridge Monitor:**
Includes 17" Slavemonitor with repeater.

AO14.3 1 **DNV certification Large cranes:**
The crane is designed, manufactured and tested acc to DNV requirements for offshore cranes. As option a third party certification by DNV can be included. This includes complete DNV design review/approval, manufacturing control, FAT test attendance.

AO15.1 1 **Tugger winches 2x4T:**
2 x 4 ton hydraulic tugger winches, side-tiltable +/- 15 degrees. Both winches are foot operated from crane cabin. Winches are located on side of crane king, just below main jib cylinders.

AO17.1 **Personnel lift:**
Crane designed for personnel lifting capability. Emergency operation assumed run with el. power from ship emergency generator system / alternatively ext. HPU supply.

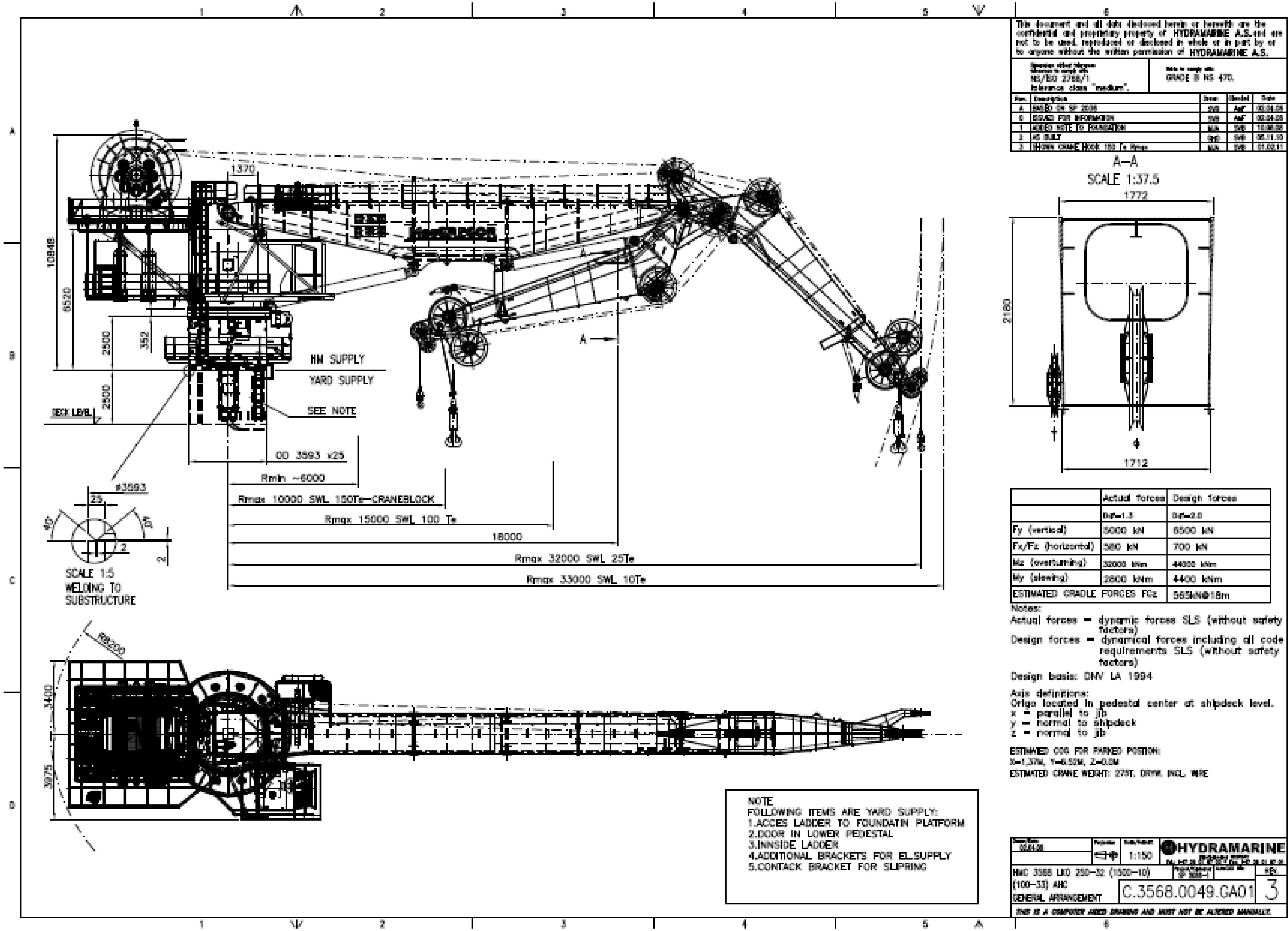
AO19.1 1 **Air ventilation, pedestal:**
The crane is equipped with an air cooler in pedestal, suitable for normal to cold climates.

AO19.2 1 **Water cooling, pedestal:**
The crane is equipped with a water cooler in pedestal, suitable for all climatic conditions. Customer to provide ice water.

AO22.2 1 **Bolted Counter foundation / bolt set HMC 3568:**
The crane is quoted with a standard, 5m high pedestal, with the lower end prepared for welding towards deck / substructure.

An alternative is to bolt the crane to deck, and this option includes the 5m pedestal to be flanged for bolting in the lower end, prepared for interface towards supplied counter pedestal (400mm incl. flange, due to torque tool for the bolts). Bolts will be supplied by Cargotec.

AO23.1 1 Arctic package, large cranes:
The crane is equipped with an additional package for extreme cold conditions.
Includes ice-scrapers, open gratings, heating for oil and motors, steel covers over essential components, low temperature cables and hoses, hydraulic system designed for low temperatures.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NS/ISO 2768/1
tolerance class "medium".
GRADE B NS 470.
A–A
SCALE 1:37.5
1772
2180
1712
1370
10848
6520
2500
2500
352
DECK LEVEL
HM SUPPLY
YARD SUPPLY
SEE NOTE
OD 3593 x25
Rmin ~6000
Rmax 10000 SWL 150Te–CRANEBLOCK
Rmax 15000 SWL 100 Te
18000
Rmax 32000 SWL 25Te
Rmax 33000 SWL 10Te
A
ø3593
25
40°
2
SCALE 1:5
WELDING TO
SUBSTRUCTURE
R8200
3400
3975
	Actual forces	Design forces
	Dyf=1.3	Dyf=2.0
Fy (vertical)	5000 kN	6500 kN
Fx/Fz (horizontal)	580 kN	700 kN
Mz (overturning)	32000 kNm	44000 kNm
My (slewing)	2800 kNm	4400 kNm
ESTIMATED CRADLE FORCES FCz		565kN@18m
Notes:
Actual forces = dynamic forces SLS (without safety factors)
Design forces = dynamical forces including all code requirements SLS (without safety factors)
Design basis: DNV LA 1994
Axis definitions:
Origo located in pedestal center at shipdeck level.
x = parallel to jib
y = normal to shipdeck
z = normal to jib
ESTIMATED COG FOR PARKED POSITION:
X=1.37M, Y=6.52M, Z=0.0M
ESTIMATED CRANE WEIGHT: 275T, DRY, INCL. WIRE
NOTE
FOLLOWING ITEMS ARE YARD SUPPLY:
1.ACCES LADDER TO FOUNDATIN PLATFORM
2.DOOR IN LOWER PEDESTAL
3.INNSIDE LADDER
4.ADDITIONAL BRACKETS FOR EL.SUPPLY
5.CONTACK BRACKET FOR SLIPRING
HYDRAMARINE
1:150
HMC 3568 LKO 250–32 (1500–10)
(100–33) AHC
GENERAL ARRANGEMENT
C.3568.0049.GA01
3
THIS IS A COMPUTER AIDED DRAWING AND MUST NOT BE ALTERED MANUALLY.