2017

NATIONAL TECHNICAL UNIVERSITY OF ATHENS (NTUA)
SCHOOL OF NAVAL ARCHITECTURE AND MARINE ENGINEERING
POST GRADUATE PROGRAM MARINE AND OCEAN TECHNOLOGY AND SCIENCE

POST GRADUATE THESIS

Compressed Natural Gas (CNG) Carrier Design

Author: **Panagiotis S. Mouzakis**
(Student Card Number: 260834768432)
(NTUA Student Number: 08115827)
Naval Architect & Marine Engineer NTUA

EXAMINATION BOARD:
Konstantinos Spyrou
George Zaraphonitis
Gregory Grigoropoulos

The **CNG** picture at the front page of this post graduate thesis has been taken from the bibliographical source: [Wikipedia: (Compressed natural gas)].

(The Following Dedications can be placed in Any Order)

Dedicated to those who support
European Idea and **Consolidation**.

Dedicated to my friend & colleague **Nicky (Νίκη)**

(The **Wonderful Female Garden**

of **Altruistic Love**, **Passion** and **Beauty**).

Dedicated to **Greek, Swiss** & **French**
people and to **British women**

Dedicated to **Hellenic Armed Forces (**Including **Hellenic Police)** and their **Alliances (United States of America, Israel, Egypt and Cyprus)**.

The European Union flag which is presented in page 3 of this present research work comes from the bibliographical source: (European Commission Corporate Communication, 2012).

IT MUST BE UNDERLINED THAT TWO DIFFERENT PERSONAL COMPUTERS HAVE BEEN USED FOR THE PURPOSES OF THE PRESENT POST RADUATE THESIS. THE FIRST P.C (1) IS THE LAPTOP OF THE AUTHOR (ONLY OPEN OFFICE, ADOBE READER AND NIST HAVE BEEN INSTALLED) WHILE THE SECOND ONE (P.C (2)) IS P.C OWNED FROM NATIONAL TECHNICAL UNIVERSITY OF ATHENS AND IT HAS ALL THE OTHER LICENSES AND THE RELATIVE PROGRAMS INSTALLED. P.C 1 IS NOT CONNECTED ON INTERNET WHILE P.C 2 IS CONNECTED ON INTERNET. IN ORDER HACKING TO BE AVOIDED (THE AUTHOR UNFORTUNATELLY HAS VERY BAD EXPERIENCE THE LAST 10 YEARS) THE JUST REFFERED P.Cs ARE NOT CONNECTED VIA LAN,WI-FI OR USB STICK. THE RESULTS AND EVERYTHING MADE FROM P.C 2 ARE PRINTED AND THEN THEY SCANNED FROM P.C 1. THE JUST REFFERED SCANNED ELECTRONIC IMAGES ARE USED FROM P.C 1. IT IS UNDERLINED THAT WHEN IT IS SAID THAT THERE IS NOT INTERNET CONNECTION WE MEAN THAT THE WI-FI IS CLOSED. UNFORTUNATELLY, THE WI-FI CAN BE OPENED BY EXPERTS….. . EVERY TIME I OPEN THIS FILE I FIND IT SLIGHLY CHANGED AND DIFFERENT.

Contact Details:

Panagiotis S. Mouzakis

Card Number: 260834768432
NTUA Student Number: 08115827

E-Mails:

panagiotis.mouzakis.09@gmail.com

p.mouzakis@teemail.gr

panos.mouzakis@yahoo.com

Mobile Phone Number:

+30 698 14 09 818

Acknowledgements

The following gratitude expressions can be expressed ***in any order:***

I would like to express my thanks to **Prof. Konstantinos Spyrou** not only for their prompt offer to supervise my degree dissertation but also for their absolutely helpful notifications. The lack of his contribution would be sufficient to make the completion of this post graduate thesis unachievable.

I would like to express my gratitude to **Prof. John Prousalidis** for his contribution to my attempt to express my passion as well as my creativity for marine engineering. I would also like to thank him for his sustain to my effort to build up my skills in science and to tolerate the very tiring way I would like to work on.

I think that I cannot express my gratitude in any sufficient good way to **Prof. Lambros Kaiktsis** for his uncountable valuable contribution to my studies in NTUA, for his offer to enter me to the wonderful world of science and research, to teach me the basic principles of research methodology, to give me the opportunity to get in touch with the magic world of fluids, to tolerate the very tiring way I would like to work on and also for their unaccountable contribution throughout my life. I thank him so much.

I would also like to thank very much **Prof. Christos Papadopoulos** for their contribution to my studies in NTUA, to my ship design project as well as to the limited research I have done so far.

I would like to thank my parents **(Spyros and Stefany Mouzakis)** as well as my brother (**Odysseas Mouzakis**) for their valuable help not only during my studies in NTUA but also for their unaccountable contribution throughout my life. I think that I cannot express my gratitude in any sufficient good way. I thank them so much.

I would like to thank the School of Naval Architecture and Marine Engineering and NTUA in general for their sustain to my effort to express my love as well as my passion for creativity and to build up my skills regarding research and science in general. In addition, I thank them very much for their prompt reply to recognize the possible value of my efforts throughout my studies in NTUA by giving me prizes and awards.

Last but not least I would like to thank my postgraduate thesis examination board (**Prof. Konstantinos Spyrou, Prof. Gregory Grigoropoulos and Prof. George Zaraphonitis**) for their prompt offer to read and examine my thesis.

It is noted that for the present post graduate analysis, the following commercial software packages have been used:

Windows 7, Microsoft Office, Open Office, Matlab, Maxsurf, Hydromax, Autocad, Rhinoceros, Nist, WinRAR, MathType and Adobe Acrobat Reader

It is noted that when there is reference like (for example):

- (Maxsurf) ***without writing the word Source:*** *it means that software package or bibliographical source has been used and processed* ***without*** *taken word to word part of it.*
- ***Source:*** (Module 2: Ship Energy Efficiency Regulations and Related Guidelines)*, it means that bibliographical source has been used word to word.*

Contents

Abstract

The present post graduate thesis presents the technical characteristics of the design of a compressed natural gas carrier which has pressure bottles made from steel. That ship will be able to carry and supply with natural gas the Cyclades group of islands in Aegean Sea and in detail Syros, Tinos and Mykonos. The use of compressed natural gas is strongly recommended in medium distances and small gas flow and because in this case the construction of natural gas pipeline is considered as no profitable. Last but not least, by the use of natural gas, carbon dioxide, nitrogen and sulfur oxides as well as particulate matters reduction is achieved. The last is achieved especially when there is no interpolation of other power systems (ex. electric power) and it is used as fuel directly for thermal energy production.

Introduction

The present research work contains a broad analysis regarding the CNG Carrier design aspects. The benefits of using Natural Gas as Fuel among others are the reduction of carbon dioxide (CO_2), nitrogen oxides (NOx), sulfur oxides (SOx) and Particulate Matters (PM). However, Natural Gas must be handled with care as when it is released in the atmosphere, it is 25 times more dangerous for the environment than CO_2. Moreover, there no need for natural gas production as after its extraction it is almost ready to be used. Due to its chemical composition, it is the fossil fuel which emits the smallest amount of carbon dioxide emission for the same energy output. Furthermore it is of higher net calorific value than other fossil fuels such as propane, butane, gasoline and diesel. On the top of that, it is of higher octane number (avoiding knock), smaller flammability range and it is much cheaper than other fossil fuels (**N.G (~250$/t)**, **LSHFO (~400$/t)**). It must be underlined that more and more cars and marine vessels in all over the world are natural gas powered with the Chinese market as leader. The last brings one more time to foreground the need for natural gas shipping. So far, the most efficient ways of natural gas transportation are pipeline (land based applications) and shipping in Liquefied (LNG) and Compressed (CNG) form. As it is presented, natural gas transportation in compressed form is more preferable in medium amounts and distances. The CNG mean of transportation can be divided in several CNG tanks like steel or composite pressure bottles, Coselle, containerized vessels and VOTRANS. For the purposes of the present postgraduate thesis, only non-containerized steel pressure bottles will be examined for reasons which will be explained. Later on, the supply scenario of Syros, Tinos and Mykonos as well as the CNG Carrier proposed routes will be contained in the present document. It is underlined that even if the needs of the three just referred islands and their distance from southern Cyprus are placed in stranded area, the closest mean of transport is that of compressed natural gas. The needs analysis will be followed by the ABS & IMO constraints and restrictions with the first calculation results which concern the design vessel main particulars and technical characteristics. In brief, the cargo capacity of the vessel is of 1500t of natural gas corresponding to 16 routes per year and to a vessel of 153.81m in length, 29.58m in breadth, 17.27m in depth, 6.68m in draft, to a sailing speed of 15knots and to a power not more than 12MW (with power margin). On the top of that, the **pressure bottles filling time (2.89 days)** and vessels capacity will be estimated (**1500t natural gas** or **7871m^3 (water volume)** or **2 Mscm – M**illion standard cubic meter **(gas volume)**). This will be followed by the load line, fore collision bulkhead, lines fairing, general arrangement and capacity drawing, hydrostatics, tonnage & crew synthesis, resistance & propulsion, ships strength in **two loading conditions (Full Load Departure** & **Water Ballast Arrival)**. Ships damage stability (probabilistic analysis), ship motions in Regular & IRRegular waves as well as the acquiring cost & money flows (net present value & payback period (**19 years (normal reserve)** or **7 years (stranded reserve)**) analysis will take place **(acquiring cost 72 M$)**. Last but not least, the examined vessel

satisfies the up to now **strictest requirements** for **Nitrogen** and **Sulfur oxides** emissions.

1. The use of Natural Gas in Liquefied (LNG) and Compressed (CNG) form

The use of natural gas the last decades has raised a lot in all aspects of human life. Among others, it includes domestic use and electric power production. In the mean time between 1998 and 2003, natural gas use counts the 24% of all energy used in the United States (figure1).

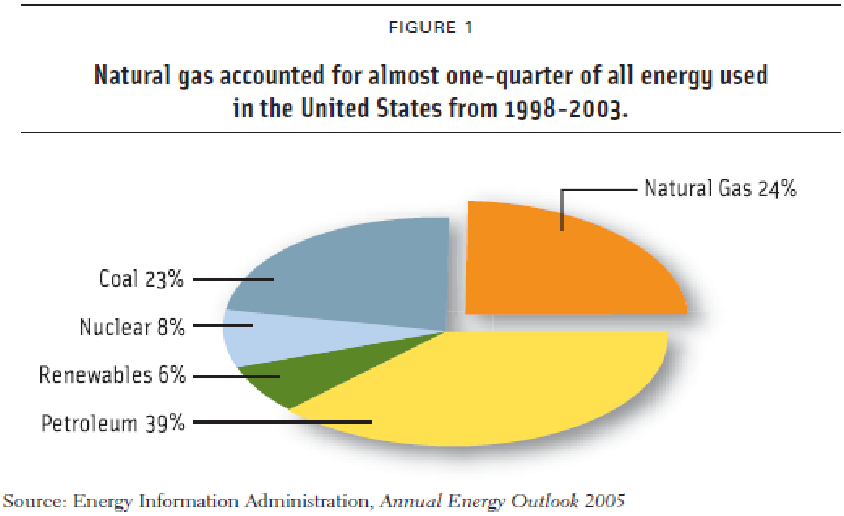


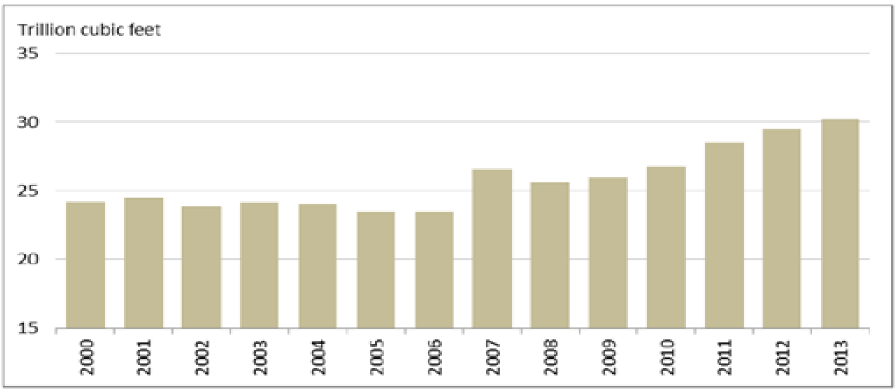
FIGURE 1

Natural gas accounted for almost one-quarter of all energy used in the United States from 1998-2003.

Source: Energy Information Administration, *Annual Energy Outlook 2005*

Figure 1. Annual Energy Outlook in the United States 2005. Source: (Liquefied Natural Gas: Understanding the Basic Facts).

In figure2, the chart shows the natural gas production in United States.



Source: U.S. Department of Energy, Energy Information Administration, Natural Gas Gross Withdrawals and Production, http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_NUS_m.htm.

Figure 2. The United States Natural Gas Production 2000-2013. Source: (Bill Canis et al., 2014)

Despite the fact that natural gas use in vehicles is still very limited, the forecast is optimistic enough as it is presented in figure 3.

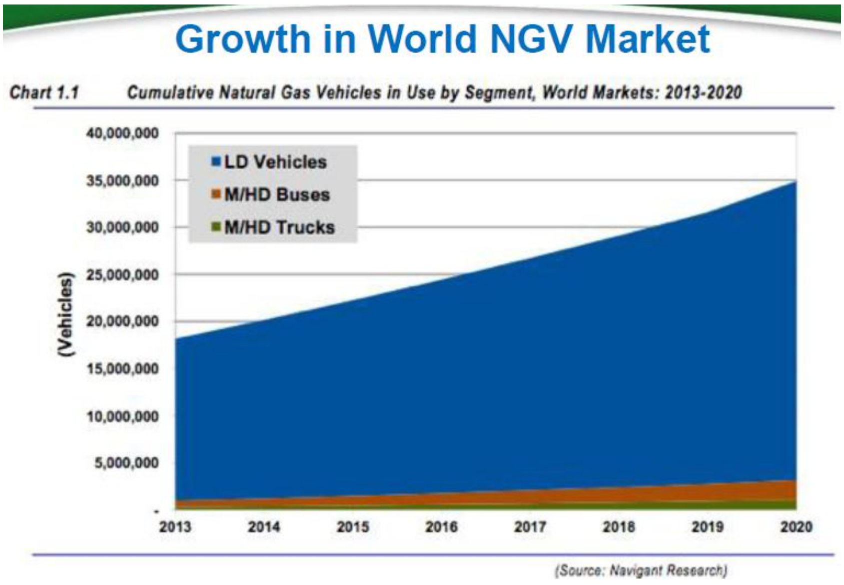


Figure 3. **The Growth of World Natural Gas Vehicles (prediction). Source:** (Natural Gas Vehicles – The Here and Now Technology: A Workshop for New England Sponsored By: Clean Cities Coalitions of Northern New England Clean Cities, 2014)

For the purposes of that growth, several CNG and LNG stations around United States and Canada have been opened or have been planned to be opened as it is pictured in picture1.

Picture 1. **LNG stations around United States and Canada. Source:** (CNG and LNG: What's Best for Your Fleet, Powering transportation A Westport and Clean Energy Webinar, 2013).

As it is drawn in figure 4, almost half of the vehicles which are powered from alternative fuels use natural gas in the United States.

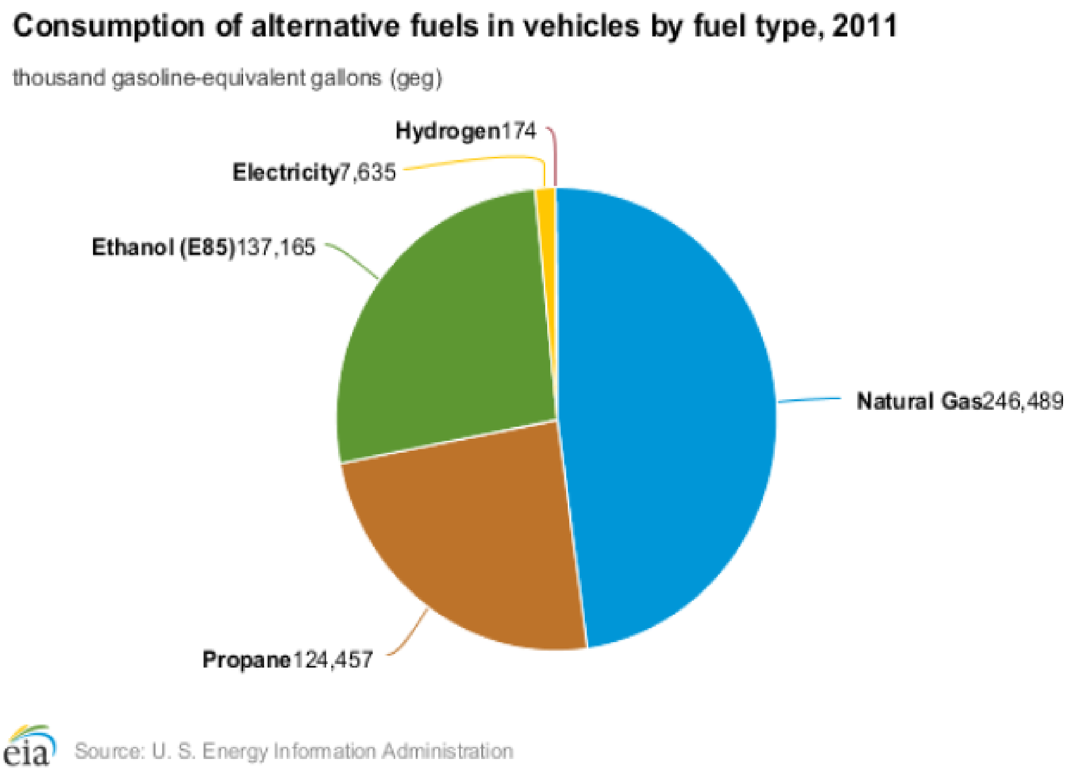


Figure 4. **Consumptions of Alternative Fuels in Vehicles by Fuel Type 2011 in the United States. Source: (Natural Gas Vehicles for America FACT SHEET NGVAMERICA)**

However, if we want to deepen in natural gas superiority it is strictly recommended to present the more detailed natural gas characteristics and benefits.

2. Technical Characteristics of Natural Gas

According to bibliographical source: (LNG AS SHIP FUEL THE FUTURE – TODAY, 2014), the use of natural gas (LNG) can completely remove SOX and particulate PM emissions and a reduction of NOX emission of up to 85% can be achieved. On the top of that, this use can decrease CO2 emissions by at least 20% in comparison to conventional oil-based fuels.

However the following table (table 1) will show why natural gas is more antagonistic than other gaseous fuels according to bibliographical source: (Natural Gas Vehicles for America FACT SHEET NGVAMERICA).

A Comparison of Compressed Natural Gas and Propane	
Compressed Natural Gas (CNG)	**Propane (LPG)**
The Basics	
Methane is the primary component of natural gas. It is the simplest hydrocarbon with a chemical formula of CH4.	Propane is the primary component of LPG and is derived from the processing of crude oil or natural gas. Propane is a three carbon alkane with a chemical formula of C3H8.
Natural gas has the highest energy to carbon ratio (4:1) of any fossil fuel and thus produces less carbon dioxide per unit of energy than any other fossil fuel. Natural gas is compressed to 3,600 psi to become CNG, which is stored inside high pressure cylinders onboard natural gas vehicles (NGV). One gasoline gallon equivalent (GGE) is the amount of alternative fuel it takes to equal the energy content of one liquid gallon of gasoline. One GGE of CNG contains 114,898 Btu's. One GGE of CNG will power a vehicle the same number of miles as one gallon of gasoline.	With only 3 carbon atoms per molecule, propane is a cleaner burning fossil fuel than gasoline or diesel. Propane is compressed to 120 psi and stored as a liquid inside steel tanks onboard LPG vehicles. One gallon of propane contains about 28% less energy than one gallon of gasoline or one GGE of CNG. One gallon of propane contains about 83,500 Btu's. One gallon of propane will power a vehicle about 28% fewer miles than one gallon of gasoline.
Fuel Safety	
Natural gas is lighter than air with a specific gravity of 0.5537. When present in the environment, natural gas will dissipate into the atmosphere quickly, minimizing fire potential. Very narrow flammability range: 5% to 15% Auto-ignition temperature: 1,004° F	Propane is heavier than air with a specific gravity of 1.5219. When present in the environment, propane does not puddle in liquid form but will pool near the ground similar to gasoline vapors. Very narrow flammability range: 2% to 9.5% Auto-ignition temperature: 850° F to 950° F

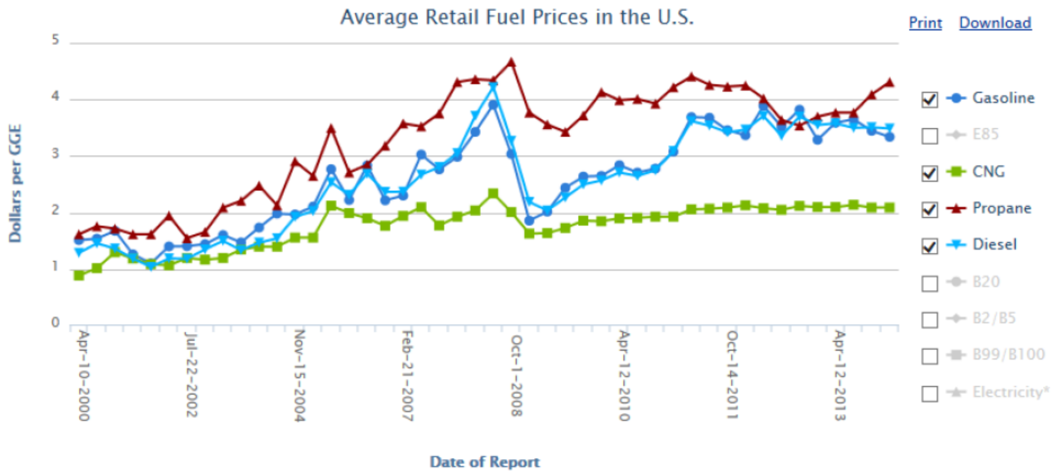
Table 1. A Comparison of Compressed Natural Gas and Propane. The Basics and Fuel Safety. Source: (Natural Gas Vehicles for America FACT SHEET NGVAMERICA).

Table2 gives the economic point of view regarding the use of natural gas in vehicles according to the source: (Natural Gas Vehicles for America FACT SHEET NGVAMERICA).

Economics	
Station Construction Stations require greater initial investment of $500K–$750K to build a standard fast-fill station. •Investment partners are often willing to install private/public stations when fleet demand exists. •CNG offers a second option, called time-fill. Time-fill stations provide concurrent fueling of multiple vehicles (up to 100's) at a slower rate per vehicle. Example: A station can fill one truck at 8 GGE/minute on fast-fill or 100 trucks at 480 GGE/hour on time-fill. o If a fleet's vehicles sit in a parking lot overnight, every night, this is the most cost and time effective method of fueling. Time-fill stations are considerably less expensive than fast-fill stations, which reduces costs and increases convenience where applicable.	Station Construction Fueling facilities are less expensive to install than CNG stations—about $45k–$175k to build an LPG filling station. A very simple dispensing system can be as low as $25K. Propane suppliers will often install private stations when fleet demand exists.

Table 2. Economic Aspects of the Use of Natural Gas (CNG) and Propane. Source: (Natural Gas Vehicles for America FACT SHEET NGVAMERICA)

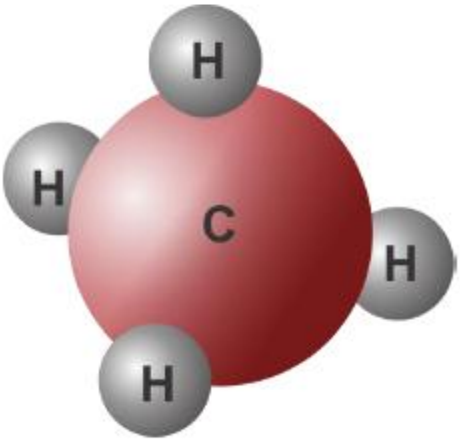
Additionally to the previous table, figure 5 shows us the superiority of natural gas in comparison to other fuels regarding its price. Source: (Natural Gas Vehicles for America FACT SHEET NGVAMERICA)



Source: US DOE AFDC Price Report (January 2014): http://www.afdc.energy.gov/fuels/prices.html

Figure 5. Average Retail Fuel Prices in the U.S. Source: (Natural Gas Vehicles for America FACT SHEET NGVAMERICA)

As it can be seen from figure 5, the cost of natural gas (CNG) per its energy content (Gasoline Gallon Equivalent, GGE) nowadays is much smaller than the other fossil fuels. Less cost even from propane can be achieved despite the fact that the last is gaseous fuel.



Picture 2. **The molecule of Methane (Natural Gas). Source:** (Natural Gas Vehicles – The Here and Now Technology: A Workshop for New England Sponsored By: Clean Cities Coalitions of Northern New England Clean Cities, 2014)

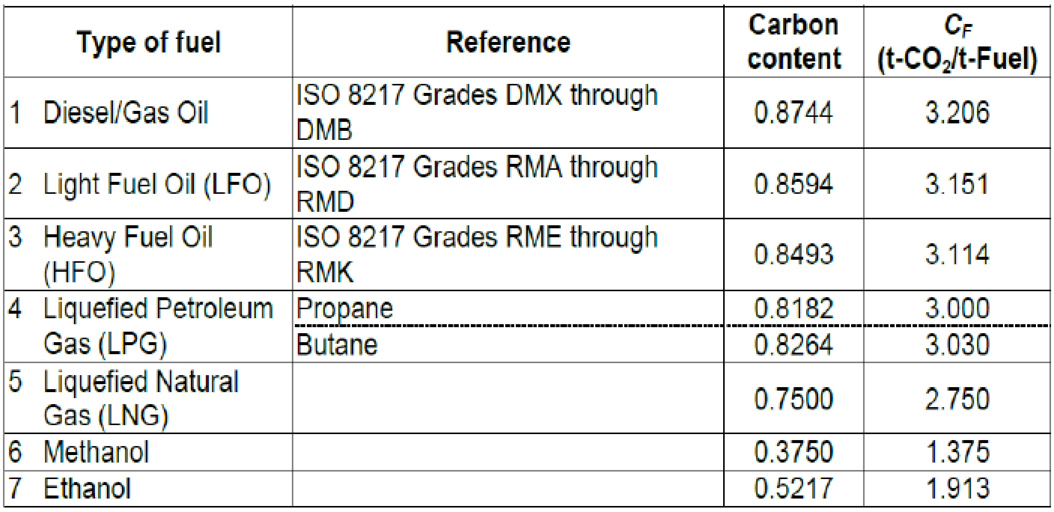
The benefit from the usage of natural gas would be clearer, if we have a look at Table3. According to (Section: Appendix A Lower and Higher Heating Values of Gas, Liquid and Solid Fuels), Natural Gas has higher LHV (Lower Heating Value) than the other fossil fuels.

	Lower Heating Value [MJ/kg]
Natural Gas @ 32 F and 1 atm	47,141
Crude Oil	42,686
Gasoline	43,448
LPG	46,607
Coal	22,732

Table 3. **Lower Heating Values of Various Fuels. Source:** (Section: Appendix A Lower and Higher Heating Values of Gas, Liquid and Solid Fuels)

This means that (if the efficiency is kept constant), for the same energy output, we need smaller amount of fuel only by using natural gas.

On the top of this, even if the amount of mass of natural gas is the same, the amount of CO2 emissions by burning this amount of fuel is reduced considerably. Source: (Module 2: Ship Energy Efficiency Regulations and Related Guidelines). Table 4, presents that difference.



Type of fuel	Reference	Carbon content	C_F (t-CO_2/t-Fuel)
1 Diesel/Gas Oil	ISO 8217 Grades DMX through DMB	0.8744	3.206
2 Light Fuel Oil (LFO)	ISO 8217 Grades RMA through RMD	0.8594	3.151
3 Heavy Fuel Oil (HFO)	ISO 8217 Grades RME through RMK	0.8493	3.114
4 Liquefied Petroleum Gas (LPG)	Propane	0.8182	3.000
	Butane	0.8264	3.030
5 Liquefied Natural Gas (LNG)		0.7500	2.750
6 Methanol		0.3750	1.375
7 Ethanol		0.5217	1.913

Table 4. CO2 Emission Factor of various Fuels. Source: (Module 2: Ship Energy Efficiency Regulations and Related Guidelines)

3. Comparison between Compressed Natural Gas (CNG) and Liquefied Natural Gas (LNG).

In the previous paragraphs, the benefits of using natural gas were presented. However, the main question remains: it is more beneficial to consume natural gas in liquefied or in compressed form and in what condition it should be carried?

According to experts: (CNG and LNG: What's Best for Your Fleet, Powering transportation A Westport and Clean Energy Webinar, Westport, 2013) CNG is for light, medium and some heavy duty applications (<250miles/day). In this case, it is stored at 4500psi and it is dispensed to vehicles at 3600psi. CNG fast fill requires large capital investment.

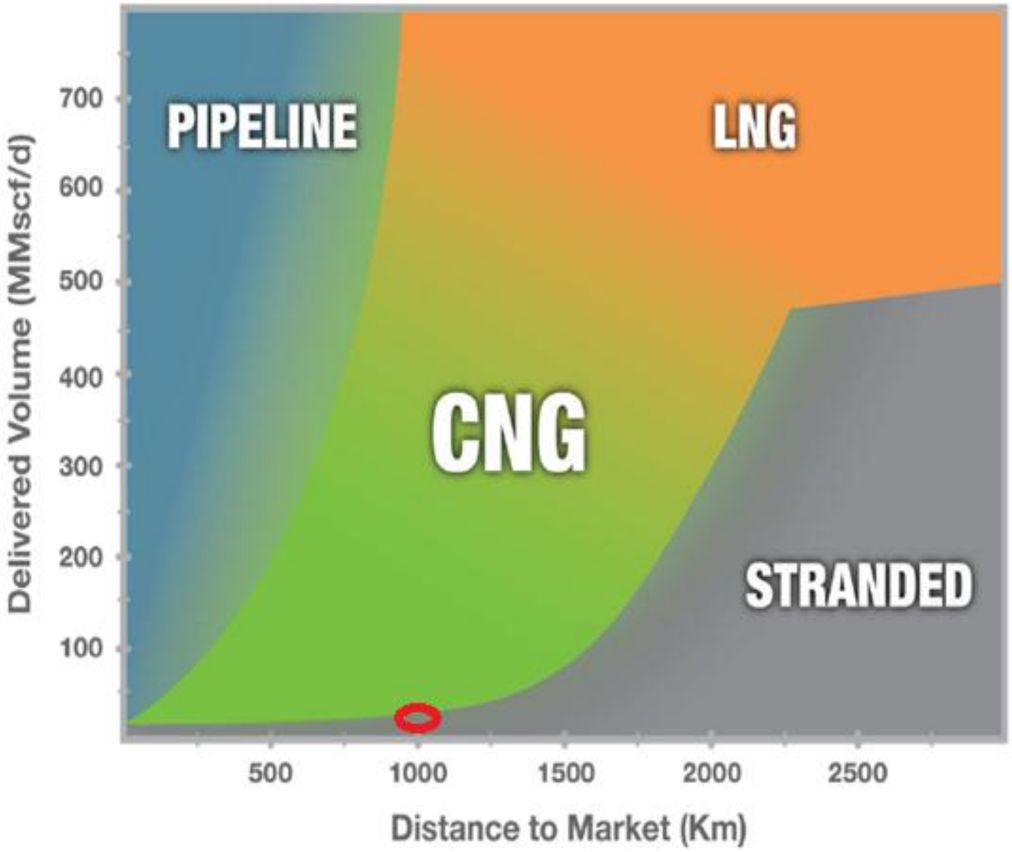
On the other side of the problem, according to the source: (CNG and LNG: What's Best for Your Fleet, Powering transportation A Westport and Clean Energy Webinar, Westport, 2013), LNG is more suitable for >250 miles/day and for 5-7days/week operation.

Regarding their technical characteristics, the following can be said:

Compressed Natural Gas (CNG) production facilities are less expensive than those of LNG. This means that, they are more suitable for areas with high political risk. Moreover, the existence of other gases does not affect its production. It is clear that in compressed form there is no boil-off gas problem in comparison with the liquefied one. Shipping in compressed form, it is almost ready for the final customer (it is only requested pressure drop in order to be sold to the final customer). On the top of that, there is no problem with natural gas spills because in this form it is vented to the atmosphere. Furthermore, in small reserves, it is no profitable to build liquefied natural gas production unit. (This paragraph is the personal statement of the author and it has been created by reading newspapers, magazines and exchanging ideas with experts).

However, the main question regarding natural gas transportation remains. Regardless the natural gas condition ready for sale, in what condition it is more profitable to be carried? In Compressed or in Liquefied form?

Picture 3, may answer to the previous question. According to source: (Sea NG - COMPRESSED NATURAL GAS Half the density, half the cost, twice the value, 2012) the map shows that CNG seems to be suitable for medium distances and volumes.

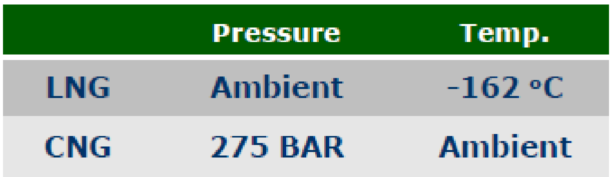


Picture 3. Natural Gas Transportation Map. Source: (Sea NG - COMPRESSED NATURAL GAS Half the density, half the cost, twice the value, 2012)

The **red point** in **Picture 3** is the **point to solution** of the **present thesis** *as it will be described later on*).

(2MMscm/route) [see page 47]
***(((1/0.3048)(ft/m))^3)*(16routes/year)*((1/365)year/d)=~3MMscf/d**

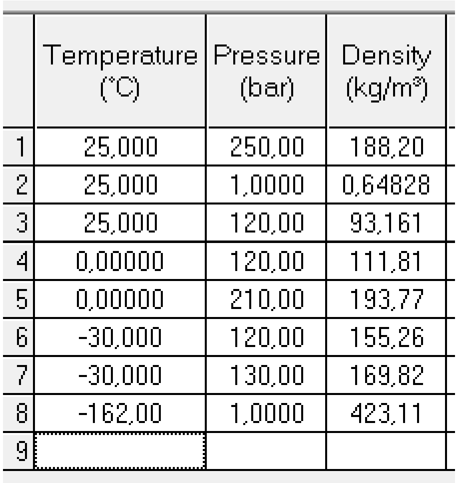
It is repeated, that from the same source, the pressure and temperature conditions of shipping natural gas are the following:



	Pressure	Temp.
LNG	Ambient	-162 °C
CNG	275 BAR	Ambient

Table 5. Natural Gas Temperature and Pressure Shipping Conditions. Source: (Sea NG - COMPRESSED NATURAL GAS Half the density, half the cost, twice the value, 2012)

For the purposes of the present research work, according to the source: (NIST 12, 2005), the pressures and temperatures of the table 5 have the following thermodynamical characteristics (Table 6).



	Temperature (°C)	Pressure (bar)	Density (kg/m^3)
1	25,000	250,00	188,20
2	25,000	1,0000	0,64828
3	25,000	120,00	93,161
4	0,00000	120,00	111,81
5	0,00000	210,00	193,77
6	-30,000	120,00	155,26
7	-30,000	130,00	169,82
8	-162,00	1,0000	423,11
9			

Table 6. Natural Gas Thermodynamical Properties. Source: (NIST 12, 2005)

4. Ways of Compressed Natural Gas (CNG) Shipping

The most important ways of shipping natural gas are the following:

- Containerized CNG
- In pressure bottles (steel or synthetic)
- In Coselle (Sea-NG)
- VOTRANS (Volume Optimized Transport and Storage system, EnerSea)

According to (http://www.kline.co.jp), in votrans, as the pressure - decreases to (120bar (@-30C), the weight of the tank can also become half in comparison to those which carry CNG in 250bar.

In accordance with (David Stenning, James Cran), the coselle way of CNG transport has the following specifications:

COSELLE	
Total Weight [t]	445
Pipe [miles]	9,9
Gas Pressure [psi]	3000
Gas Temperature [F]	30
Total Gas Weight [t]	71

Table 7. Coselle Technical Specifications. Source: (David Stenning, James Cran)

As far as the CNG transportation via pressure bottle is concerned, thermodynamical characteristics should be taken from the table 6, while the reader regarding the weights and the costs of the pressure bottles, should be advised bibliographical reference: (CNG tanks: Pressure vessel epicenter).

CNG Type I: All-metal construction, generally steel. **CNG Type II:** Mostly steel or aluminum with a fiber-reinforced polymer overwrap in the hoop direction, featuring glass, carbon or basalt fiber; the metal vessel and wound composite materials share about equal structural loading. **CNG Type III:** Metal liner (typically aluminum) with full carbon fiber composite overwrap; the composite materials carry the structural loads. **CNG Type IV:** Metal-free construction. A carbon fiber or hybrid carbon/glass fiber composite is filament wound over a thermoplastic polymer (typically HDPE or polyamide) liner; the composite materials carry the structural loads. **CNG Type V:** An all-composite construction. The vessel is linerless, and features a carbon fiber or hybrid carbon/glass fiber composite wound over a collapsible or sacrificial mandrel; the composite materials carry all the loads

Table 8. Pressure Bottles Technical Characteristics 1/2. Source: (CNG tanks: Pressure vessel epicenter)

Each type of pressure vessel has its benefits and liabilities. CNG Type I vessels are the least expensive, with estimated production costs of roughly **$5 per liter of volume**. The metalworking skills and equipment needed to produce them are widely available internationally. To their detriment, Type I vessels also are the heaviest, weighing approximately 3.0 lb/liter (**1.4 kg/liter**). By comparison, CNG Type II vessels cost about 50 percent more to manufacture but can reduce the weight of the storage containers by 30 to 40 percent. Type III and Type IV vessels take the weight savings even further, weighing between 0.75 and 1.0 lb/liter (0.3 to 0.45 kg/liter). The cost of Type III and IV vessels, however, is roughly twice that of Type II vessels and 3.5 times greater than Type I tanks. Types III and IV, moreover, are keys to the current growth equation for three reasons. First, constructing pressure vessels, in whole or in part, from composites reduces fuel system and vehicle weight. On a typical transit bus or commercial truck, for example, the use of Type III and Type IV vessels easily could reduce the weight of the gas containment system by more than 1,000 lb (454 kg). This weight reduction would not only improve fuel economy but also increase load-carrying capacity and introduce other operational benefits, making it possible for the more expensive tanks to buy their way onto vehicles. Second, composite vessels extend the practical limit for gas containment pressures and provide better energy storage density. For many high-pressure applications — requiring cylinders rated at 5,000 psi (344.7 bar) or greater — Type III and Type IV vessels represent the most practical solution. Third, composite materials significantly improve a pressure vessel's corrosion resistance and overall safety. For composite vessels that incorporate carbon fiber tow as reinforcement, the excellent fatigue resistance of these fibers also extends the vessel's service life. Carbon fiber-reinforced Type III and Type IV pressure vessels can remain in use for as many as 30 years before they require replacement — twice the interval allowed for Type I and Type II vessels. New to the fray are Type V vessels. Certified in 2013, they represent the current state-of-the-art in terms of weight-to-pressure ratio. Composite Technology Development (Lafayette, Colo.) and Clean NG (Tulsa, Okla.) are reported to offer an additional 10 to 20 percent weight reduction compared to CNG Type IV vessels (Click on "Next-generation pressure vessels," under "Editor's Picks," at top right). By virtue of the simplified laminate, it is believed, Type V vessels will eventually become less expensive options than the CNG Type III and IV vessels. And this is expected to be true despite some higher materials costs, owing to new toughened epoxy resin systems and the nanocomposites needed to prevent gas leakage in the absence of a liner.

Table 9. Pressure Bottles Technical Characteristics 2/2. Source: (CNG tanks: Pressure vessel epicenter)

According to the technical data coming from tables 5,6,7,8 and 9, table 10 can be produced which in some way presents the "transportation efficiency" or in other words, the ratio of the tare of the CNG tank to the total weight of the tank filled with gas.

		PRESSURE BOTTLES					
TRANSPORTATION MEAN	*COSELLE*	*TYPE 1 PRESSURE BOTTLE*	*TYPE 2 PRESSURE BOTTLE (PARTIALLY COMPOSITE)*	*TYPE 3 PRESSURE BOTTLE (COMPOSITE)*	*TYPE 4 PRESSURE BOTTLE (COMPOSITE)*	*TYPE 5 PRESSURE BOTTLE (COMPOSITE)*	*VOTRANS*
GAS PRESSURE [bar]	**210**	**250**	**250**	**250**	**250**	**250**	**120**
GAS TEMPERATURE [C]	**0**	**25**	**25**	**25**	**25**	**25**	**-30**
GAS DENSITY [t/m3]	**0,194**	**0,188**	**0,188**	**0,188**	**0,188**	**0,188**	**0,155**
TARE PER NET VOLUME [t/L]	0,00121	**0,00140**	0,00091	**0,00040**	0,00040	0,00034	0,00070
TARE (WTARE) [t]	**445**	22,96	14,92	6,56	6,56	5,58	11,48
NET VOLUME (VNET) [m3]	366,41	**16,4**	16,4	16,4	16,4	16,4	16,4
GAS WEIGHT (WNET) [t]	**71**	3,09	3,09	3,09	3,09	3,09	2,54
TOTAL WEIGHT (WTOTAL) [t]	516	26,05	18,01	9,65	9,65	8,66	14,02

WTARE/WTOTAL [-]	*0,86*	*0,88*	*0,83*	*0,68*	*0,68*	*0,64*	*0,82*
TARE COST [€]	-	82000	123000	369000	369000	-	-
TARE COST PER NET VOLUME [€/m3]	-	**5000**	7500	22500	22500	**-**	-
COST PER TARE [€/t]	**-**	*3571,43*	*8241,76*	*56250*	*56250*	*-*	*-*

Table 10. “Transportation Efficiency” in various CNG means of transport.

From the Table10, it is clear that regarding the transportation efficiency (tare weight / total weight) the use of composite pressure bottles seems to be the more efficient solution. On the other side of the problem, the steel pressure bottles in accordance with the given data are the cheapest solution. Unfortunately, due to lack of data, no cost examination took place regarding the coselle and votrans means of CNG transport. (Despite the fact that according to (David Stenning, James Cran), the coselle CNG carrier costs approximately the one third of an equivalent “bottle” ship, due to data uncertainty, no coselle mean of transport was examined). Moreover, due to lack of paternal vessels, the use of steel pressure bottles as it is according to the author the simplest solution, it was chosen for the present analysis. In Table 10 it is noted that the letters in bold are the input data.

From bibliographical reference: **(Graf et al.,2003)**, it is clear that for a **pressure bottle** of **1.0m in diameter** and **36m in length** working at **250bar@room temperature** and made from **X80** material, its **weight (empty)** counts **31metric tonnes**. This means that for these sizes, it will be of 31t/(1.0*1.0*(3.1415/4)*36)=**1.1kg/liter**. However if it is **supposed** that for the **present analysis** purposes, **pressure bottles** of **1.2m in diameter** will be used, their specific weight would be approximately ((1.1kg/liter)/1.0m)*1.2m**=~1.32kg/liter <1.4kg/liter** (brief and simplistic approximation). This is approximatelly equal to the data coming from **tables 8** & **9** (CNG tanks: Pressure vessel epicenter). It would be acceptable if for that purposes, the data regarding the **weight** and **cost** from the just referred tables (**CNG pressure bottles TYPE 1**) (CNG tanks: Pressure vessel epicenter) will be used (Table 10).

The **CNG pressure bottle** of **1.2m in diameter** will be **<u>hypothetical</u>** and in this paragraph it is underlined the **importance** of using the **higher diameter pressure bottles** as in this case the **pressure bottles accommodation** becomes **more efficient**. This happens because it is needed **smaller number of pressure bottles** thus **smaller number of 0.38m gaps between the pressure bottles**.

Last but not least the **pressure bottles** which will be used (**1.2m in diameter @ 14.4m in length** & **250bar@room temperature**) will be **<u>special order</u>**.

5. CNG Supply Scenario – Syros, Tinos and Mykonos Group of Islands Energy Needs

For the purposes of the present research, the energy needs of Syros, Tinos and Mykonos in natural gas were analyzed. As it is clear from the pictures 4,5 and 6, the designed vessel should not be longer than **160 meters** and its draft must not be more than **7 meters**. It is underlined that it will be designed to carry natural gas in compressed from the natural gas sources southern to Cyprus to Cyclades (Syros, Tinos and Mykonos).

Picture 4. **Map of Syros Island. Source:** (www.all4yachting.com/maps/syros.htm)

Picture 5. **Map of Tinos Island. Source:** (www.all4yachting.com/maps/tinos.htm)

Picture 6. **Map of Mykonos Island. Source:** (www.all4yachting.com/maps/mykonos.htm)

In this stage, the annual natural gas needs of these three islands must be estimated. It must be underlined that when needs are reported, it does not concern the electric power production but only requirements in **thermal energy** and this for **heating** and **cooking**.

Firstly, in accordance with bibliographical data, the annual equal population of these three islands must be calculated as follows:

SANITARY UNIT	POPULATION	TOTAL SUMMER POPULATION
SYROS	19793	204234
TINOS	8115	507665
MYKONOS	9274	296084
* The population data of summer concern only the arrivals via coastal connection. Source: Local Port Authorities.		

Table 11. Population Data Winter – Summer of Syros, Tinos and Mykonos Islands. Source: (ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ ΠΕΡΙΦΕΡΕΙΑΣ ΝΟΤΙΟΥ ΑΙΓΑΙΟΥ ΠΕΡΙΦΕΡΕΙΑ ΝΟΤΙΟΥ ΑΙΓΑΙΟΥ, 2012)

The average size of the housekeeping in Greece according to the bibl. Source: (Η ΔΙΑΔΡΟΜΗ ΑΠΟΓΡΑΦΗ ΠΛΗΘΥΣΜΟΥ 2011 τελικά αποτελέσματα) is tabled in table 12.

AVERAGE SIZE OF HOUSEKEEPING IN GREECE	
MUMBER OF PERSONS	2,6

Table 12. Average Size of Housekeeping in Greece. Source: (Η ΔΙΑΔΡΟΜΗ ΑΠΟΓΡΑΦΗ ΠΛΗΘΥΣΜΟΥ 2011 τελικά αποτελέσματα)

From bibliographical source: (ΑΠΟΤΕΛΕΣΜΑΤΑ ΠΡΩΤΟΓΕΝΟΥΣ ΕΡΕΥΝΑΣ ΤΟΥΡΙΣΤΙΚΗΣ ΑΓΟΡΑΣ ΤΩΝ ΚΥΚΛΑΔΩΝ [Α.Π. 1091] ΓΙΑ ΤΗΝ ΑΝΑΠΤΥΞΙΑΚΗ ΕΤΑΙΡΕΙΑ ΚΥΚΛΑΔΩΝ Α.Ε. ΑΠΟ ΤΗΝ CENTRUM research), the country of permanent residence of tourists who come in Greece (average) is:

TOURISTS PROFILE – COUNTRY OF PERMANENT RESIDENCE	
GREECE	65,00%
OTHER COUNTRIES	35,00%

Table 13. Tourists Profile – Country of Permanent Residence – Percentage. Source: (ΑΠΟΤΕΛΕΣΜΑΤΑ ΠΡΩΤΟΓΕΝΟΥΣ ΕΡΕΥΝΑΣ ΤΟΥΡΙΣΤΙΚΗΣ ΑΓΟΡΑΣ ΤΩΝ ΚΥΚΛΑΔΩΝ [Α.Π. 1091] ΓΙΑ ΤΗΝ ΑΝΑΠΤΥΞΙΑΚΗ ΕΤΑΙΡΕΙΑ ΚΥΚΛΑΔΩΝ Α.Ε. ΑΠΟ ΤΗΝ CENTRUM research)

In accordance with the same bibliographical reference: (ΑΠΟΤΕΛΕΣΜΑΤΑ ΠΡΩΤΟΓΕΝΟΥΣ ΕΡΕΥΝΑΣ ΤΟΥΡΙΣΤΙΚΗΣ ΑΓΟΡΑΣ ΤΩΝ ΚΥΚΛΑΔΩΝ [Α.Π. 1091] ΓΙΑ ΤΗΝ ΑΝΑΠΤΥΞΙΑΚΗ ΕΤΑΙΡΕΙΑ ΚΥΚΛΑΔΩΝ Α.Ε. ΑΠΟ ΤΗΝ CENTRUM research), the night spends in function to the country of origin are tabled in table 14.

NIGHT SPENDS	
AVERAGE OF GREEKS	6,5
AVERAGE OF OTHERS	6,1

Table 14. **Average Night Spends in function to the Tourists Country of Origin. Source:** (ΑΠΟΤΕΛΕΣΜΑΤΑ ΠΡΩΤΟΓΕΝΟΥΣ ΕΡΕΥΝΑΣ ΤΟΥΡΙΣΤΙΚΗΣ ΑΓΟΡΑΣ ΤΩΝ ΚΥΚΛΑΔΩΝ [Α.Π. 1091] ΓΙΑ ΤΗΝ ΑΝΑΠΤΥΞΙΑΚΗ ΕΤΑΙΡΕΙΑ ΚΥΚΛΑΔΩΝ Α.Ε. ΑΠΟ ΤΗΝ CENTRUM research)

From tables 13 and 14, the average night spends of tourists is: **6.36 nights**.

In this stage, as a relatively clean view of the population in these three islands regarding the population (permanent and the summer one which is coming via coastal connection) has been given, it is necessary to deepen to the population coming via air connection. It is underlined that only Syros and Mykonos have airports.

According to (Επιβατική κίνηση ελληνικών αεροδρομίων (2011)), the national and international arrivals at **Syros** in **2011** are **9927 arrivals** which corresponds to (9927*6.36)/(365*2.6)=**66.52 additional equivalent annual housekeeping (houses) in Syros Islands due to summer arrivals**.

As far as the Mykonos air connection arrivals are concerned, by using tables 15 and 16 the additional equivalent annual housekeeping (houses) arrivals in Mykonos islands can easily be calculated. For these two tables, bibliographical reference: (Δρ. Άρης Ίκκος et al., 2015-2016).

YEAR	MILLION OF PASSENGERS IN PERIPHERIAL AIRPORTS (PROGRAMMED) 2015-2016
2016	14,9

Table 15. **Number of Air Flight Arrivals in Peripheral Airports (Programmed) in Million. Source:** (Δρ. Άρης Ίκκος et al., 2015-2016)

From Tables 15 and 16, it is clear that the annual expected passengers from **air arrivals** in **Mykonos island** are approximately 14.9*10^6*0.0259=**3.859*10^5 passenger arrivals** or (0.3859*10^6*6.36/(365*2.6))=**2586 annual equivalent housekeeping (houses or families) arrivals**.

It must be underlined that the passengers (tourists) from arrivals do not spend whole year in the islands. They are just visitors. So, according to a simplistic analysis, if we multiply the number of passengers with the nights they passed in the island divided by the number of the days of the year (365) we will find the annual equivalent passengers (who spend whole year in the island). If we also divide the last number with the number

of persons which the average housekeeping counts, we will find the annual equivalent housekeeping (houses or families) arrivals.

PERIPHERAL AIRPORTS MARKET SHARE (PROGRAMMED)	
IRAKLIO	23,14%
RODOS	16,81%
THESSALONIKI	10,93%
CORFU	10,84%
KOS	8,16%
CHANIA	8,01%
ZAKYNTHOS	5,49%
SANTORINI	3,43%
MYKONOS	2,59%
AKTIO	1,99%
KEFALLONIA	1,84%
SKIATHOS	1,60%
OTHERS	5.17%

Table 16. Peripheral Airports Market Share (Programmed). Source: (Δρ. Άρης Ίκκος et al., 2015-2016)

By using the above tabulated data, table 17 gives us the number of the total housekeeping (families or houses) which spend all year in each island.

NUMBER OF HOUSEKEPING (NATIVES) AND ARRIVALS (HOUSEKEEPING) FROM COASTAL CONNECION					
SANITARY UNIT	**NUMBER OF HOUSEKEEPING WHICH SPEND ALL YEAR IN THE ISLANDS**	**TOTAL NUMBER OF HOUSE KEEPING IN THE SUMMER**	**ADDITIONAL HOUSEKEEPING NUMBER IN SUMMER**	**ANNUAL EQUIVALENTT ADDITIONAL HOUSEKEEPING NUMBER IN SUMMER**	**ANNUAL EQUIVALENT TOTAL NUMBER OF HOUSEKEEPING**
SYROS	7612,69	78551,54	70938,85	1236,09	8848,78
TINOS	3121,15	195255,77	192134,62	3347,88	6469,03
MYKONOS	3566,92	113878,46	110311,54	1922,14	5489,06

Table 17. Number of Housekeepings which stay all time in the islands (natives) and the arrivals from coastal connection.

By summing the last column of table 17 with the numbers given in page 30 we obtain the total number of average annual equivalent housekeeping natives and coming from coastal and air connection. These data are presented in table 18.

AVERAGE ANNUAL EQUIVALENT NUMBER OF HOUSEKEEPING FROM AIR CONNECTION (NATIONAL AND INTERNATIONAL (IF IT EXISTS) + COASTAL CONNECTION + NATIVES	
SANITARY UNIT	**NUMBER OF HOUSEKEEPING**
SYROS	8915
TINOS	6469
MYKONOS	8075

Table 18. **Average Annual Equivalent Total Number of Housekeepings (Natives, Coastal Connection and Natives)**

The question arising with all these data is which are the thermal energy needs of these housekeepings. Table 19, answers to this question. Source: (ΔΕΛΤΙΟ ΤΥΠΟΥ - ΕΡΕΥΝΑ ΚΑΤΑΝΑΛΩΣΗΣ ΕΝΕΡΓΕΙΑΣ ΣΤΑ ΝΟΙΚΟΚΥΡΙΑ 2011-2012, 2013)

ANNUAL AVERAGE ENERGY CONSUMPTION PER HOUSEKEEPING [kWh]	
THERMAL ENERGY	**10244**
ELECTRIC ENERGY	**3750**
TOTAL	13994

Table 19. **Average Annual Energy Consumption per Housekeeping [kWh]. Source:** (ΔΕΛΤΙΟ ΤΥΠΟΥ - ΕΡΕΥΝΑ ΚΑΤΑΝΑΛΩΣΗΣ ΕΝΕΡΓΕΙΑΣ ΣΤΑ ΝΟΙΚΟΚΥΡΙΑ 2011-2012, 2013)

From tables 18 and 19 it is easy to calculate the total annual amount of thermal energy which is required from these three islands. The last is tabulated in table 20.

TOTAL AVERAGE ANNUAL THERMAL ENERGY CONSUMPTION [kWh]	
SYROS	91328396
TINOS	66268781
MYKONOS	82723908

Table 20. **Average Annual Thermal Energy Consumption in [kWh] of Syros, Tinos and Mykonos.**

If the **natural gas Lower Heating Value** is taken into consideration in accordance with bibliographical source: (Section: Appendix A Lower and Higher Heating Values of Gas, Liquid and Solid Fuels) which is equal to **47141kJ/kg**, the required amount of natural gas is tabulated in table 21. In table 22 and in figure 6, it is presented the annual natural gas consumption in tones. For these purposes, a capacity margin of 30% has been taken into consideration.

AVERAGE ANNUAL NATURAL GAS CONSUMPTION [kg]	
ISLAND	**NUMBER OF HOUSEKEEPING**
SYROS	6974443
TINOS	5060724
MYKONOS	6317347

Table 21. **Average Annual Natural Gas Consumption [kg].**

AVERAGE ANNUAL NATURAL GAS CONSUMPTION [t] WITH CAPACITY MARGIN 30%	
UNIT	**HOUSEKEEPING POPULATTION**
SYROS	9067
TINOS	6579
MYKONOS	8213
TOTAL	*23858*

Table 22. **Average Annual Natural Gas Consumption with Capacity Margin 30%.**

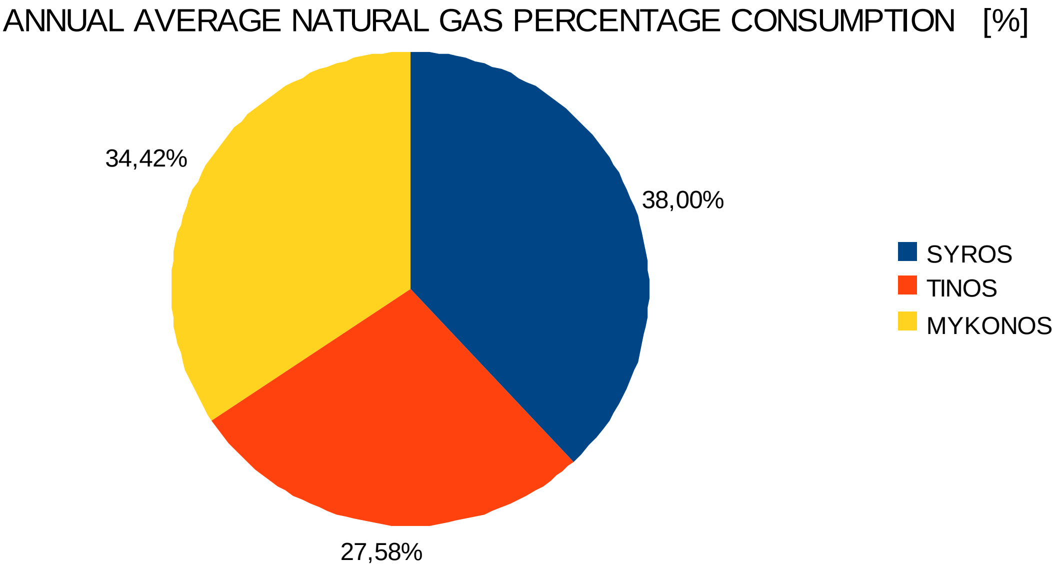


Figure 6. **Annual Average Natural Gas Percentage Consumption [%] of Syros, Tinos and Mykonos.**

6. CNG Carrier (Vessel) proposed Routes

In accordance with the present analysis, in table 23, in order to choose the vessels capacity, the annual requested amount of natural gas is combined with the number of routes the vessel will do from the southern Cyprus to Cyclades.

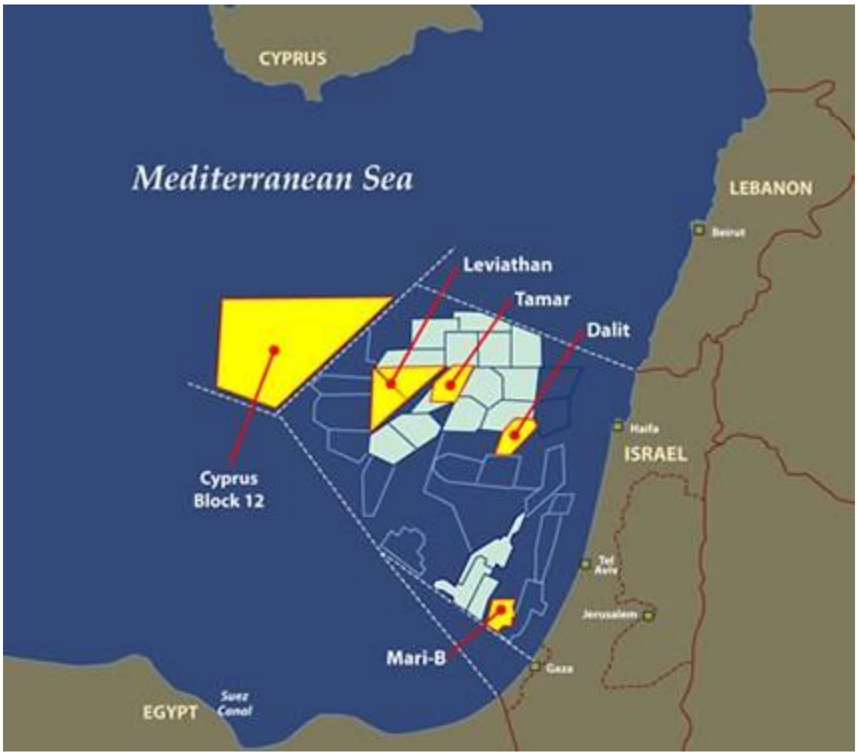
	ROUTES – AMOUNT of CNG [t/y]			
	CYPRUS – SYROS – TINOS - MYKONOS	CYPRUS - SYROS	CYPRUS – TINOS	CYPRUS – MYKONOS
TOTAL [t/y]	23858	9067	6579	8213
Number of Routes	**VESSEL CARGO WEIGHT [t]**			
1	23858	9067	6579	8213
2	11929	4533	3289	4106
3	7953	3022	2193	2738
4	5965	2267	1645	2053
5	4772	1813	1316	1643
6	3976	1511	1096	1369
7	3408	1295	940	1173
8	2982	1133	822	1027
9	2651	1007	731	913
10	2386	907	658	821
11	2169	824	598	747
12	1988	756	548	684
13	1835	697	506	632
14	1704	648	470	587
15	1591	604	439	548
16	**1491**	567	411	513

Table 23. **ROUTES – AMOUNT of CNG [t/y].**

For these purposes, the number of **16 routes per year** is chosen, the vessel will make the route **Cyprus-> Syros-> Tinos->Mykonos** and must have a cargo capacity of **1500t of natural gas** in compressed form **(CNG).**

It is supposed that the designed vessel as it has been underlined previously, it is supposed that the **gas fields of southern Cyprus** are profitable and the case of being **stranded (small amount & long distance)** will also be examined.

Picture 7 presents the written gas fields. Source: (MB50's "LIQUID MUD" RANT)



Picture 7. **Cyprian Gas Fields. Source:** (MB50's "LIQUID MUD" RANT)

In this stage, it should be evaluated the distance between the place of departure and arrival.

According to bibliographical source: (gr.distance24.org), the distance between **Athens** and **Cyprus** is approximately **923km**. Supposed that this distance is **1000km** and taking into consideration the **return,** its route accounts **2000km**. This means that the **vessels endurance** can be **5000 sea miles (at Pmax(P propulsion installed))** or **5000*1.852km=9260km**. It is also considered that the **bunkering** of the vessel will be made at **Piraeus port** and the **construction of the vessel** will be taken place at **Hellenic Shipyards**.

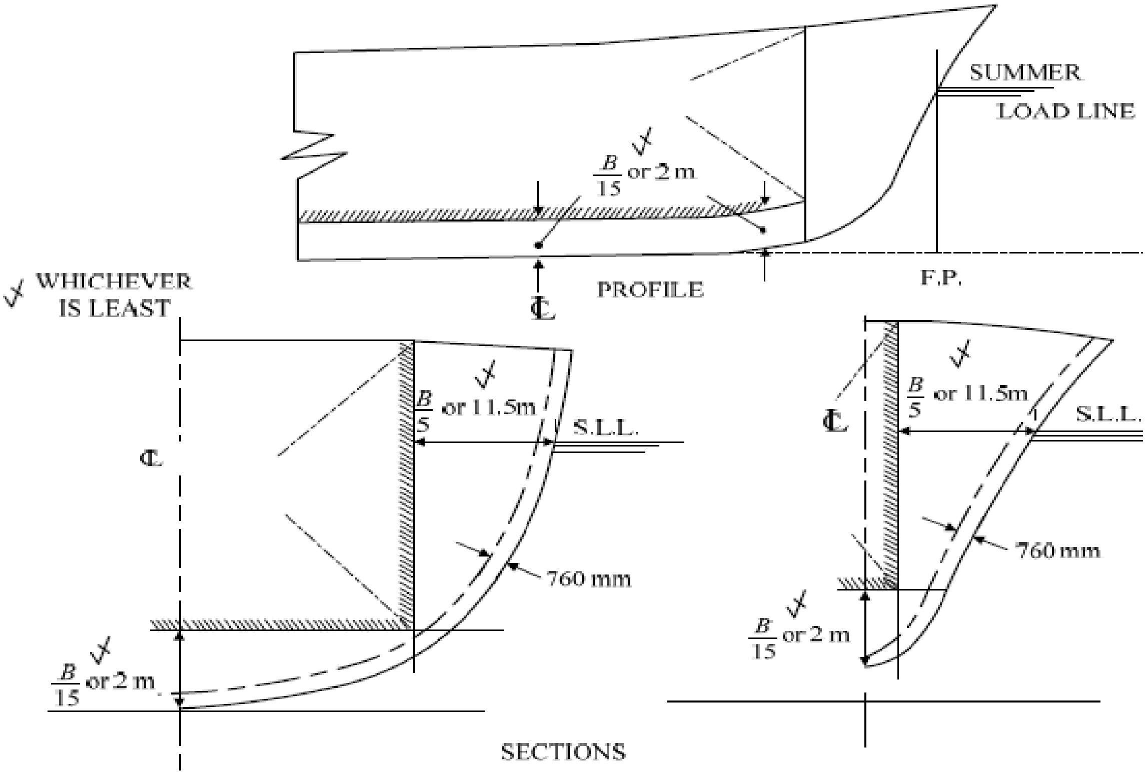
As it will be noted later on, the **vessel** will have **general bunkering once each month** and for **the same time period** will be able to make **up to two routes with return**.

On the top of that, the **vessel** must be **fully autonomous**. This means that in its **forecastle** will carry **adequate number of gas compressors** carrying at the same time **enough amount** of **Heavy Fuel Oil** for its **propulsion** and **adequate** amount of **Marine Diesel/Gas Oil** for **electric power generation** for its **electrical needs (normal load and gas compressors)**. A **fuel capacity margin** of **30%** will be taken into consideration. Last but not least, its **propulsion** and **diesel gen** sets will be **Dual-Fueled** being in this case able to **burn natural gas**. Because of the fact that the **pre-referred engines** will be **Tier II**, **Selective Catalytic Reduction** components will be **available** in the **machinery room**. As far as the **sulfur oxides** are concerned, both of **these two oily fuels** will be of adequate **low sulfur content**.

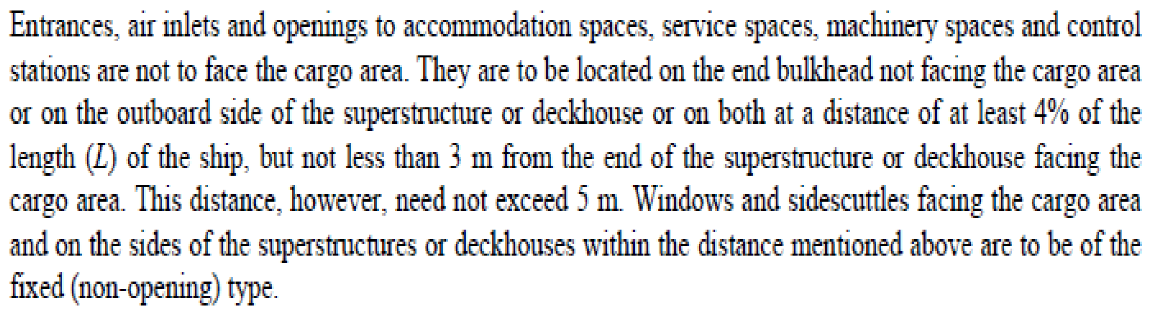
7. American Bureau of Shipping & International Maritime Organization Restrictions, Calculation Process and First Results

The first estimation and calculation process are presented in picture 17. Moreover, the constrictions regarding the distance between the pressure bottles, the space between the cargo area and the vessels side shell as well as the distance between the cargo space and the superstructure are pictured in pictures 8, 9,10 and 11 (ABS GUIDE FOR VESSELS INTENDED TO CARRY COMPRESSED NATURAL GASES IN BULK , 2005). In pictures 12-16 and table 24, the IMO (SOLAS & MARPOL) requirements are presented. Source: (SOLAS Consolidated Edition, 2012), (MARPOL Consolidated Edition 2011, 2011) and (Marine Engine IMO Tier ll and Tier lll Programme MAN Diesel & Turbo 2016).

FIGURE 1
Tank Location Requirements as Set Out in Chapter 3, Section 6

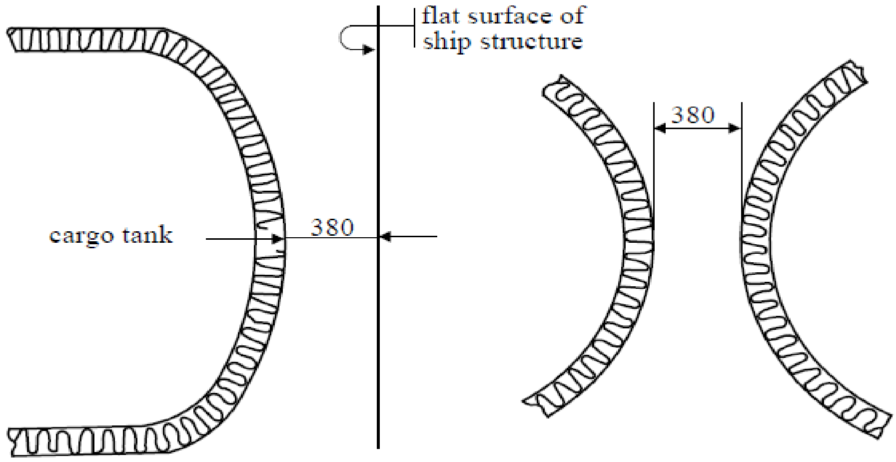


Picture 8. Distance between the cargo space and the hull. Source: (ABS GUIDE FOR VESSELS INTENDED TO CARRY COMPRESSED NATURAL GASES IN BULK , 2005)



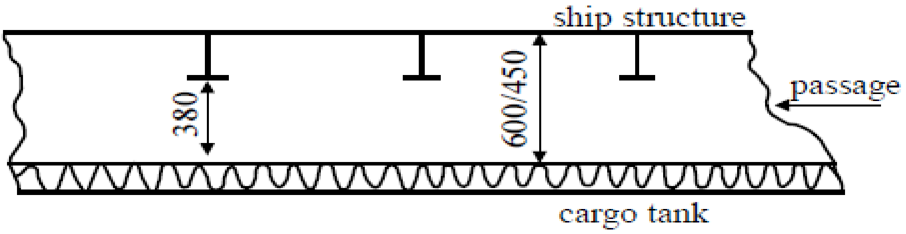
Entrances, air inlets and openings to accommodation spaces, service spaces, machinery spaces and control stations are not to face the cargo area. They are to be located on the end bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse or on both at a distance of at least 4% of the length (*L*) of the ship, but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance, however, need not exceed 5 m. Windows and sidescuttles facing the cargo area and on the sides of the superstructures or deckhouses within the distance mentioned above are to be of the fixed (non-opening) type.

Picture 9. **Distance between the Superstructure and the Cargo Area. Source:** **(ABS GUIDE FOR VESSELS INTENDED TO CARRY COMPRESSED NATURAL GASES IN BULK , 2005)**



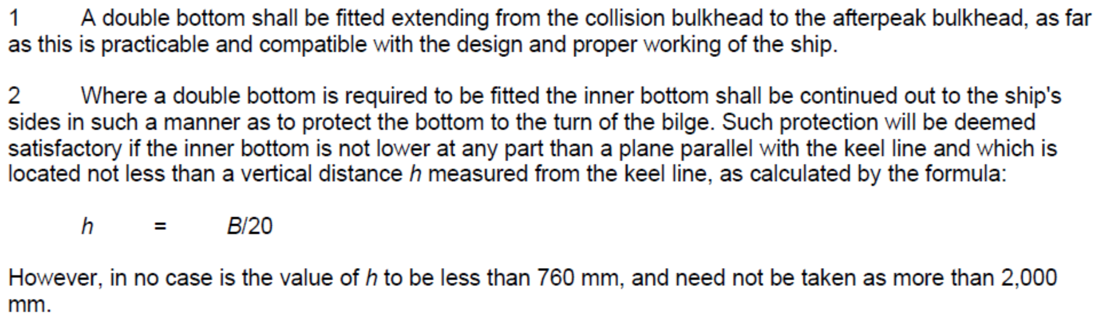
Picture 10. **Distance between Pressure Bottles. Source:** **(ABS GUIDE FOR VESSELS INTENDED TO CARRY COMPRESSED NATURAL GASES IN BULK , 2005)**

FIGURE 1



Picture 11. **Distance between Ship Structure and Cargo Tanks. Source:** **(ABS GUIDE FOR VESSELS INTENDED TO CARRY COMPRESSED NATURAL GASES IN BULK , 2005)**

It must be noted that for the first estimation of the vessels technical characteristics, MATLAB, Microsoft Office, Autocad, Adobe Acrobat Reader and Open Office have been used. Source: (MATLAB, 2017), (OpenOffice, 2017), (AUTOCAD, 2017), (Microsoft Office, 2017), (ADOBE ACROBAT READER), (Microsoft Windows 7).



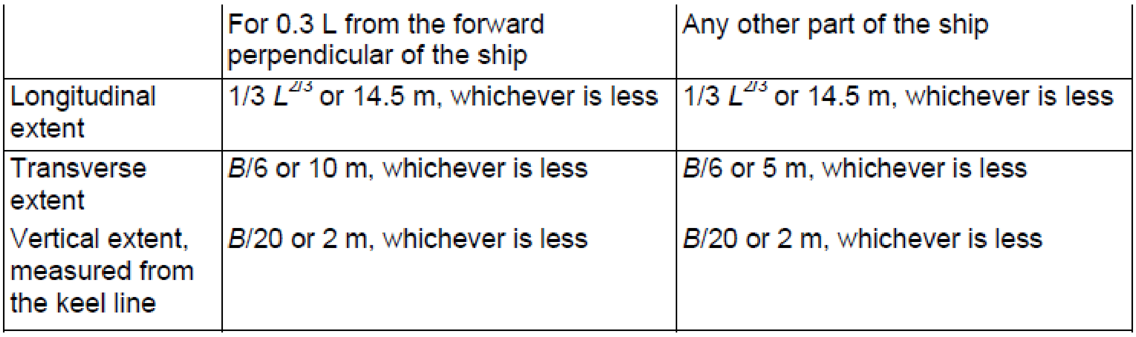
1 A double bottom shall be fitted extending from the collision bulkhead to the afterpeak bulkhead, as far as this is practicable and compatible with the design and proper working of the ship.

2 Where a double bottom is required to be fitted the inner bottom shall be continued out to the ship's sides in such a manner as to protect the bottom to the turn of the bilge. Such protection will be deemed satisfactory if the inner bottom is not lower at any part than a plane parallel with the keel line and which is located not less than a vertical distance *h* measured from the keel line, as calculated by the formula:

$$h = B/20$$

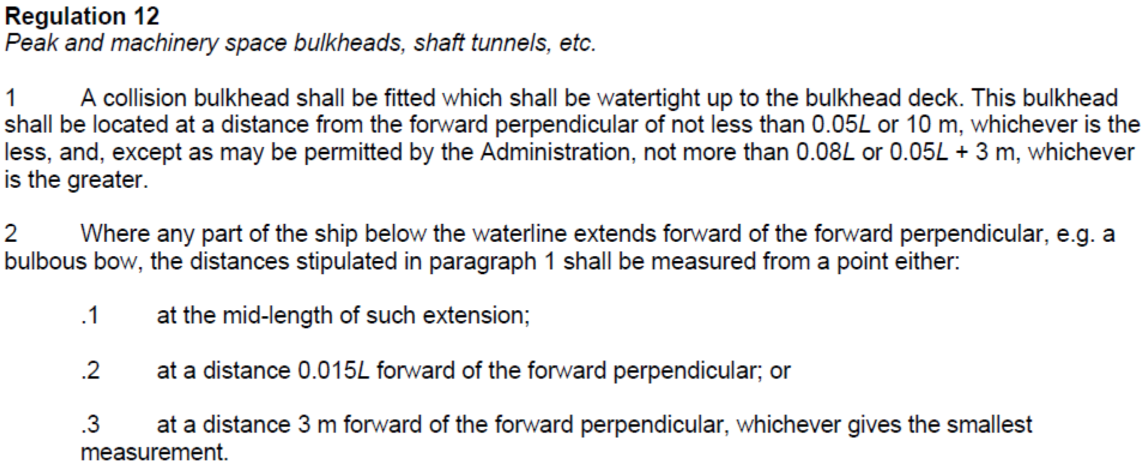
However, in no case is the value of *h* to be less than 760 mm, and need not be taken as more than 2,000 mm.

Picture 12. Double Bottom Dimension Requirements. Source: (SOLAS Consolidated Edition, 2012)



	For 0.3 L from the forward perpendicular of the ship	Any other part of the ship
Longitudinal extent	1/3 $L^{2/3}$ or 14.5 m, whichever is less	1/3 $L^{2/3}$ or 14.5 m, whichever is less
Transverse extent	*B*/6 or 10 m, whichever is less	*B*/6 or 5 m, whichever is less
Vertical extent, measured from the keel line	*B*/20 or 2 m, whichever is less	*B*/20 or 2 m, whichever is less

Table 24. Damage Extent. Source: (SOLAS Consolidated Edition, 2012)



Regulation 12

Peak and machinery space bulkheads, shaft tunnels, etc.

1 A collision bulkhead shall be fitted which shall be watertight up to the bulkhead deck. This bulkhead shall be located at a distance from the forward perpendicular of not less than 0.05*L* or 10 m, whichever is the less, and, except as may be permitted by the Administration, not more than 0.08*L* or 0.05*L* + 3 m, whichever is the greater.

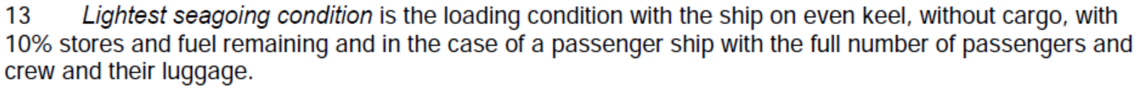
2 Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g. a bulbous bow, the distances stipulated in paragraph 1 shall be measured from a point either:

.1 at the mid-length of such extension;

.2 at a distance 0.015*L* forward of the forward perpendicular; or

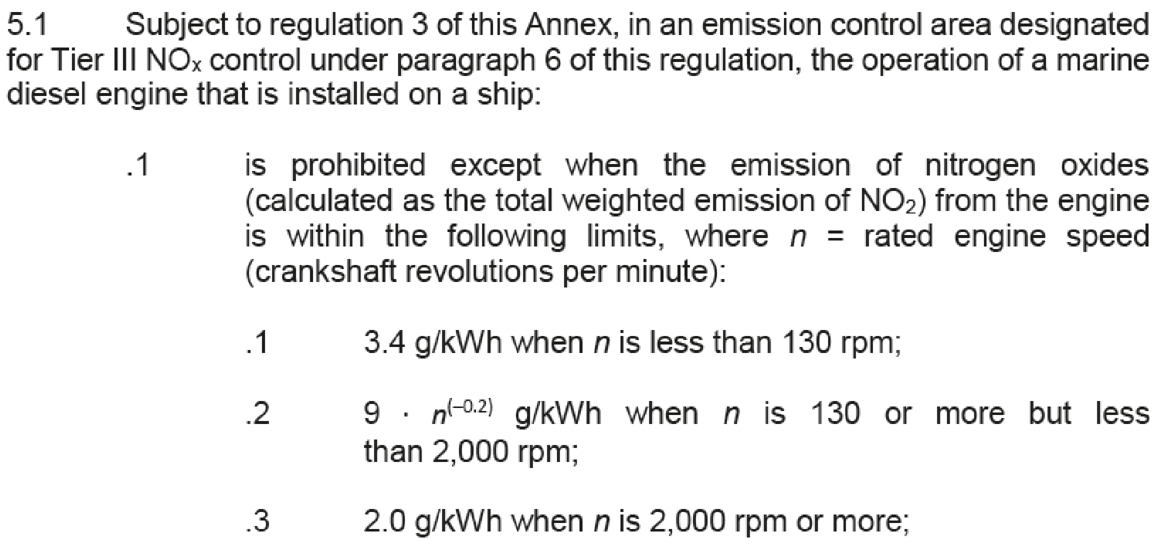
.3 at a distance 3 m forward of the forward perpendicular, whichever gives the smallest measurement.

Picture 13. Peak and Machinery Space Bulkheads. Source: (SOLAS Consolidated Edition, 2012)



13 *Lightest seagoing condition* is the loading condition with the ship on even keel, without cargo, with 10% stores and fuel remaining and in the case of a passenger ship with the full number of passengers and crew and their luggage.

Picture 14. Latest Seagoing Condition Definition. Source: (SOLAS Consolidated Edition, 2012)



5.1 Subject to regulation 3 of this Annex, in an emission control area designated for Tier III NO_x control under paragraph 6 of this regulation, the operation of a marine diesel engine that is installed on a ship:

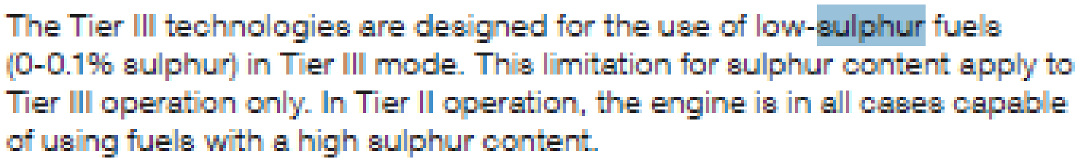
.1 is prohibited except when the emission of nitrogen oxides (calculated as the total weighted emission of NO_2) from the engine is within the following limits, where n = rated engine speed (crankshaft revolutions per minute):

  .1 3.4 g/kWh when n is less than 130 rpm;

  .2 $9 \cdot n^{(-0.2)}$ g/kWh when n is 130 or more but less than 2,000 rpm;

  .3 2.0 g/kWh when n is 2,000 rpm or more;

Picture 15. Tier III NOx Limitations. Source: **(MARPOL Consolidated Edition 2011, 2011)**

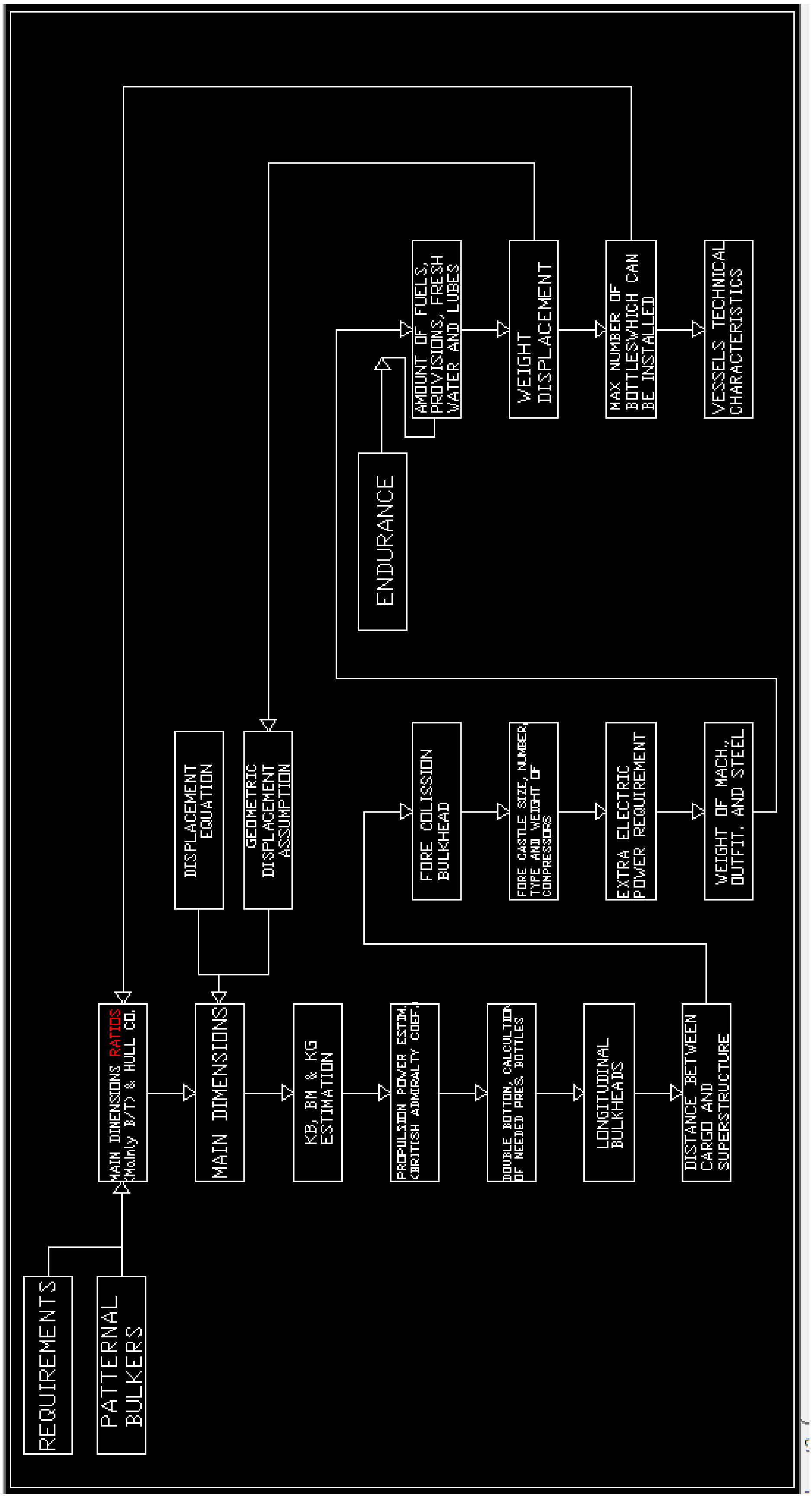


The Tier III technologies are designed for the use of low-sulphur fuels (0-0.1% sulphur) in Tier III mode. This limitation for sulphur content apply to Tier III operation only. In Tier II operation, the engine is in all cases capable of using fuels with a high sulphur content.

Picture 16. Sulphur Limitations. Source: **(Marine Engine IMO Tier II and Tier III Programme MAN Diesel & Turbo 2016)**

It is underlined that around oily liquids tanks (fuel oil, marine diesel oil, marine gas oil, lubricant oil, oily water, sewage, sludge bilge, e.t.c), **the distance between the inner and the outer hull is at least 2 meters**. (ΚΩΝ/ΝΟΣ ΣΠΥΡΟΥ, 2004), (MARPOL Consolidated Edition 2011, 2011)

Last but not least, the just referred requirements satisfies the requirements coming from **(RESOLUTION MSC.370(93) (adopted on 22 May 2014) (IGC CODE))**, **(RESOLUTION MSC.391(95) (adopted on 11 June 2015) (IGF CODE))**, **((IMDG CODE) volume 1, 2006)** and **((IMDG CODE) Volume 2, 2006)**.



Picture 17. Vessel Calculation Process. (AUTOCAD, 2017)

In Tables 25and 26 the main technical characteristics are presented of existing **CNGs** and **LNGs designs** and **vessels**.

	CNG Carriers						
Cargo Equipment Type	*VOTRANS* ***[1]***	*CONVENTIONAL VERTICAL PRESSURE BOTTLES* ***[2]***	*CONVENTIONAL VERTICAL PRESSURE BOTTLES* ***[2]***	*CONVENTIONAL VERTICAL PRESSURE BOTTLES* ***[2]***	*CONVENTIONAL VERTICAL PRESSURE BOTTLES* ***[2]***	*CONVENTIONAL VERTICAL PRESSURE BOTTLES* ***[2]***	*COSELLE* ***[3]***
Size Classification		**HANDYSIZE**	**HANDYSIZE**	**AFRAMAX**	**VLCC**		
L_oa [m]							**243**
L_bp [m]	**247**	**135**	**147**	**184**	**300**	**165**	**231,8**
B [m]	**47,5**	**22,5**	**24,4**	**37**	**54**	**27,5**	**38**
D [m]	**26,8**	**14**	**14,3**	**22,1**	**25,3**	**15,3**	**25,9**
T [m]	**10,3**	**7**	**7,2**	**12,3**	**16,9**	**7**	**10,3**
W [t] hull+accessories		**4703**	**5688**	**13971**	**41359**		
W [t] cargo containers		**8093**	**10561**	**41242**	**147414**		
DWT [t]	**27900**	**2000**	**2530**	**8325**	**27000**		
Displacement [t]		**15804**	**20000**	**66748**	**222641**	**22856**	
Cargo Weight Capacity / Displacement		0,07	0,08	0,10	0,11		
Cargo Weight Capacity / DWT	0,43	0,58	0,66	0,80	0,92		
Cargo Weight [t]	**12000**	**1162**	**1660**	**6640**	**24900**		**7700**
No. Coselles							**108**
Total Capacity [MM Ncf]		49,4	70,6	282,5	1059,4	70,6	**330**
Total Capacity [MM Nm3]		**1,4**	**2**	**8**	**30**	**2**	9,3
Engine BHP [kW]						**12000**	
Speed [knots]	**18**						
Cb		0,723	0,753	0,775	0,791	0,700	

Table 24. **Existing CNG Carrier Designs. Source:** See Next Page

Bibliographical Sources of **Table 25**:

[1] Source: (http://www.kline.co.jp)

[2] Source: (James Weiss et al., 2009)

[3] Source: (David Stenning, James Cran)

	LNG Carriers				
Vessel	**1 *[1]***	**2 *[1]***	**3 *[1]***	**4 *[1]***	**5 *[2]***
L_oa [m]					**98,6**
L_bp [m]	**315**	**315**	**335**	**345**	**93**
B [m]	**50**	**50**	**51**	**55**	**14,2**
D [m]	**27**	**27**	**27**	**28**	**7,6**
T [m]	**12**	**12**	**12**	**12,2**	**4**
DWT [t]					**1900**
No. Holds	**4**	**4**	**5**	**5**	
Total Capacity [cf]	7416080,0	7663282,7	8581464,0	9429016,0	105944,0
Total Capacity [m3]	**210000**	**217000**	**243000**	**267000**	**3000**
Speed [knots]					**12**

Table 25. **Existing LNG Carrier Designs. Source:** See Below

Bibliographical Sources of **Table 26**:

[1] Source: (Peter Noble)

[2] Source: (Bjorn Munko)

From table 25 the following comparison can be produced (Table 27). This comparison concerns only the **first estimation**.

Loa/Lbp							1,05
Lbp/B	5,20	6,00	6,02	4,97	5,56	6,00	6,10
B/T	4,61	3,21	3,39	3,01	3,20	3,93	3,69
D/T	2,60	2,00	1,99	1,80	1,50	2,19	2,51
DWT/Displ.		0,13	0,13	0,12	0,12		
Cargo Weight Capacity / DWT	0,43	0,58	0,66	0,80	0,92		
Cargo Weight Capacity / Displacement		0,07	0,08	0,10	0,11		
Fn	0,19						

Table 26. **CNGs Main Dimension Ratios from Table 25.**

The **first approach (estimation) data** coming from the calculation process are tabulated in table 28. It is noted that in this table only the **basic input and output data** are given. Later on, the draft among others will be changed.

payload [t]	1500,00	**Length Between Perpendicular [m]**	153.81
DWT [t]	3.6904e+003	**Length Overall [m]**	161.25
Displacement Weight[t]	2.4008e+004	**Breadth [m]**	29.64
Light Ship[t]	2.0317e+004	**Draft [m]**	6,37
Wm [t]	1.1564e+003	**Depth [m]**	17.27
WOT [t]	1.2699e+004	**Block Coefficient [-]**	0.80
Wst [t]	6.4614e+003	**Midship Coefficient [-]**	0,99
pressure bottles weight [t]	1.0971e+004	**c_p_new_array_final =**	0,81
Super Structure Weight [t]	441.11	**Waterline Coefficient [-]**	0,87
Forecastle Weight [t]	319.83		
KB [m]	3,33	**Fuel Oil[t]**	1089
BM [m]	11,02	**Diesel Oil[t]**	819
KG [m]	11,51	**Lube Oil[t]**	4,5
GM [m]	2,84	**Fresh Water[t]**	76,4
MCT [tm/cm]	475,02	**Water Ballast[t]**	0
Vessel Speed [m/sec]	7,77	**Provisions**	20
Main Engine Power [kW]	12802,00	**Stores**	178
Propeller Diameter [m]	3,82	**Crew**	4
Total Installed Electric Power [kW]	1.0398e+004	**Endurance [sm] (at Pmax(P propulsion installed))**	5000
Maximum Number of Pressure Bottles which can be installed [-]	477,00		
Number of Compressors [-]	104,00	**Pressure Bottle Diameter [m]**	1.2
Filling Time of Pressure Bottles [d]	2,88	**Pressure Bottle Length [m]**	~14.4
Double Bottom Space [m]	1,98	**Pressure of Bottles [bar]**	**250**
Space Between Side Shell and Cargo Space [m]	5,93	**P. Bottles Temperature [C]**	**25**
Distance Between Cargo space and Superstructure [m]	5,00		

Table 28. **Basic Input and Output Data of the First Estimation. Sources:**

(Βασικές Αρχές Πρόωσης Πλοίων, 2004), (ΥΔΡΟΔΥΝΑΜΙΚΗ ΠΛΟΙΟΥ (Αντίσταση - Πρόωση) ΣΤΟΙΧΕΙΑ ΓΙΑ ΥΠΟΛΟΓΙΣΜΟΥΣ, 1982), (American Bureau of Shipping (ABS), 2008), (MATLAB, 2017), (OpenOffice, 2017), (Microsoft Office, 2017), (ΜΕΛΕΤΗ & ΣΧΕΔΙΑΣΗ ΠΛΟΙΩΝ ΕΙΔΙΚΟΥ ΤΥΠΟΥ Σημειώσεις Μαθήματος, 2016-2017), (ADOBE ACROBAT READER), (D. Watson), (H. Schneekluth et al., 1998), (A. Παπανικολάου, 2004), (A. Παπανικολάου et al., ΘΕΜΑ ΜΕΛΕΤΗΣ ΚΑΙ ΣΧΕΔΙΑΣΗΣ ΠΛΟΙΟΥ 2007), (A. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι,

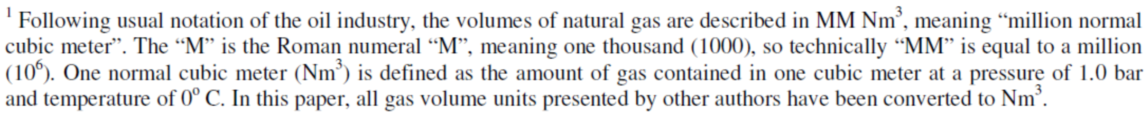
2005), (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ ΙΙ ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ ΓΕΝΙΚΗ ΔΙΑΤΑΞΗ, ΕΝΔΙΑΙΤΗΣΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ, 2006), (ΑΠΟΣΤΟΛΟΥ Δ. ΠΑΠΑΝΙΚΟΛΑΟΥ, Μελέτη Πλοίου ΤΟΜΟΣ Α: ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ), (ΑΠΟΣΤΟΛΟΥ Δ. ΠΑΠΑΝΙΚΟΛΑΟΥ, Μελέτη Πλοίου ΤΟΜΟΣ Β: ΕΓΧΕΙΡΙΔΙΟ ΜΕΛΕΤΗΣ), (Απόστολος Παπανικολάου et al., 2015), (Γ. ΓΡΗΓΟΡΟΠΟΥΛΟΣ, 2004) (ΘΟΔΩΡΟΥ Α. ΛΟΥΚΑΚΗ et al., 2000), (Γ. ΓΡΗΓΟΡΟΠΟΥΛΟΣ et al., 1998) (Γ.Κ. ΠΟΛΙΤΗ et al., 23/11/2005), (Γερασίμου Κ. Πολίτη, 2005), (Ι. ΙΩΑΝΝΙΔΗ, 2005), (ΚΩΝ/ΝΟΣ ΣΠΥΡΟΥ, 2004), (Κων/νος Σπύρου, 2012), (Χ. Σαρηγιαννίδης, 2016), (Χρήστος Ι. Παπαδόπουλος et al.), (ΕΥΑΓΓΕΛΟΣ ΧΑΤΖΙΚΟΣ, 2003), (ABS GUIDE FOR VESSELS INTENDED TO CARRY COMPRESSED NATURAL GASES IN BULK , 2005), (James Weiss et al., 2009), (High Pressure Natural Gas Compressors BAUER COMPRESSORS), (NIST 12 An abbreviated version of NIST REFPROP, 2005), (CNG tanks: Pressure vessel epicenter), (Marine Engine IMO Tier II Programme 2014 MAN Diesel & Turbo), (WARTSILA SOLUTIONS FOR MARINE AND OIL & GAS MARKETS 2013), (SOLAS Consolidated Edition, 2012), (MARPOL Consolidated Edition 2011, 2011), (WARTSILA Thrusters), (WARTSILA PROPULSION SYSTEMS), (Wärtsilä Solutions for Marine and Oil & Gas Markets WÄRTSILÄ), (MAN 51/60DF), (MAN L35/44DF), (Marine Engine IMO Tier II and Tier III), (MathType, 2017), (Marine Engine IMO Tier II and Tier III Programme MAN Diesel & Turbo 2016), (Ι. ΙΩΑΝΝΙΔΗ, 1998), (Χρίστος Φραγκόπουλος, 2007), (Graf et al.,2003)

From Table 28, the **examined vessel** dimension ratios are:

Loa/Lbp=1.048, **Lbp/B=5.189**, **L/D=8.906**,**B/T=4.653**, **Payload/Displacement=0.0625**,**DWT/Displacement=0.154**

8. Pressure Bottles Filling Time and Vessel Capacity in Standard Cubic Meters Estimation

As it has been underlined, the **payload** capacity of the designed vessel is **1500t of Compressed Natural Gas (CNG)**. However the **volume** or the **volume rate** at the filling process **strongly depends on** the **pressure** and **temperature** conditions. It would be more convenient, to **talk about volume** at **standardized pressure** and **temperature**. For this instance according to bibliographical source: (James Weiss et al., 2009) the **Normal Cubic Meter** is defined as:



[1] Following usual notation of the oil industry, the volumes of natural gas are described in MM Nm^3, meaning “million normal cubic meter”. The “M” is the Roman numeral “M”, meaning one thousand (1000), so technically “MM” is equal to a million (10^6). One normal cubic meter (Nm^3) is defined as the amount of gas contained in one cubic meter at a pressure of 1.0 bar and temperature of 0^o C. In this paper, all gas volume units presented by other authors have been converted to Nm^3.

Picture 18. **Definition of Normal Cubic Meter. Source:** (James Weiss et al., 2009)

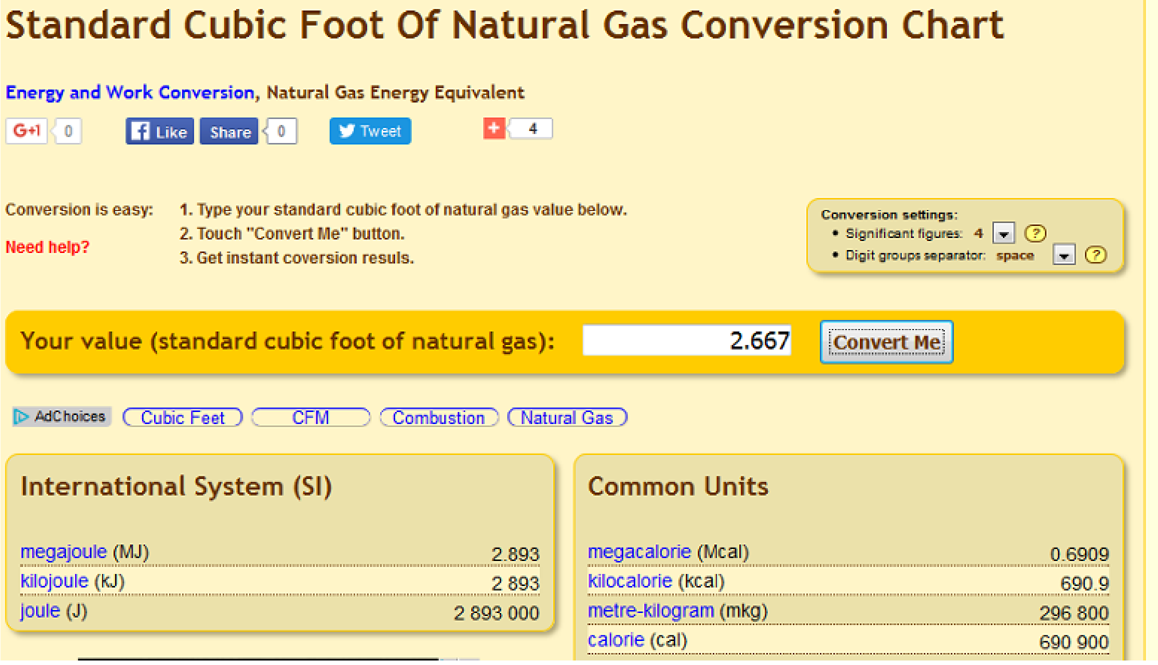
In the same wavelength, the **Standard Cubic Meter (scm)** is defined according to the bibliographical source: (Standard cubic foot WIKIPEDIA) as above but in **15 Celsius degrees** and the **Standard Cubic Foot (scf)** is equal to **0.02831 Standard Cubic Meters** from the same source.

For the present design, **104 natural gas compressors** type: **BAUER C280** have been chosen. Each of these compressors is of **125HP**, **160 Standard Cubic Foots per Minute** and is of **four stages**. Source: (High Pressure Natural Gas Compressors BAUER COMPRESSORS).

As it is tabled in table 28, it will be installed **480 pressure bottles**. **Each pressure bottle** will be of (3.1415/4)*(1.2^2)*14.5=**16.4m3**. This means that the **total** water **volume** of the pressure bottles will be of 480*16.4=**7871m3**. From the above can find that the **density inside the cargo pressure bottles** will be of 1500t/7871m3=**0.19t/m3** which is very close to the **first row** of **table 6**.

According the Source: (High Pressure Natural Gas Compressors BAUER COMPRESSORS) as above, the **volume rate of each compressor** is 160scf/min=**2.667scf/sec**.

In accordance with bibliographical source: (Standard Cubic Foot Of Natural Gas Conversion Chart), **2.667scf/sec=690.9kcal/sec of natural gas** (Picture 19). From bibliographical source: (WIKIPEDIA Heat of combustion), the **Lower Heating Value** of **Natural Gas** is equal to **50000kJ/kg** or 50000/4.18=**11961kcal/kg**. Furthermore, (690.9kcal/sec)/(11961kcal/kg)= **0.058kg/sec (each)**. As it was calculated above, the density of natural gas in the pressure bottles is equal to 0.19t/m3. So, the volume rate (water volume) of each compressor is equal to (0.058kg/sec)/(190kg/m3)= **0.0003053m3/sec**. However, according to table 28, 104 natural gas compressors have been installed for this purpose. This means that **the filling time** of the **pressure bottles** will be 7871m3/(104*0.0003053m3/sec)=**247896sec=4131min= 68.86h=*2.87days***.



Standard Cubic Foot Of Natural Gas Conversion Chart

Energy and Work Conversion, Natural Gas Energy Equivalent

Conversion is easy:
1. Type your standard cubic foot of natural gas value below.
2. Touch "Convert Me" button.
3. Get instant coversion resuls.

Need help?

Conversion settings:
- Significant figures: 4
- Digit groups separator: space

Your value (standard cubic foot of natural gas): 2.667

International System (SI)

megajoule (MJ)	2.893
kilojoule (kJ)	2 893
joule (J)	2 893 000

Common Units

megacalorie (Mcal)	0.6909
kilocalorie (kcal)	690.9
metre-kilogram (mkg)	296 800
calorie (cal)	690 900

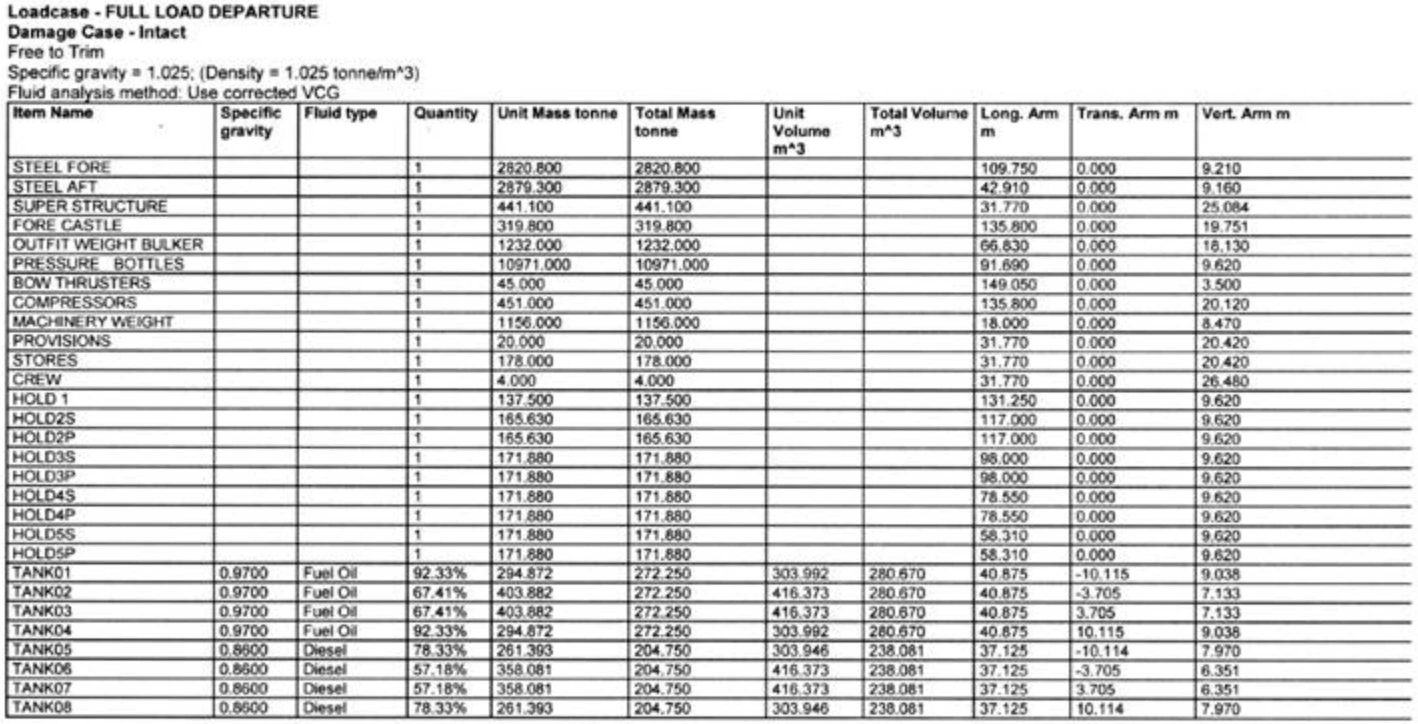
Picture 19. **Standard Cubic Foot of Natural Gas Conversion Chart. Source:** (Standard Cubic Foot Of Natural Gas Conversion Chart)

From above it was clear that **2.667scf** of **natural gas** is equal to **0.00030m3** in *pressure bottles* **pressure** and **temperature (253bar, 25C)**. It was also referred that the **pressure bottles total volume** is equal to **7871m3.** Now, it is clear that the **cargo capacity** of the **CNG carrier** is (2.667scf/0.00030m3)*7871m3=**70*10^6scf**=**2*10^6scm**.

Regarding the bow-thruster selection, because of the need that this vessel must be fully autonomous (no need for tugs), for that purpose, the **two biggest Wartsila** bow thrusters have been selected. In detail, the **bow thrusters** according to the bibliographical source: (WARTSILA Thrusters) are the: **2 X Wartsila CT/FT300 M**.

9. Weights & Masses (Full Load Departure)

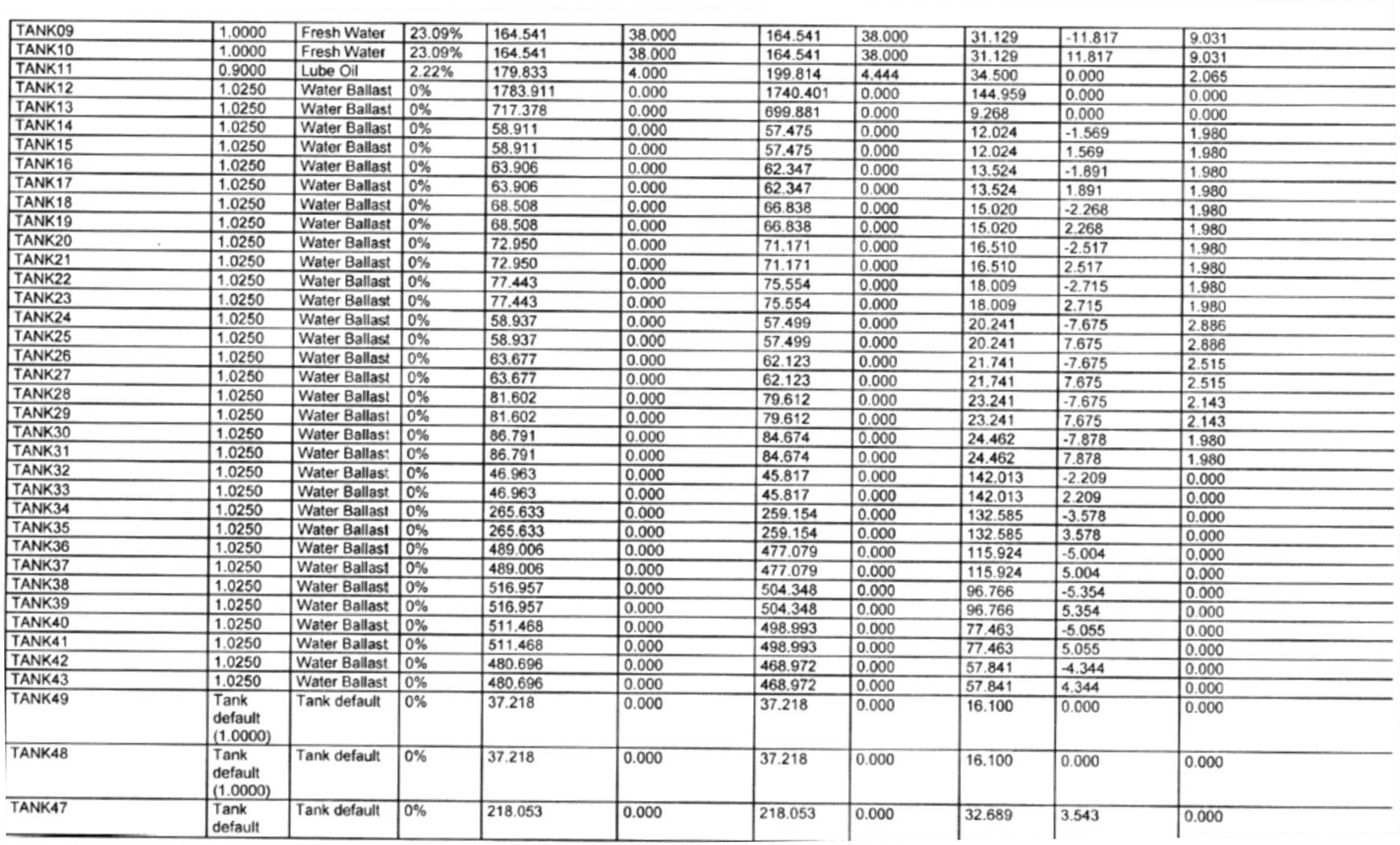
The weight and masses of the examined CNG carrier are modeled in HYDROMAX (Hydromax).



Loadcase - FULL LOAD DEPARTURE
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

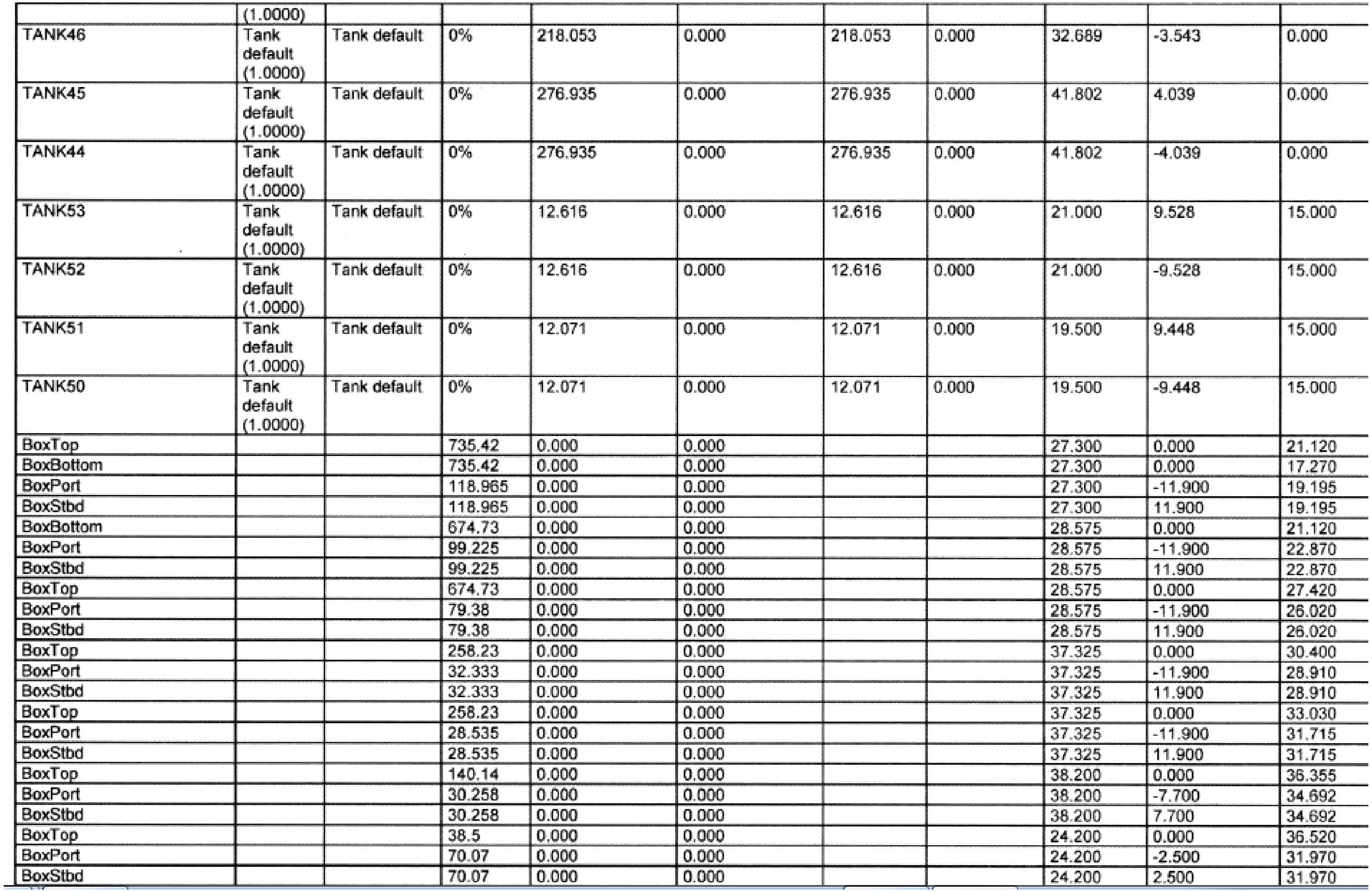
Item Name	Specific gravity	Fluid type	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m
STEEL FORE			1	2820.800	2820.800			109.750	0.000	9.210
STEEL AFT			1	2879.300	2879.300			42.910	0.000	9.160
SUPER STRUCTURE			1	441.100	441.100			31.770	0.000	25.084
FORE CASTLE			1	319.800	319.800			135.800	0.000	19.751
OUTFIT WEIGHT BULKER			1	1232.000	1232.000			66.830	0.000	18.130
PRESSURE BOTTLES			1	10971.000	10971.000			91.690	0.000	9.620
BOW THRUSTERS			1	45.000	45.000			149.050	0.000	3.500
COMPRESSORS			1	451.000	451.000			135.800	0.000	20.120
MACHINERY WEIGHT			1	1156.000	1156.000			18.000	0.000	8.470
PROVISIONS			1	20.000	20.000			31.770	0.000	20.420
STORES			1	178.000	178.000			31.770	0.000	20.420
CREW			1	4.000	4.000			31.770	0.000	26.480
HOLD 1			1	137.500	137.500			131.250	0.000	9.620
HOLD2S			1	165.630	165.630			117.000	0.000	9.620
HOLD2P			1	165.630	165.630			117.000	0.000	9.620
HOLD3S			1	171.880	171.880			98.000	0.000	9.620
HOLD3P			1	171.880	171.880			98.000	0.000	9.620
HOLD4S			1	171.880	171.880			78.550	0.000	9.620
HOLD4P			1	171.880	171.880			78.550	0.000	9.620
HOLD5S			1	171.880	171.880			58.310	0.000	9.620
HOLD5P			1	171.880	171.880			58.310	0.000	9.620
TANK01	0.9700	Fuel Oil	92.33%	294.872	272.250	303.992	280.670	40.875	-10.115	9.038
TANK02	0.9700	Fuel Oil	67.41%	403.882	272.250	416.373	280.670	40.875	-3.705	7.133
TANK03	0.9700	Fuel Oil	67.41%	403.882	272.250	416.373	280.670	40.875	3.705	7.133
TANK04	0.9700	Fuel Oil	92.33%	294.872	272.250	303.992	280.670	40.875	10.115	9.038
TANK05	0.8600	Diesel	78.33%	261.393	204.750	303.946	238.081	37.125	-10.114	7.970
TANK06	0.8600	Diesel	57.18%	358.081	204.750	416.373	238.081	37.125	-3.705	6.351
TANK07	0.8600	Diesel	57.18%	358.081	204.750	416.373	238.081	37.125	3.705	6.351
TANK08	0.8600	Diesel	78.33%	261.393	204.750	303.946	238.081	37.125	10.114	7.970

Picture 20. **Weights & Masses (1/5) – Full Load Departure – Steel Pressure Bottles - (Hydromax), (Maxsurf)**



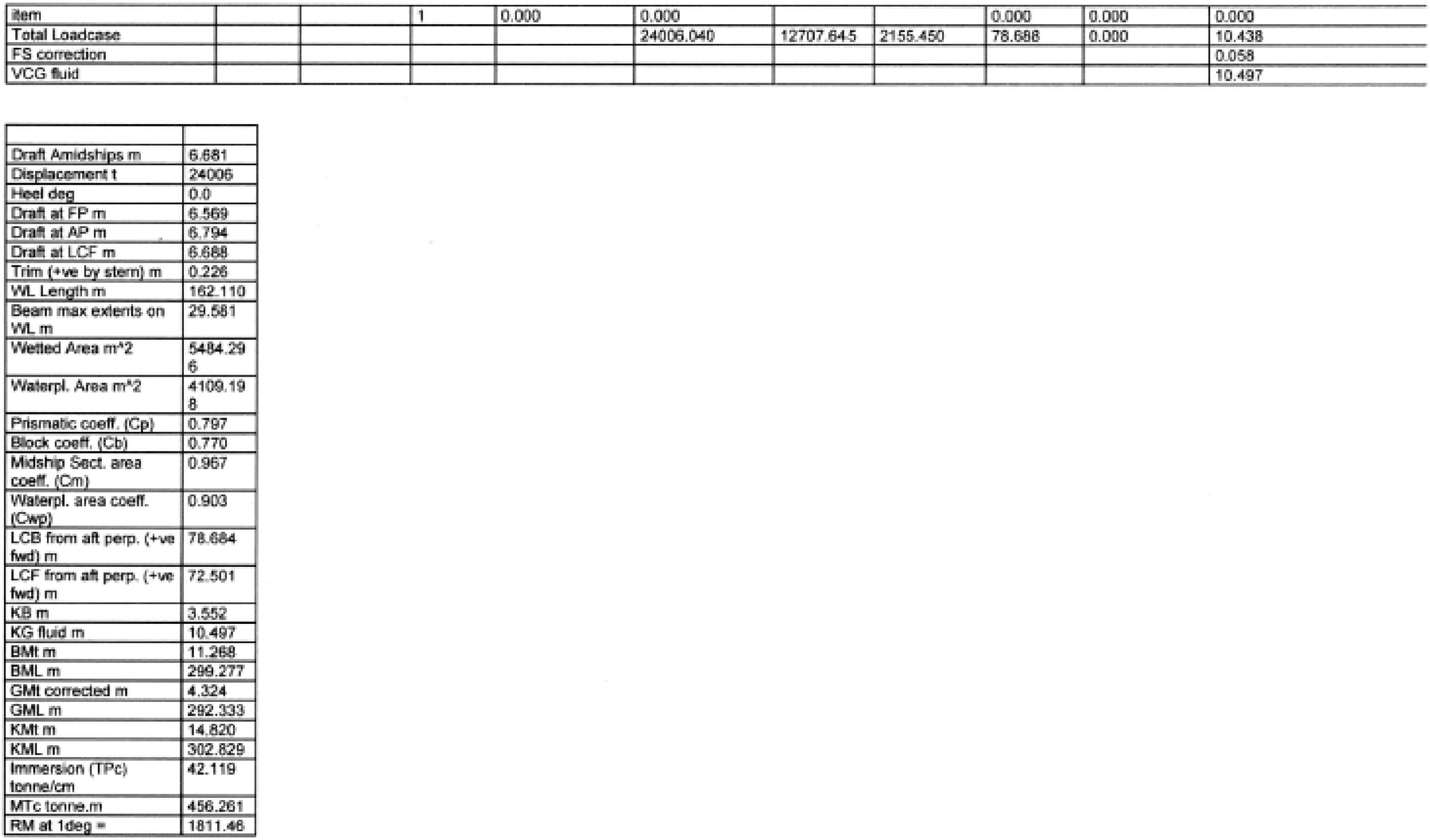
TANK09	1.0000	Fresh Water	23.09%	164.541	38.000	164.541	38.000	31.129	-11.817	9.031
TANK10	1.0000	Fresh Water	23.09%	164.541	38.000	164.541	38.000	31.129	11.817	9.031
TANK11	0.9000	Lube Oil	2.22%	179.833	4.000	199.814	4.444	34.500	0.000	2.065
TANK12	1.0250	Water Ballast	0%	1783.911	0.000	1740.401	0.000	144.959	0.000	0.000
TANK13	1.0250	Water Ballast	0%	717.378	0.000	699.881	0.000	9.268	0.000	0.000
TANK14	1.0250	Water Ballast	0%	58.911	0.000	57.475	0.000	12.024	-1.569	1.980
TANK15	1.0250	Water Ballast	0%	58.911	0.000	57.475	0.000	12.024	1.569	1.980
TANK16	1.0250	Water Ballast	0%	63.906	0.000	62.347	0.000	13.524	-1.891	1.980
TANK17	1.0250	Water Ballast	0%	63.906	0.000	62.347	0.000	13.524	1.891	1.980
TANK18	1.0250	Water Ballast	0%	68.508	0.000	66.838	0.000	15.020	-2.268	1.980
TANK19	1.0250	Water Ballast	0%	68.508	0.000	66.838	0.000	15.020	2.268	1.980
TANK20	1.0250	Water Ballast	0%	72.950	0.000	71.171	0.000	16.510	-2.517	1.980
TANK21	1.0250	Water Ballast	0%	72.950	0.000	71.171	0.000	16.510	2.517	1.980
TANK22	1.0250	Water Ballast	0%	77.443	0.000	75.554	0.000	18.009	-2.715	1.980
TANK23	1.0250	Water Ballast	0%	77.443	0.000	75.554	0.000	18.009	2.715	1.980
TANK24	1.0250	Water Ballast	0%	58.937	0.000	57.499	0.000	20.241	-7.675	2.886
TANK25	1.0250	Water Ballast	0%	58.937	0.000	57.499	0.000	20.241	7.675	2.886
TANK26	1.0250	Water Ballast	0%	63.677	0.000	62.123	0.000	21.741	-7.675	2.515
TANK27	1.0250	Water Ballast	0%	63.677	0.000	62.123	0.000	21.741	7.675	2.515
TANK28	1.0250	Water Ballast	0%	81.602	0.000	79.612	0.000	23.241	-7.675	2.143
TANK29	1.0250	Water Ballast	0%	81.602	0.000	79.612	0.000	23.241	7.675	2.143
TANK30	1.0250	Water Ballast	0%	86.791	0.000	84.674	0.000	24.462	-7.878	1.980
TANK31	1.0250	Water Ballast	0%	86.791	0.000	84.674	0.000	24.462	7.878	1.980
TANK32	1.0250	Water Ballast	0%	46.963	0.000	45.817	0.000	142.013	-2.209	0.000
TANK33	1.0250	Water Ballast	0%	46.963	0.000	45.817	0.000	142.013	2.209	0.000
TANK34	1.0250	Water Ballast	0%	265.633	0.000	259.154	0.000	132.585	-3.578	0.000
TANK35	1.0250	Water Ballast	0%	265.633	0.000	259.154	0.000	132.585	3.578	0.000
TANK36	1.0250	Water Ballast	0%	489.006	0.000	477.079	0.000	115.924	-5.004	0.000
TANK37	1.0250	Water Ballast	0%	489.006	0.000	477.079	0.000	115.924	5.004	0.000
TANK38	1.0250	Water Ballast	0%	516.957	0.000	504.348	0.000	96.766	-5.354	0.000
TANK39	1.0250	Water Ballast	0%	516.957	0.000	504.348	0.000	96.766	5.354	0.000
TANK40	1.0250	Water Ballast	0%	511.468	0.000	498.993	0.000	77.463	-5.055	0.000
TANK41	1.0250	Water Ballast	0%	511.468	0.000	498.993	0.000	77.463	5.055	0.000
TANK42	1.0250	Water Ballast	0%	480.696	0.000	468.972	0.000	57.841	-4.344	0.000
TANK43	1.0250	Water Ballast	0%	480.696	0.000	468.972	0.000	57.841	4.344	0.000
TANK49	Tank default (1.0000)	Tank default	0%	37.218	0.000	37.218	0.000	16.100	0.000	0.000
TANK48	Tank default (1.0000)	Tank default	0%	37.218	0.000	37.218	0.000	16.100	0.000	0.000
TANK47	Tank default	Tank default	0%	218.053	0.000	218.053	0.000	32.689	3.543	0.000

Picture 21. **Weights & Masses (2/5) – Full Load Departure – Steel Pressure Bottles - (Hydromax), (Maxsurf)**



	(1.0000)									
TANK46	Tank default (1.0000)	Tank default	0%	218.053	0.000	218.053	0.000	32.689	-3.543	0.000
TANK45	Tank default (1.0000)	Tank default	0%	276.935	0.000	276.935	0.000	41.802	4.039	0.000
TANK44	Tank default (1.0000)	Tank default	0%	276.935	0.000	276.935	0.000	41.802	-4.039	0.000
TANK53	Tank default (1.0000)	Tank default	0%	12.616	0.000	12.616	0.000	21.000	9.528	15.000
TANK52	Tank default (1.0000)	Tank default	0%	12.616	0.000	12.616	0.000	21.000	-9.528	15.000
TANK51	Tank default (1.0000)	Tank default	0%	12.071	0.000	12.071	0.000	19.500	9.448	15.000
TANK50	Tank default (1.0000)	Tank default	0%	12.071	0.000	12.071	0.000	19.500	-9.448	15.000
BoxTop			735.42	0.000	0.000			27.300	0.000	21.120
BoxBottom			735.42	0.000	0.000			27.300	0.000	17.270
BoxPort			118.965	0.000	0.000			27.300	-11.900	19.195
BoxStbd			118.965	0.000	0.000			27.300	11.900	19.195
BoxBottom			674.73	0.000	0.000			28.575	0.000	21.120
BoxPort			99.225	0.000	0.000			28.575	-11.900	22.870
BoxStbd			99.225	0.000	0.000			28.575	11.900	22.870
BoxTop			674.73	0.000	0.000			28.575	0.000	27.420
BoxPort			79.38	0.000	0.000			28.575	-11.900	26.020
BoxStbd			79.38	0.000	0.000			28.575	11.900	26.020
BoxTop			258.23	0.000	0.000			37.325	0.000	30.400
BoxPort			32.333	0.000	0.000			37.325	-11.900	28.910
BoxStbd			32.333	0.000	0.000			37.325	11.900	28.910
BoxTop			258.23	0.000	0.000			37.325	0.000	33.030
BoxPort			28.535	0.000	0.000			37.325	-11.900	31.715
BoxStbd			28.535	0.000	0.000			37.325	11.900	31.715
BoxTop			140.14	0.000	0.000			38.200	0.000	36.355
BoxPort			30.258	0.000	0.000			38.200	-7.700	34.692
BoxStbd			30.258	0.000	0.000			38.200	7.700	34.692
BoxTop			38.5	0.000	0.000			24.200	0.000	36.520
BoxPort			70.07	0.000	0.000			24.200	-2.500	31.970
BoxStbd			70.07	0.000	0.000			24.200	2.500	31.970

Picture 22. **Weights & Masses (3/5) – Full Load Departure – Steel Pressure Bottles - (Hydromax), (Maxsurf)**



Item			1	0.000	0.000			0.000	0.000	0.000
Total Loadcase					24006.040	12707.645	2155.450	78.688	0.000	10.438
FS correction										0.058
VCG fluid										10.497

Draft Amidships m	6.681
Displacement t	24006
Heel deg	0.0
Draft at FP m	6.569
Draft at AP m	6.794
Draft at LCF m	6.688
Trim (+ve by stern) m	0.226
WL Length m	162.110
Beam max extents on WL m	29.581
Wetted Area m^2	5484.296
Waterpl. Area m^2	4109.198
Prismatic coeff. (Cp)	0.797
Block coeff. (Cb)	0.770
Midship Sect. area coeff. (Cm)	0.967
Waterpl. area coeff. (Cwp)	0.903
LCB from aft perp. (+ve fwd) m	78.684
LCF from aft perp. (+ve fwd) m	72.501
KB m	3.552
KG fluid m	10.497
BMt m	11.268
BML m	299.277
GMt corrected m	4.324
GML m	292.333
KMt m	14.820
KML m	302.829
Immersion (TPc) tonne/cm	42.119
MTc tonne.m	456.261
RM at 1deg =	1811.46

Picture 23. Weights & Masses (4/5) – Full Load Departure – Steel Pressure Bottles - (Hydromax), (Maxsurf)

GMt.Disp.sin(1) tonne.m	9
Max deck inclination deg	0.0841
Trim angle (+ve by stern) deg	0.0841

Key point	Type	Freeboard m
Margin Line (freeboard pos = -8.3 m)		10.387
Deck Edge (freeboard pos = -8.3 m)		10.463

Picture 24. **Weights & Masses (5/5) – Full Load Departure – Steel Pressure Bottles - (Hydromax), (Maxsurf)**

It is underlined that **stores weight** is increased **(178t)**. This happens because there is **increased demand in spare parts for compressors, pressure bottles, piping system and for diesel (DF) generators**.

10. Load Line

For the purposes of this design and in accordance with bibliography: (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005), the load line of the examined vessel has been calculated.

For a start it is assumed that the examined vessel will have **forecastle** of **35m** in **length** and **5m** in **height** for the **natural gas compressors accommodation**.

L load line=max(0.96L1,L2)

L1=Water Line Length at 85% of (D+12mm) =163.18m

L2=Bow Line – Rudder Axis at 85% of (D+12mm) =154.88m

L load line =max(0.96L1,L2)=max(0.96*163.18,154.88)=
max(156.65,154.88)=**156.65m**

It is assumed that the examined vessel is of ***TYPE A*** regarding its load line classification as there are **no cargo holds openings** on the **main deck**.

In accordance with (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ, 2005), for **L load line =156.65m** the minimum **free board height** is **2073.74mm**.

1) Correction for Ships under 100m in Length:
   L=156.65m thus *NO-CORRECTION* **free board height** is **2073.74mm**.
2) Block Coefficient Correction:

   Cb=0.77

   $Cb_{0.85Df}$=Cb((0.85Df/T)^((Cwl/Cb0)-1)=
   =0.77*((0.85*(17.27+0.012)/6.68)^((0.903/0.77)-1))=0.882

Free Board Height New=Free Board Height Old*(
$Cb_{0.85Df}$+0.68)/1.36=2073.74*(0.882+0.68)/1.36=**2381.75mm**

3) Correction for Side Shell Height

Df=17.27+0.012=17.282m

L/15=156.65/15=10.44m

R=250

Free Board Height New= Free Board Height Old+(Df-L/15)*R=2381.75+(17.282-156.65/15)*250=**4091.42mm**

4) Correction for Superstructures

Super Structure Height=3.85m (First Level)

hs=2.30m (normal height)

Super Structure Length=30.9m (First Level)

Super Structure Breadth=23.8m (First Level)

Forecastle Exists

(B-b)/2=(29.58-23.8)/2=2.89m

0.04*B=1.183m -> The superstructure is considered as superstructure tower.

0.6*B=17.75m

E: the actual superstructure length

S: the theoretical superstructure length

It is underlined that the aft superstructure height is higher than the normal. So no correction takes place.

The forecastle (fore super structure) exists from star board half-breadth to the port half-breadth. The height (5m) is higher than the normal. So no correction takes place.

E=S(b/Bs)+Forecastle Length=30.9*(23.8/29.07)+35=**60.3m**

E/L=60.3/156.65=0.385-> 29.5%

Normal Free Board Rate Deduction=1070mm

Free Board Height New= Free Board Height Old-1070*0.295= 4091.42-1070*0.295=**3775.77mm**

5) Shear Correction:

It is assumed that there is **no shear**.

Normal Shear:

MNA=8.3375*(L/3+10)=8.3375*(156.65/3+10)=518.73mm

MNF=16.6750*(L/3+10)=16.6750*(156.65/3+10)=1037.46mm

MN=0.5*(MNF+ MNA)=0.5*(518.73+1037.46)=778.1mm

MN*(0.75-S/(2L))=778.1*(0.75-(30.9+35)/(2*156.65))=419.91mm

Where S is the theoretical superstructures length.

Free Board Height New Minimum Requested= Free Board Height Old+419.91=3775.77+419.91=**4195.68mm**

Minimum Requested Fore height =56*L*(1-L/500)*(1.36/($Cb_{0.85Df}$+0.68))=56*156.65*(1-156.65/500)*(1.36/(0.882+0.68))=**5245mm**

Actual Freeboard Height=17.27+0.012-6.68=**10.602m=10602mm**>4195.8mm

Actual Fore Height=17.27+0.012+5.0-6.68=**15.602m=15602mm**>5245mm

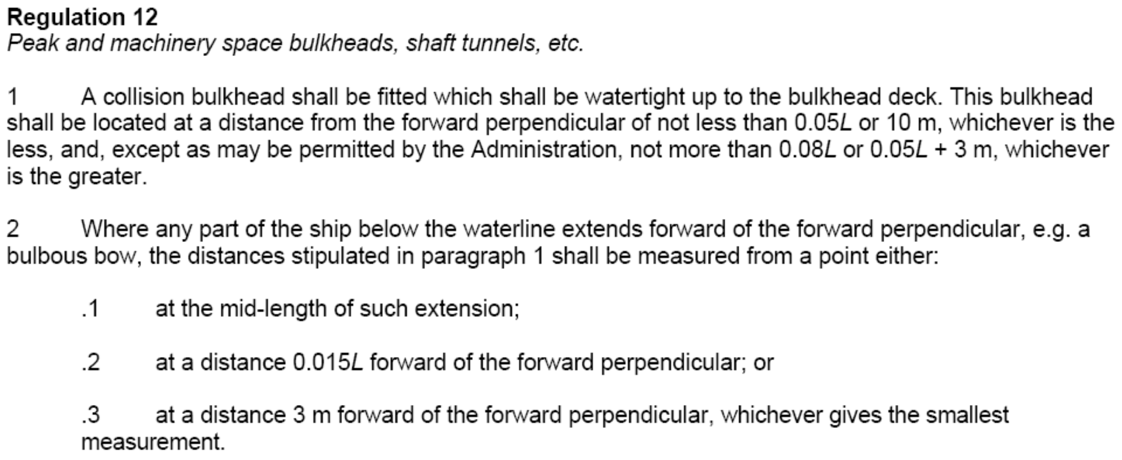
It is clear that the **Load Line Requirements** are **satisfied**.

Equation1. **Load Line Group of Equations.** (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)

11. Fore Collision Bulkhead

In accordance with SOLAS (SOLAS Consolidated Edition, 2012), the fore collision bulkhead distances are calculated in picture 25.

Load Line Length=**156.65m**



Regulation 12
Peak and machinery space bulkheads, shaft tunnels, etc.

1 A collision bulkhead shall be fitted which shall be watertight up to the bulkhead deck. This bulkhead shall be located at a distance from the forward perpendicular of not less than 0.05*L* or 10 m, whichever is the less, and, except as may be permitted by the Administration, not more than 0.08*L* or 0.05*L* + 3 m, whichever is the greater.

2 Where any part of the ship below the waterline extends forward of the forward perpendicular, e.g. a bulbous bow, the distances stipulated in paragraph 1 shall be measured from a point either:

.1 at the mid-length of such extension;

.2 at a distance 0.015*L* forward of the forward perpendicular; or

.3 at a distance 3 m forward of the forward perpendicular, whichever gives the smallest measurement.

Picture 25. **Fore Collision Bulkhead Calculation. Source: (SOLAS Consolidated Edition, 2012)**

Distance$>=\min(0.05L, 10)=\min(0.05*156.65,10)=\min(7.83,10)=$**7.83m**

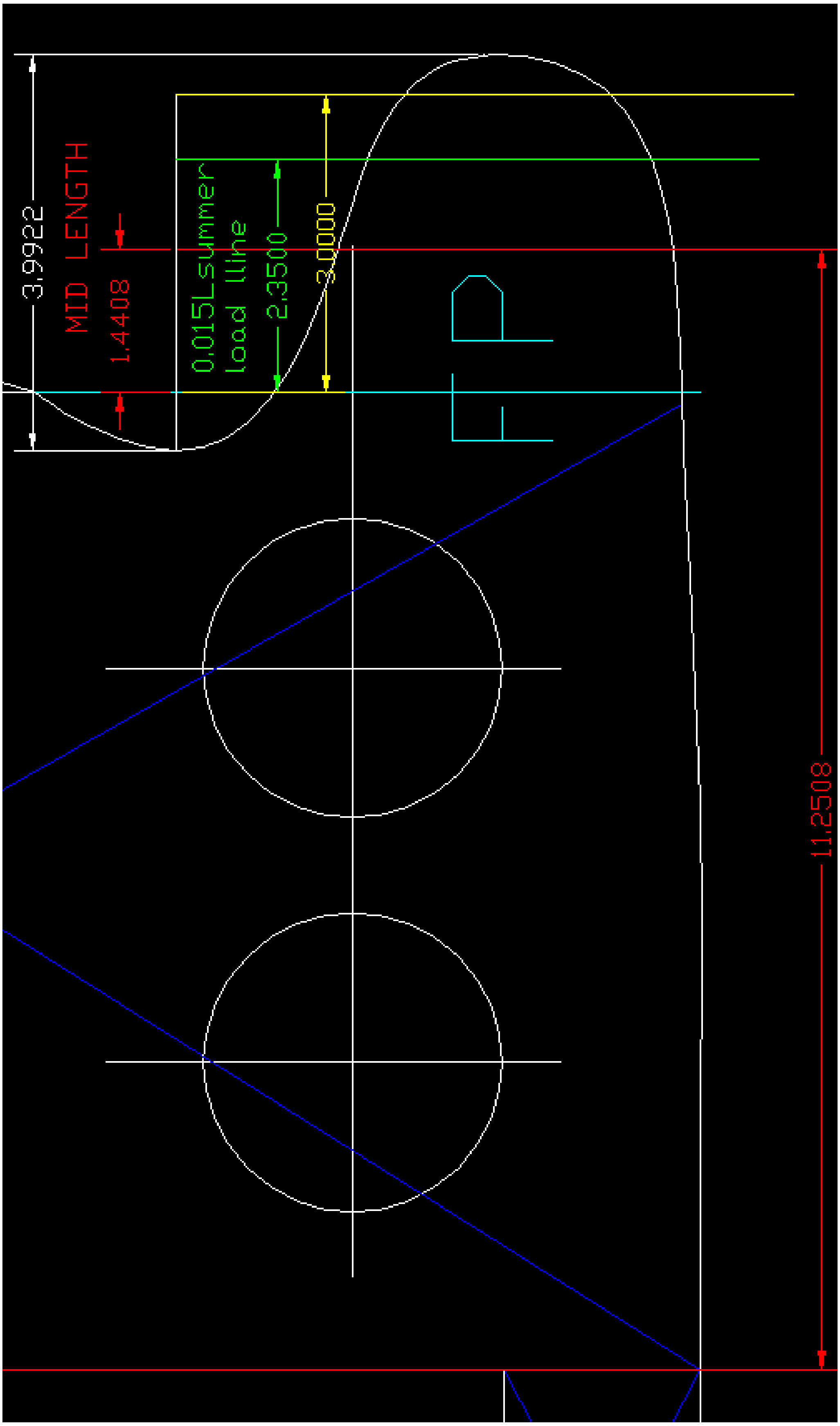
Distance$<=\max(0.08L, 0.05L+3)=\max(0.08*156.65,0.05*156.65+3)=$
$=\max(12.53,10.83)=$**12.53m**

The above distances because of the fact that there bulbous bow exists, must be measured from the minimum of the three following distances:

$\mathrm{Min}(\mathbf{1.44},0.015*L,3)=\min(1.44,0.015*156.65,3)=\min(1.44,2.35,3)=\mathbf{1.44}$.

The **Distance values** must be **measured** from the **mid of the bulb**.

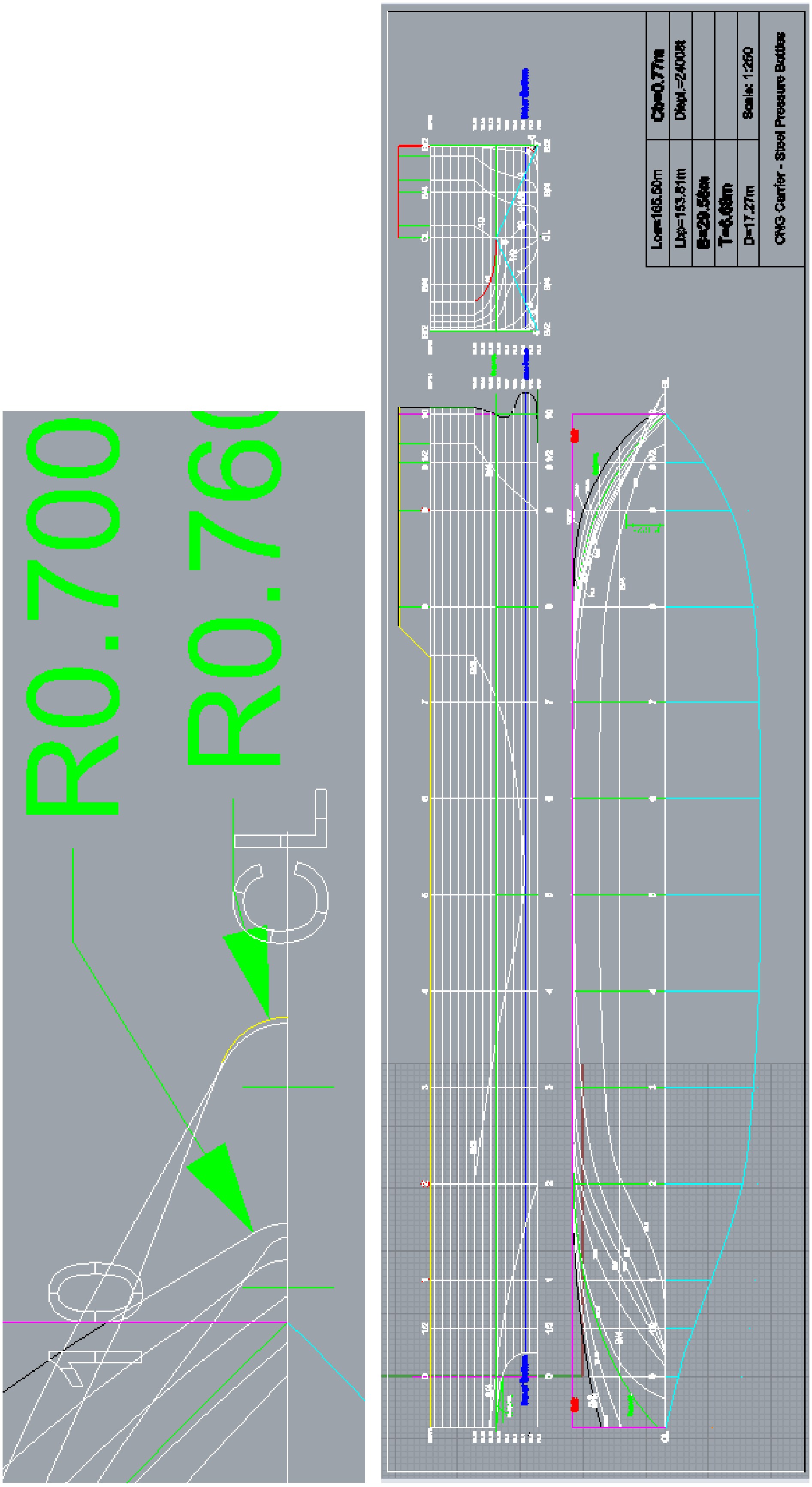
Equation2. **Fore Collision Bulkhead Group of Equations.** (SOLAS Consolidated Edition, 2012)



Picture 26. **Fore Collision Bulkhead Distances**. (AUTOCAD, 2017)

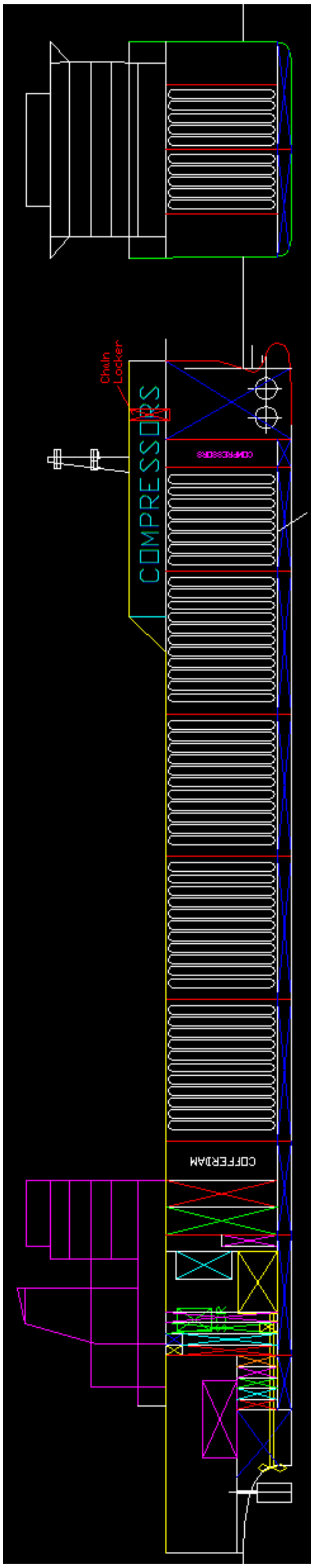
12. Lines Offset Calculation & Fairing

From the bibliographical reference (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005), **FORMDATA STANDARD SERIES** are used for the lines offsets. Rhinoceros (Rhinoceros, 2017) and Autocad (AUTOCAD, 2017) are used for the fairing. Picture 27 displays the faired lines.

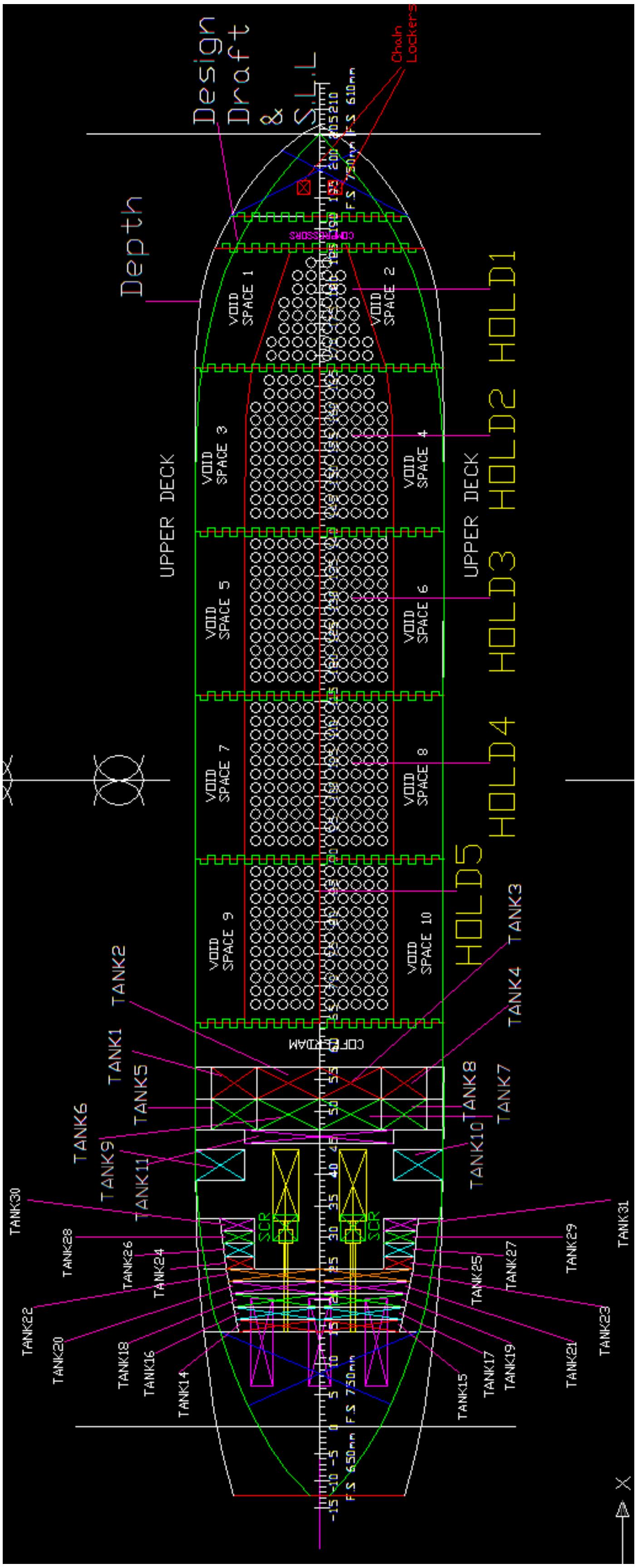


Picture 27. **Hull Faired Lines with Steel Pressure Bottles. Rhinoceros Design Program has been used. (Rhinoceros, 2017)**

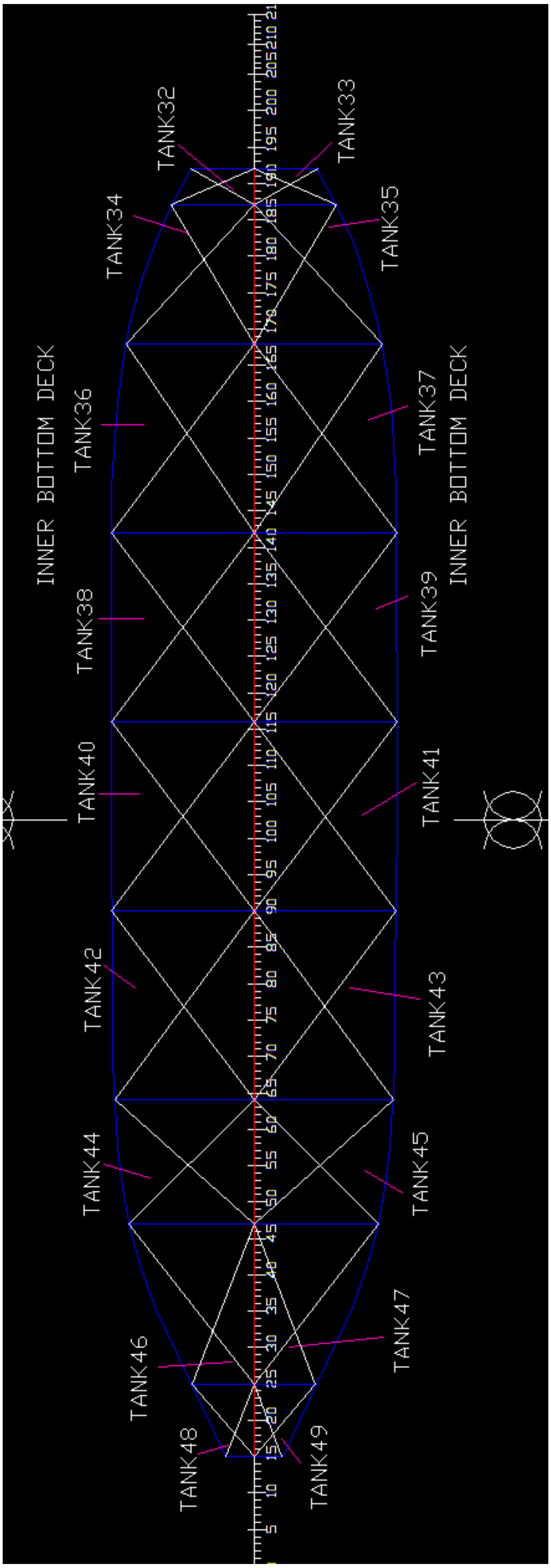
13. General Arrangement and Capacity Plan



Picture 28. **General Arrangement & Capacity Plan. Autocad Design Program has been used. (AUTOCAD, 2017)**



Picture 29. **General Arrangement & Capacity Plan (Upper Deck). Autocad Design Program has been used. (AUTOCAD, 2017)**



Picture 30. General Arrangement & Capacity Plan (Inner Deck). Autocad Design Program has been used. (AUTOCAD, 2017)

HEAVY FUEL OIL TANKS (HFO)					
TANK NAME	**l [m]**	**b [m]**	**IT [m4]**	**IL [m4]**	**γ[t/m3]**
TANK 1	3.75	5.41	49.48	23.77	0.97
TANK 2	3.75	7.41	127.15	32.56	0.97
TANK 3	3.75	7.41	127.15	32.56	0.97
TANK 4	3.75	5.41	49.48	23.77	0.97

DIESEL OIL TANKS (DO)					
TANK NAME	**l [m]**	**b [m]**	**IT [m4]**	**IL [m4]**	**γ[t/m3]**
TANK 5	3.75	5.41	49.48	23.77	0.86
TANK 6	3.75	7.41	127.15	32.56	0.86
TANK 7	3.75	7.41	127.15	32.56	0.86
TANK 8	3.75	5.41	49.48	23.77	0.86

FRESH WATER TANKS (FW)					
TANK NAME	**l [m]**	**b [m]**	**IT [m4]**	**IL [m4]**	**γ[t/m3]**
TANK 9	3.75	5.89	63.86	25.88	1
TANK 10	3.75	5.89	63.86	25.88	1

LUBE OIL TANKS (LO)					
TANK NAME	**l [m]**	**b [m]**	**IT [m4]**	**IL [m4]**	**γ[t/m3]**
TANK 11	1.5	17.78	702.60	5.00	0.9

WATER BALLAST TANKS (WB)					
TANK NAME	**l [m]**	**b [m]**	**IT [m4]**	**IL [m4]**	**γ[t/m3]**
TANK 12	10.87	13.09	2031.74	1401.03	1.025
TANK 13	19.55	21.9	17111.89	13636.51	1.025
TANK 32	3.75	7.41	127.15	32.56	1.025
TANK 33	3.75	7.41	127.15	32.56	1.025
TANK 34	14.25	11.14	1641.68	2686.26	1.025
TANK 35	14.25	11.14	1641.68	2686.26	1.025
TANK 36	19.5	14.24	4692.27	8798.99	1.025
TANK 37	19.5	14.24	4692.27	8798.99	1.025
TANK 38	19.5	14.74	5204.10	9107.94	1.025
TANK 39	19.5	14.74	5204.10	9107.94	1.025
TANK 40	19.5	14.74	5204.10	9107.94	1.025
TANK 41	19.5	14.74	5204.10	9107.94	1.025
TANK 42	19.5	14.6	5057.22	9021.43	1.025
TANK 43	19.5	14.6	5057.22	9021.43	1.025
TANK 44	12.75	13.78	2780.20	2380.12	1.025
TANK 45	12.75	13.78	2780.20	2380.12	1.025
TANK 46	16.5	10.14	1433.56	3795.85	1.025
TANK 47	16.5	10.14	1433.56	3795.85	1.025

TANK 48	7.5	4.68	64.06	164.53	1.025
TANK 49	7.5	4.68	64.06	164.53	1.025

Table 27. Heavy Fuel Oil, Diesel Oil, Lube Oil, Fresh Water and Water Ballast Tanks 1/2. (Hydromax), (Maxsurf)

TANKS	VOLUME [m3]	USE	LCGi [m]	TCG	VCGi [m]	MAX AVAILABLE VOLUME (98%)	MAX-MAX AVAILABLE VOLUME (98%*98%)
TANK1	303.99	HFO	40.88	-10.12	9.63	297.91	291.95
TANK2	416.37	HFO	40.88	-3.71	9.63	408.05	399.88
TANK3	416.37	HFO	40.88	3.71	9.63	408.05	399.88
TANK4	303.99	HFO	40.88	10.12	9.63	297.91	291.95
TANK5	303.95	MDO	37.13	-10.12	9.63	297.87	291.91
TANK6	416.37	MDO	37.13	-3.71	9.63	408.05	399.88
TANK7	416.37	MDO	37.13	3.71	9.63	408.05	399.88
TANK8	303.95	MDO	37.13	10.12	9.63	297.87	291.91
TANK9	164.54	FW	31.13	-11.82	11.97	161.25	-
TANK10	164.54	FW	31.13	11.82	11.97	161.25	-
TANK11	199.81	LO	34.50	0.00	5.80	195.82	191.90
TANK12	1740.40	WB	147.74	0.00	9.83	1705.59	-
TANK13	699.88	WB	5.06	0.00	5.98	685.88	-
TANK14	57.48	L.O DRAINT	12.01	-3.97	5.31	56.33	55.20
TANK15	57.48	L.O DRAINT	12.01	3.97	5.31	56.33	55.20
TANK16	62.35	M.D.O. DRAINT	13.51	-4.16	5.23	61.10	59.88
TANK17	62.35	M.D.O. DRAINT	13.51	4.16	5.23	61.10	59.88
TANK18	66.84	H.F.O. DRAINT	15.01	-4.36	5.16	65.50	64.19
TANK19	66.84	H.F.O. DRAINT	15.01	4.36	5.16	65.50	64.19
TANK20	71.17	B.H.T. DRAINT	16.51	-4.59	5.12	69.75	68.35
TANK21	71.17	B.H.T. DRAINT	16.51	4.59	5.12	69.75	68.35
TANK22	75.55	HYD. O. STOR.	18.01	-4.84	5.08	74.04	72.56
TANK23	75.55	HYD. O. STOR.	18.01	4.84	5.08	74.04	72.56
TANK24	57.50	OILY BILGE	19.51	-9.40	9.47	56.35	55.22
TANK25	57.50	OILY BILGE	19.51	9.40	9.47	56.35	55.22
TANK26	62.12	SEWAGE	21.01	-9.48	9.28	60.88	59.66
TANK27	62.12	SEWAGE	21.01	9.48	9.28	60.88	59.66

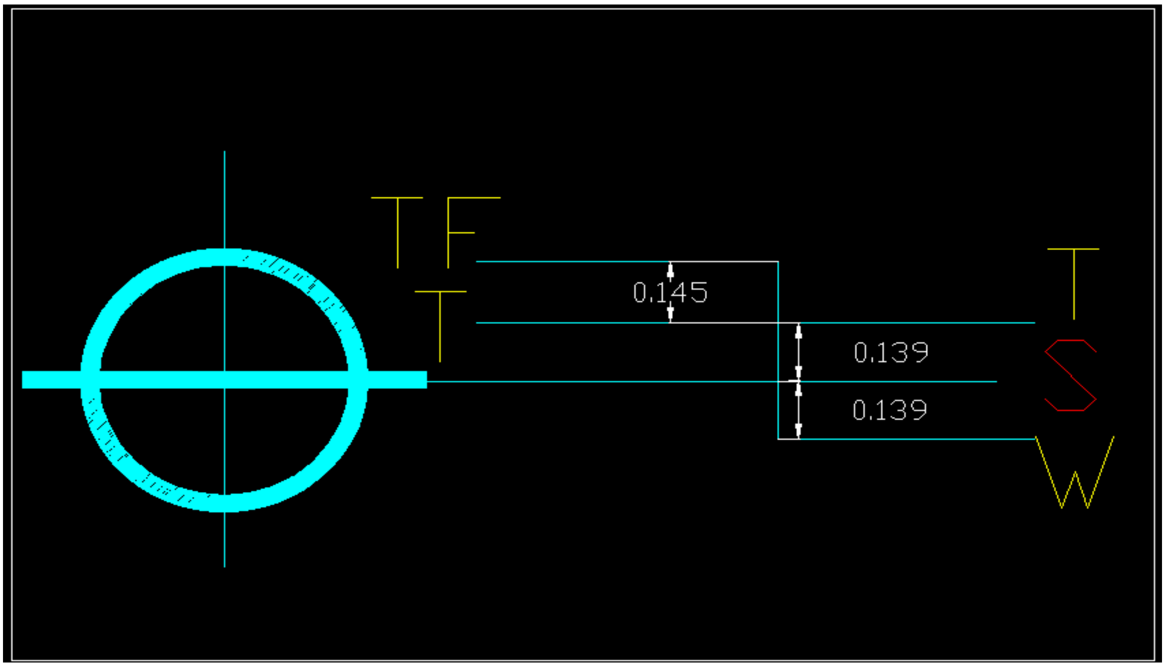
TANK28	79.61	SLUDGE	22.50	-9.56	10.23	78.02	76.46
TANK29	79.61	SLUDGE	22.50	9.56	10.23	78.02	76.46
TANK30	84.67	GRAY WATER	24.00	-9.63	10.05	82.98	81.32
TANK31	84.67	GRAY WATER	24.00	9.63	10.05	82.98	81.32
TANK 32	45.82	WB	142.04	-3.25	1.08	44.90	-
TANK 33	45.82	WB	142.04	3.25	1.08	44.90	-
TANK 34	259.15	WB	132.66	-4.83	1.06	253.97	-
TANK 35	259.15	WB	132.66	4.83	1.06	253.97	-
TANK 36	477.08	WB	116.02	-6.39	1.05	467.54	-
TANK 37	477.08	WB	116.02	6.39	1.05	467.54	-
TANK 38	504.35	WB	96.74	-6.73	1.04	494.26	-
TANK 39	504.35	WB	96.74	6.73	1.04	494.26	-
TANK 40	498.99	WB	77.30	-6.68	1.05	489.01	-
TANK 41	498.99	WB	77.30	6.68	1.05	489.01	-
TANK 42	468.97	WB	57.87	-6.35	1.08	459.59	-
TANK 43	468.97	WB	57.87	6.35	1.08	459.59	-
TANK 44	276.94	WB	41.81	-5.74	1.08	271.40	-
TANK 45	276.94	WB	41.81	5.74	1.08	271.40	-
TANK 46	218.05	WB	28.66	-4.21	1.16	213.69	-
TANK 47	218.05	WB	28.66	4.21	1.16	213.69	-
TANK 48	37.22	WB	15.47	-1.77	1.31	36.47	-
TANK 49	37.22	WB	15.47	1.77	1.31	36.47	-
TANK 50	12.07	H.F.O. OVER	19.50	-9.45	16.14	11.83	11.59
TANK 51	12.07	H.F.O. OVER	19.50	9.45	16.14	11.83	11.59
TANK 52	12.62	M.D.O OVER	21.00	-9.53	16.14	12.36	12.12
TANK 53	12.62	M.D.O OVER	21.00	9.53	16.14	12.36	12.12

Table 30. **Heavy Fuel Oil, Diesel Oil, Lube Oil, Fresh Water and Water Ballast Tanks 2/2. (Hydromax), (Maxsurf)**

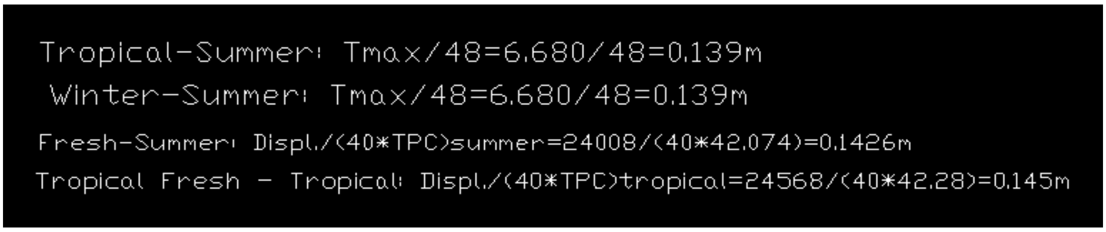
TANKS	VOLUME (98%) [m3]	USE	LOCATION
TANK1	297.9	HFO	52-57
TANK2	408.0	HFO	52-57
TANK3	408.0	HFO	52-57
TANK4	297.9	HFO	52-57
TANK5	297.9	MDO	47-52
TANK6	408.0	MDO	47-52
TANK7	408.0	MDO	47-52
TANK8	297.9	MDO	47-52
TANK9	161.3	FW	39-44
TANK10	161.3	FW	39-44
TANK11	195.8	LO	45-47
TANK12	1705.6	WB	192-bow line
TANK13	685.9	WB	stern line -15
TANK14	56.3	L.O DRAINT	15-17
TANK15	56.3	L.O DRAINT	15-17
TANK16	61.1	M.D.O. DRAINT	17-19
TANK17	61.1	M.D.O. DRAINT	17-19
TANK18	65.5	H.F.O. DRAINT	19-21
TANK19	65.5	H.F.O. DRAINT	19-21
TANK20	69.7	B.H.T. DRAINT	21-23
TANK21	69.7	B.H.T. DRAINT	21-23
TANK22	74.0	HYD. O. STOR.	23-25
TANK23	74.0	HYD. O. STOR.	23-25
TANK24	56.3	OILY BILGE	25-27
TANK25	56.3	OILY BILGE	25-27
TANK26	60.9	SEWAGE	27-29
TANK27	60.9	SEWAGE	27-29
TANK28	78.0	SLUDGE	29-31
TANK29	78.0	SLUDGE	29-31
TANK30	83.0	GRAY WATER	31-33
TANK31	83.0	GRAY WATER	31-33
TANK 32	44.9	WB	187-192

TANK 33	44.9	WB	187-192
TANK 34	254.0	WB	168-187
TANK 35	254.0	WB	168-187
TANK 36	467.5	WB	142-168
TANK 37	467.5	WB	142-168
TANK 38	494.3	WB	116-142
TANK 39	494.3	WB	116-142
TANK 40	489.0	WB	90-116
TANK 41	489.0	WB	90-116
TANK 42	459.6	WB	64-90
TANK 43	459.6	WB	64-90
TANK 44	271.4	WB	47-64
TANK 45	271.4	WB	47-64
TANK 46	213.7	WB	25-47
TANK 47	213.7	WB	25-47
TANK 48	36.5	WB	15-25
TANK 49	36.5	WB	15-25
TANK 50	11.8	H.F.O. OVER	25-27
TANK 51	11.8	H.F.O. OVER	25-27
TANK 52	12.4	M.D.O OVER	27-29
TANK 53	12.4	M.D.O OVER	27-29

Table 31. **Heavy Fuel Oil, Diesel Oil, Lube Oil, Fresh Water, Water Ballast and Dirty Water Tanks. (Hydromax), (Maxsurf)**

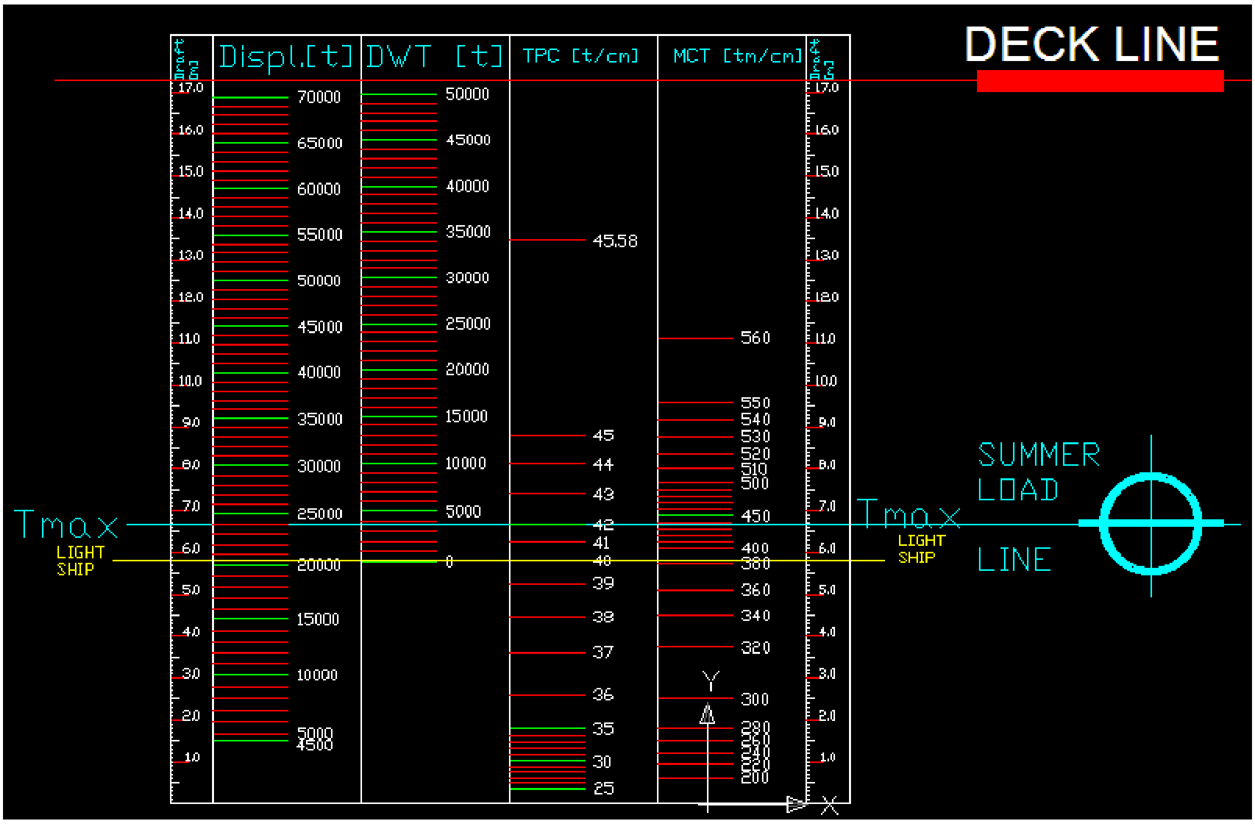


Picture 31. **Load Line. Autocad Design Program has been used. (AUTOCAD, 2017)**



Tropical-Summer: Tmax/48=6.680/48=0.139m
Winter-Summer: Tmax/48=6.680/48=0.139m
Fresh-Summer: Displ./(40*TPC)summer=24008/(40*42.074)=0.1426m
Tropical Fresh - Tropical: Displ./(40*TPC)tropical=24568/(40*42.28)=0.145m

Picture 32. Load Line Draughts. Autocad Design Program has been used. (AUTOCAD, 2017)

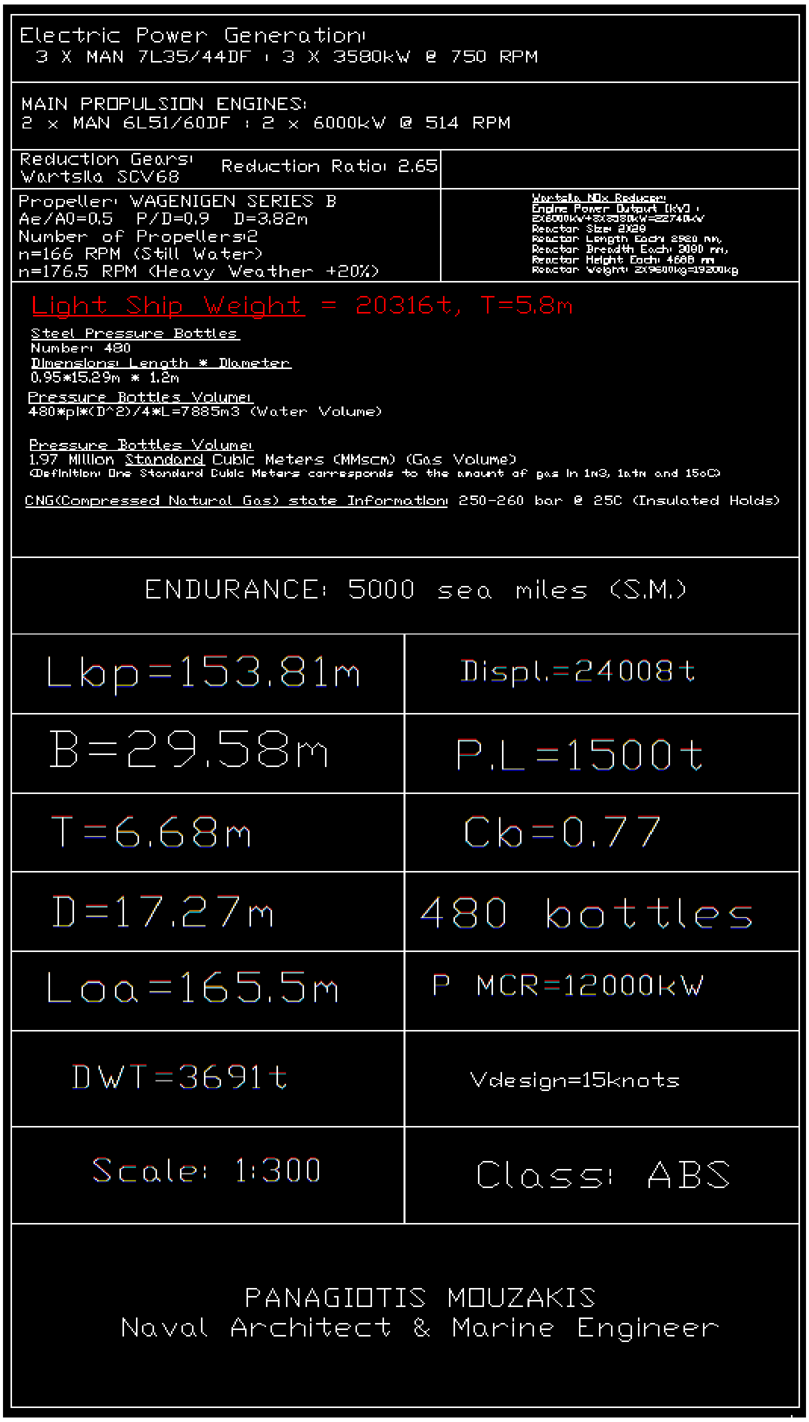


Picture 33. DWT Scale. Autocad Design Program has been used. (AUTOCAD, 2017)

The DWT Scale of picture 33 has been calculated by making hydrostatical analysis. However, the last analysis will be presented in detail in chapter 14. (AUTOCAD, 2017)

It must be underlined that up to this design stage, the **Heavy Fuel Oil & Marine Diesel/Gas Oil** are **not separated** into **service**, **settling** and **storage** tanks. This happens because at **Full Load Departure** & **Water Ballast Arrival Conditions** are **not clear how they are loaded** so the **(not corrected & corrected) KG (Vertical Center of Gravity)** varies. So, it is **more preferable** the space **to be divided into 4 tanks** for **each fuel** where **the free surface will be bigger** thus the design is **on the safe side of the problem**. Later on (on an upcoming stage / **future design**), the designers will create the requested tanks. Furthermore, there is space for all kind of tanks **(each of these four tanks is loaded ~ 80% at Full Load Departure)**. For the **endurance of**

5000 sm (at Pmax(P propulsion installed)) the **fuel capacity margin** of **30%** has **not** been taken into **consideration**. (In fact, **the endurance of the vessel is 30% higher**). For **tank 11(lube oil)** being, it is **not separated** at this stage into a **number of different tanks (main engine lube oil, D/G lube oil, compressors lube oil)** and the **requested distances between them**. On an <u>upcoming stage</u> according to a more detailed estimation, the requested tanks will be created for each engine/machine **(future analysis)**.



Electric Power Generation:
3 X MAN 7L35/44DF : 3 X 3580kW @ 750 RPM

MAIN PROPULSION ENGINES:
2 x MAN 6L51/60DF : 2 x 6000kW @ 514 RPM

Reduction Gears:
Wartsila SCV68
Reduction Ratio: 2.65

Propeller: WAGENIGEN SERIES B
Ae/A0=0.5 P/D=0.9 D=3.82m
Number of Propellers:2
n=166 RPM (Still Water)
n=176.5 RPM (Heavy Weather +20%)

Wartsila NOx Reducer:
Engine Power Output [kW] :
2X6000kW+3X3580kW=22740kW
Reactor Size: 2X20
Reactor Length Each: 2520 mm,
Reactor Breadth Each: 2080 mm,
Reactor Height Each: 4608 mm
Reactor Weight: 2X9600kg=19200kg

Light Ship Weight = 20316t, T=5.8m

Steel Pressure Bottles
Number: 480
Dimensions: Length * Diameter
0.95*15.29m * 1.2m
Pressure Bottles Volume:
480*pi*(D^2)/4*L=7885m3 (Water Volume)

Pressure Bottles Volume:
1.97 Million Standard Cubic Meters (MMscm) (Gas Volume)
(Definition: One Standard Cubic Meters corresponds to the amount of gas in 1m3, 1atm and 15oC)

CNG(Compressed Natural Gas) state Information: 250-260 bar @ 25C (Insulated Holds)

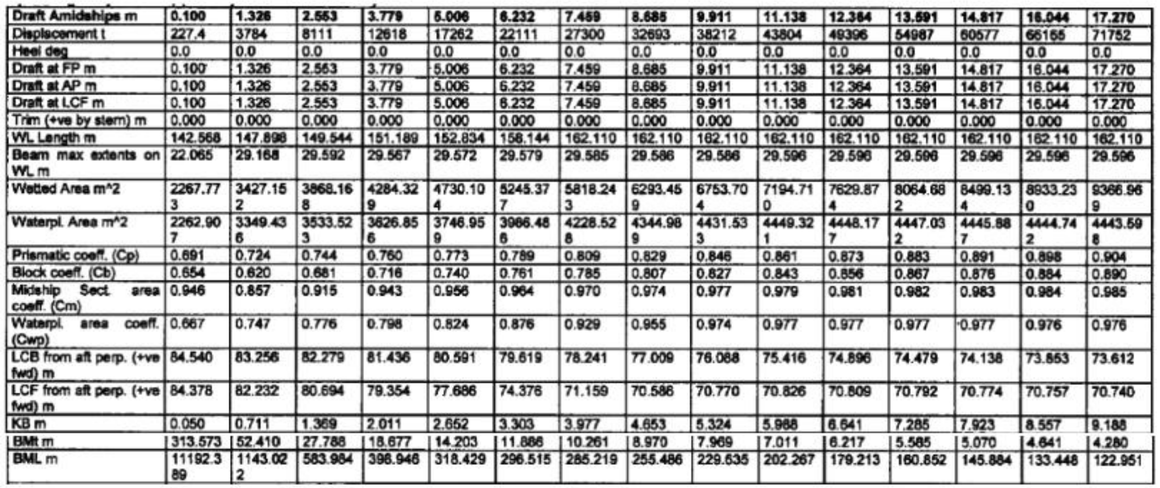
ENDURANCE: 5000 sea miles (S.M.)

Lbp=153.81m	Displ.=24008t
B=29.58m	P.L=1500t
T=6.68m	Cb=0.77
D=17.27m	480 bottles
Loa=165.5m	P MCR=12000kW
DWT=3691t	Vdesign=15knots
Scale: 1:300	Class: ABS

PANAGIOTIS MOUZAKIS
Naval Architect & Marine Engineer

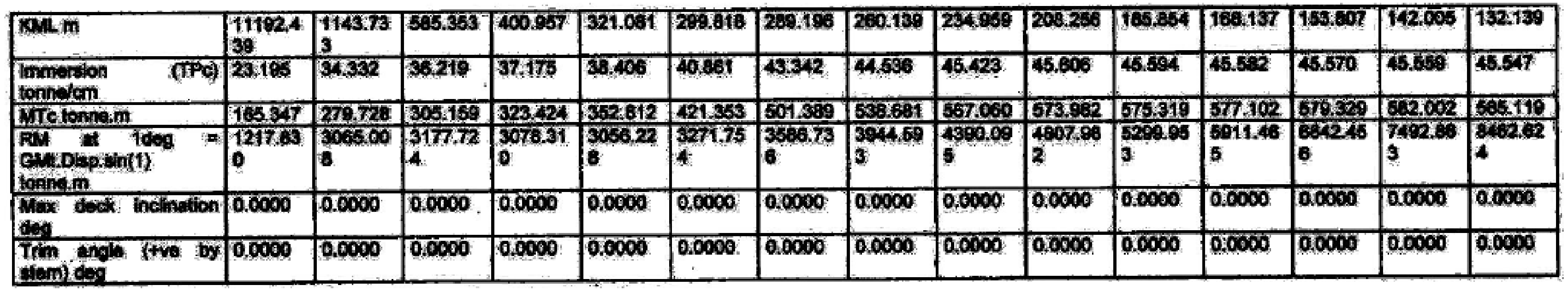
Picture 34. General Arrangement & Capacity Plan Main Dimensions and Basic Characteristics. Autocad Design Program has been used (AUTOCAD, 2017).

14. Hydrostatics



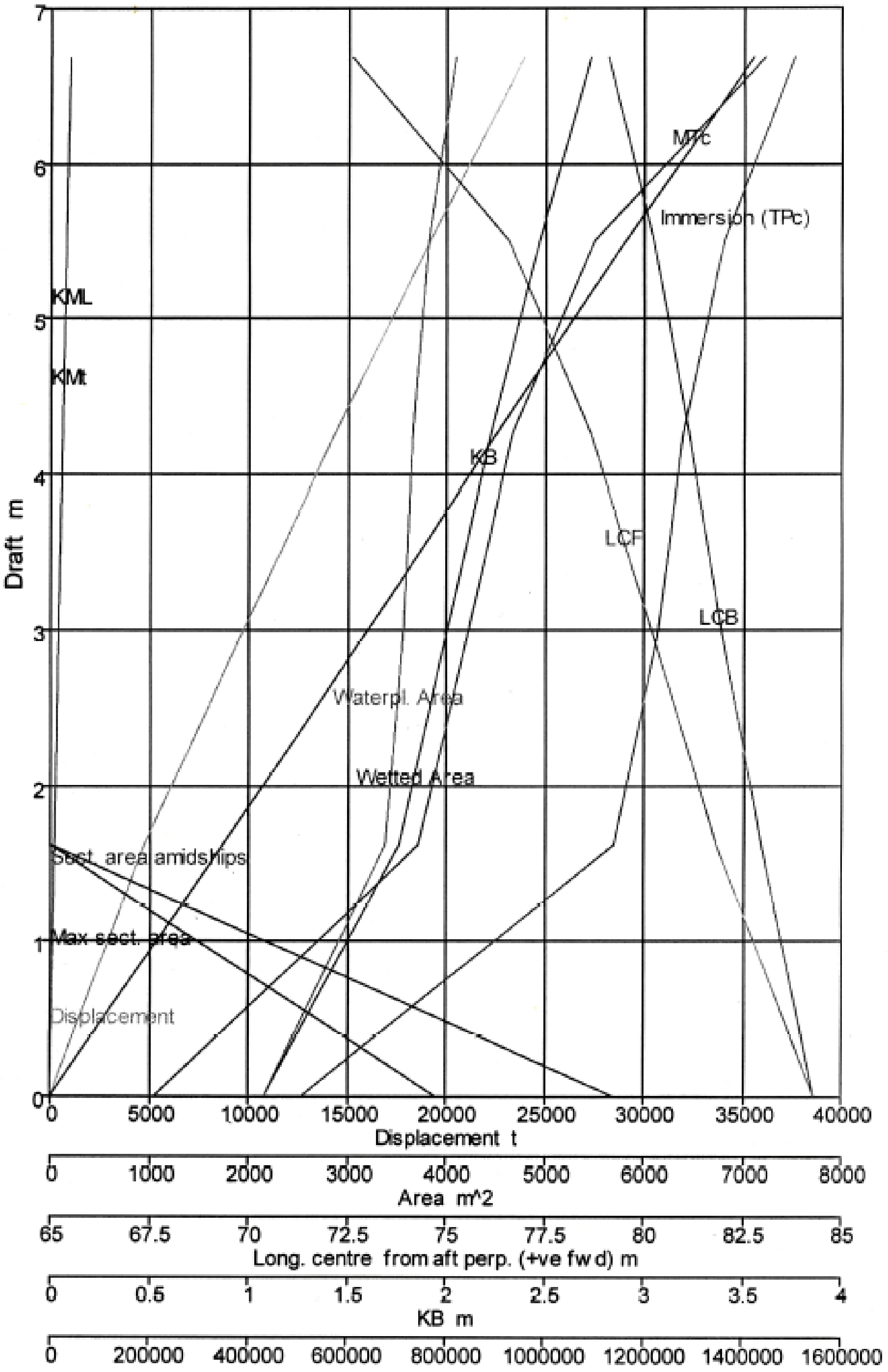
Draft Amidships m	0.100	1.326	2.553	3.779	5.006	6.232	7.459	8.685	9.911	11.138	12.364	13.591	14.817	16.044	17.270
Displacement t	227.4	3784	8111	12618	17262	22111	27300	32693	38212	43804	49396	54987	60577	66165	71752
Heel deg	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Draft at FP m	0.100	1.326	2.553	3.779	5.006	6.232	7.459	8.685	9.911	11.138	12.364	13.591	14.817	16.044	17.270
Draft at AP m	0.100	1.326	2.553	3.779	5.006	6.232	7.459	8.685	9.911	11.138	12.364	13.591	14.817	16.044	17.270
Draft at LCF m	0.100	1.326	2.553	3.779	5.006	6.232	7.459	8.685	9.911	11.138	12.364	13.591	14.817	16.044	17.270
Trim (+ve by stern) m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WL Length m	142.568	147.898	149.544	151.189	152.834	158.144	162.110	162.110	162.110	162.110	162.110	162.110	162.110	162.110	162.110
Beam max extents on WL m	22.065	29.168	29.592	29.567	29.572	29.579	29.585	29.586	29.586	29.596	29.596	29.596	29.596	29.596	29.596
Wetted Area m^2	2267.773	3427.152	3868.168	4284.329	4730.104	5245.377	5818.243	6293.459	6753.704	7194.710	7629.874	8064.682	8499.134	8933.230	9366.969
Waterpl. Area m^2	2262.907	3349.436	3533.523	3626.856	3746.959	3986.486	4228.528	4344.989	4431.533	4449.321	4448.177	4447.032	4445.887	4444.742	4443.598
Prismatic coeff. (Cp)	0.691	0.724	0.744	0.760	0.773	0.789	0.809	0.829	0.846	0.861	0.873	0.883	0.891	0.898	0.904
Block coeff. (Cb)	0.654	0.620	0.681	0.716	0.740	0.761	0.785	0.807	0.827	0.843	0.856	0.867	0.876	0.884	0.890
Midship Sect. area coeff. (Cm)	0.946	0.857	0.915	0.943	0.956	0.964	0.970	0.974	0.977	0.979	0.981	0.982	0.983	0.984	0.985
Waterpl. area coeff. (Cwp)	0.667	0.747	0.776	0.798	0.824	0.876	0.929	0.955	0.974	0.977	0.977	0.977	0.977	0.976	0.976
LCB from aft perp. (+ve fwd) m	84.540	83.256	82.279	81.436	80.591	79.619	78.241	77.009	76.088	75.416	74.896	74.479	74.138	73.853	73.612
LCF from aft perp. (+ve fwd) m	84.378	82.232	80.694	79.354	77.686	74.376	71.159	70.586	70.770	70.826	70.809	70.792	70.774	70.757	70.740
KB m	0.050	0.711	1.369	2.011	2.652	3.303	3.977	4.653	5.324	5.988	6.641	7.285	7.923	8.557	9.188
BMt m	313.573	52.410	27.788	18.677	14.203	11.886	10.261	8.970	7.969	7.011	6.217	5.585	5.070	4.641	4.280
BML m	11192.389	1143.022	583.984	398.946	318.429	296.515	285.219	255.486	229.635	202.267	179.213	160.852	145.884	133.448	122.951

Table 32. Hydrostatics Properties Table 1/2 – (Hydromax), (Maxsurf)

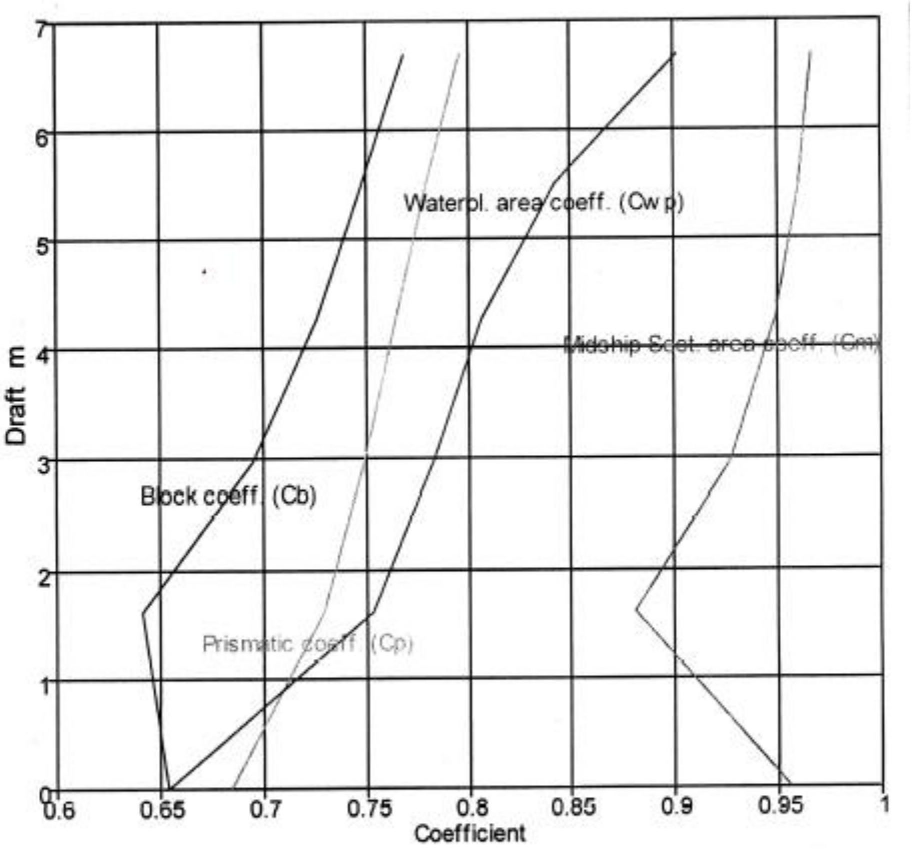


KML m	11192.439	1143.733	585.353	400.957	321.061	299.818	289.196	260.139	234.959	208.256	185.854	168.137	153.807	142.005	132.139
Immersion (TPc) tonne/cm	23.195	34.332	36.219	37.175	38.406	40.861	43.342	44.536	45.423	45.606	45.594	45.582	45.570	45.558	45.547
MTc tonne.m	165.347	279.728	305.159	323.424	352.812	421.353	501.389	536.681	567.060	573.982	575.319	577.102	579.329	582.002	585.119
RM at 1deg = GMt.Disp.sin(1) tonne.m	1217.830	3065.008	3177.724	3078.310	3056.228	3271.754	3586.736	3944.593	4390.095	4807.982	5299.953	5911.465	6642.456	7492.863	8462.624
Max deck inclination deg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Trim angle (+ve by stern) deg	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

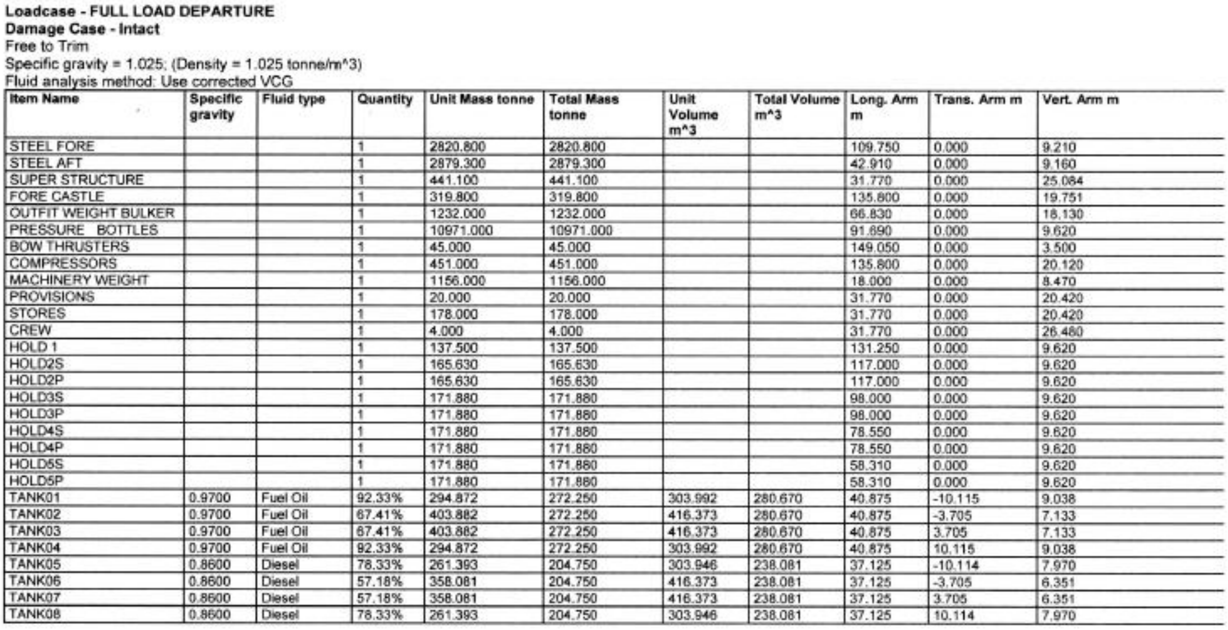
Table 33. Hydrostatics Properties Table 2/2 – (Hydromax), (Maxsurf)



Picture 35. Hydrostatics Properties Graph - 1/2 - (Hydromax), (Maxsurf)



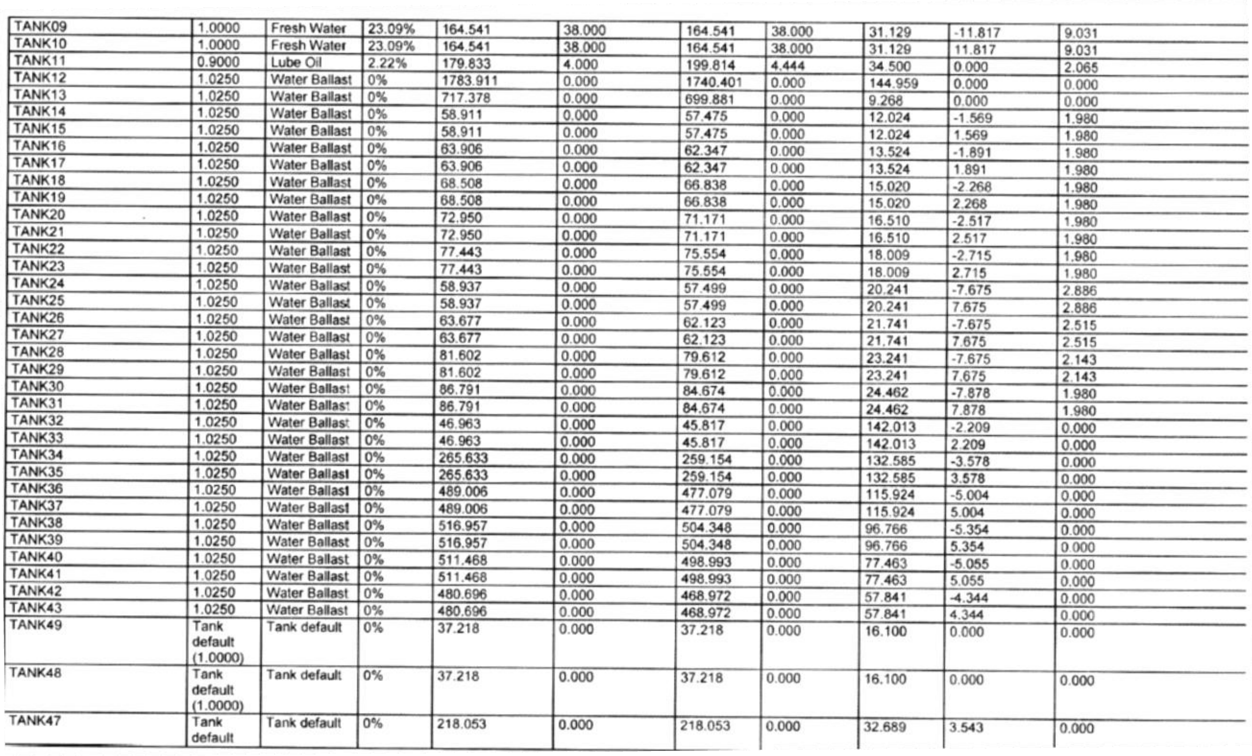
Picture 36. **Hydrostatics Properties Graph 2/2 –** (Hydromax), (Maxsurf)



Loadcase - FULL LOAD DEPARTURE
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

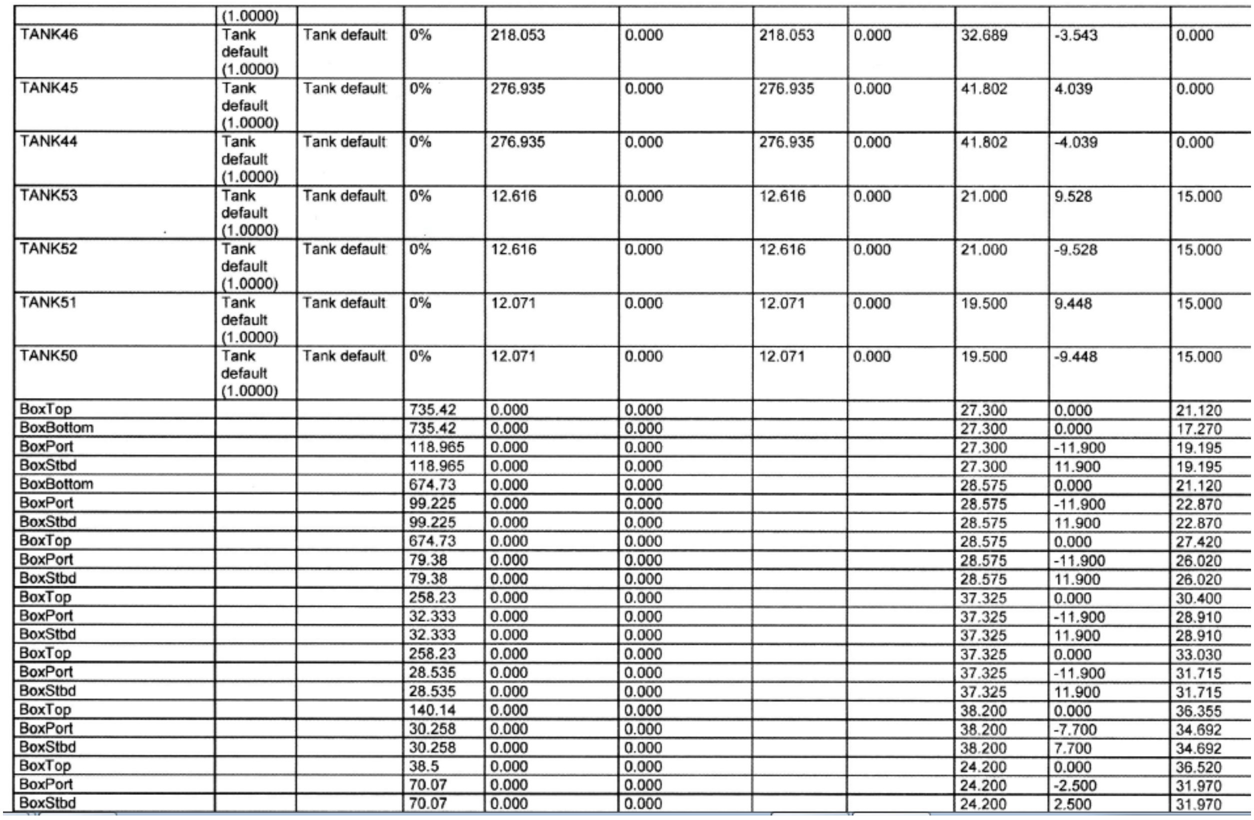
Item Name	Specific gravity	Fluid type	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m
STEEL FORE			1	2820.800	2820.800			109.750	0.000	9.210
STEEL AFT			1	2879.300	2879.300			42.910	0.000	9.160
SUPER STRUCTURE			1	441.100	441.100			31.770	0.000	25.084
FORE CASTLE			1	319.800	319.800			135.800	0.000	19.751
OUTFIT WEIGHT BULKER			1	1232.000	1232.000			66.830	0.000	18.130
PRESSURE BOTTLES			1	10971.000	10971.000			91.690	0.000	9.620
BOW THRUSTERS			1	45.000	45.000			149.050	0.000	3.500
COMPRESSORS			1	451.000	451.000			135.800	0.000	20.120
MACHINERY WEIGHT			1	1156.000	1156.000			18.000	0.000	8.470
PROVISIONS			1	20.000	20.000			31.770	0.000	20.420
STORES			1	178.000	178.000			31.770	0.000	20.420
CREW			1	4.000	4.000			31.770	0.000	26.480
HOLD 1			1	137.500	137.500			131.250	0.000	9.620
HOLD2S			1	165.630	165.630			117.000	0.000	9.620
HOLD2P			1	165.630	165.630			117.000	0.000	9.620
HOLD3S			1	171.880	171.880			98.000	0.000	9.620
HOLD3P			1	171.880	171.880			98.000	0.000	9.620
HOLD4S			1	171.880	171.880			78.550	0.000	9.620
HOLD4P			1	171.880	171.880			78.550	0.000	9.620
HOLD5S			1	171.880	171.880			58.310	0.000	9.620
HOLD5P			1	171.880	171.880			58.310	0.000	9.620
TANK01	0.9700	Fuel Oil	92.33%	294.872	272.250	303.992	280.670	40.875	-10.115	9.038
TANK02	0.9700	Fuel Oil	67.41%	403.882	272.250	416.373	280.670	40.875	-3.705	7.133
TANK03	0.9700	Fuel Oil	67.41%	403.882	272.250	416.373	280.670	40.875	3.705	7.133
TANK04	0.9700	Fuel Oil	92.33%	294.872	272.250	303.992	280.670	40.875	10.115	9.038
TANK05	0.8600	Diesel	78.33%	261.393	204.750	303.946	238.081	37.125	-10.114	7.970
TANK06	0.8600	Diesel	57.18%	358.081	204.750	416.373	238.081	37.125	-3.705	6.351
TANK07	0.8600	Diesel	57.18%	358.081	204.750	416.373	238.081	37.125	3.705	6.351
TANK08	0.8600	Diesel	78.33%	261.393	204.750	303.946	238.081	37.125	10.114	7.970

Table 34. **Full Load Departure Equilibrium 1/3 – (Hydromax), (Maxsurf)**

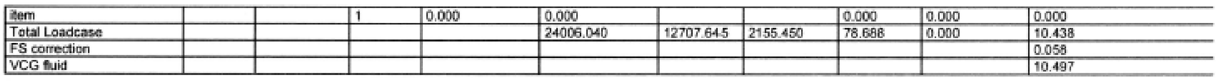


TANK09	1.0000	Fresh Water	23.09%	164.541	38.000	164.541	38.000	31.129	-11.817	9.031
TANK10	1.0000	Fresh Water	23.09%	164.541	38.000	164.541	38.000	31.129	11.817	9.031
TANK11	0.9000	Lube Oil	2.22%	179.833	4.000	199.814	4.444	34.500	0.000	2.065
TANK12	1.0250	Water Ballast	0%	1783.911	0.000	1740.401	0.000	144.959	0.000	0.000
TANK13	1.0250	Water Ballast	0%	717.378	0.000	699.881	0.000	9.268	0.000	0.000
TANK14	1.0250	Water Ballast	0%	58.911	0.000	57.475	0.000	12.024	-1.569	1.980
TANK15	1.0250	Water Ballast	0%	58.911	0.000	57.475	0.000	12.024	1.569	1.980
TANK16	1.0250	Water Ballast	0%	63.906	0.000	62.347	0.000	13.524	-1.891	1.980
TANK17	1.0250	Water Ballast	0%	63.906	0.000	62.347	0.000	13.524	1.891	1.980
TANK18	1.0250	Water Ballast	0%	68.508	0.000	66.838	0.000	15.020	-2.268	1.980
TANK19	1.0250	Water Ballast	0%	68.508	0.000	66.838	0.000	15.020	2.268	1.980
TANK20	1.0250	Water Ballast	0%	72.950	0.000	71.171	0.000	16.510	-2.517	1.980
TANK21	1.0250	Water Ballast	0%	72.950	0.000	71.171	0.000	16.510	2.517	1.980
TANK22	1.0250	Water Ballast	0%	77.443	0.000	75.554	0.000	18.009	-2.715	1.980
TANK23	1.0250	Water Ballast	0%	77.443	0.000	75.554	0.000	18.009	2.715	1.980
TANK24	1.0250	Water Ballast	0%	58.937	0.000	57.499	0.000	20.241	-7.675	2.886
TANK25	1.0250	Water Ballast	0%	58.937	0.000	57.499	0.000	20.241	7.675	2.886
TANK26	1.0250	Water Ballast	0%	63.677	0.000	62.123	0.000	21.741	-7.675	2.515
TANK27	1.0250	Water Ballast	0%	63.677	0.000	62.123	0.000	21.741	7.675	2.515
TANK28	1.0250	Water Ballast	0%	81.602	0.000	79.612	0.000	23.241	-7.675	2.143
TANK29	1.0250	Water Ballast	0%	81.602	0.000	79.612	0.000	23.241	7.675	2.143
TANK30	1.0250	Water Ballast	0%	86.791	0.000	84.674	0.000	24.462	-7.878	1.980
TANK31	1.0250	Water Ballast	0%	86.791	0.000	84.674	0.000	24.462	7.878	1.980
TANK32	1.0250	Water Ballast	0%	46.963	0.000	45.817	0.000	142.013	-2.209	0.000
TANK33	1.0250	Water Ballast	0%	46.963	0.000	45.817	0.000	142.013	2.209	0.000
TANK34	1.0250	Water Ballast	0%	265.633	0.000	259.154	0.000	132.585	-3.578	0.000
TANK35	1.0250	Water Ballast	0%	265.633	0.000	259.154	0.000	132.585	3.578	0.000
TANK36	1.0250	Water Ballast	0%	489.006	0.000	477.079	0.000	115.924	-5.004	0.000
TANK37	1.0250	Water Ballast	0%	489.006	0.000	477.079	0.000	115.924	5.004	0.000
TANK38	1.0250	Water Ballast	0%	516.957	0.000	504.348	0.000	96.766	-5.354	0.000
TANK39	1.0250	Water Ballast	0%	516.957	0.000	504.348	0.000	96.766	5.354	0.000
TANK40	1.0250	Water Ballast	0%	511.468	0.000	498.993	0.000	77.463	-5.055	0.000
TANK41	1.0250	Water Ballast	0%	511.468	0.000	498.993	0.000	77.463	5.055	0.000
TANK42	1.0250	Water Ballast	0%	480.696	0.000	468.972	0.000	57.841	-4.344	0.000
TANK43	1.0250	Water Ballast	0%	480.696	0.000	468.972	0.000	57.841	4.344	0.000
TANK49	Tank default (1.0000)	Tank default	0%	37.218	0.000	37.218	0.000	16.100	0.000	0.000
TANK48	Tank default (1.0000)	Tank default	0%	37.218	0.000	37.218	0.000	16.100	0.000	0.000
TANK47	Tank default	Tank default	0%	218.053	0.000	218.053	0.000	32.689	3.543	0.000

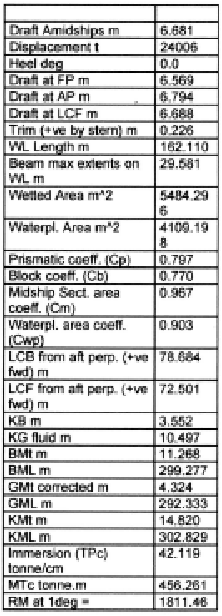
Table 35. **Full Load Departure Equilibrium 2/3 – (Hydromax), (Maxsurf)**



	(1.0000)									
TANK46	Tank default (1.0000)	Tank default	0%	218.053	0.000	218.053	0.000	32.689	-3.543	0.000
TANK45	Tank default (1.0000)	Tank default	0%	276.935	0.000	276.935	0.000	41.802	4.039	0.000
TANK44	Tank default (1.0000)	Tank default	0%	276.935	0.000	276.935	0.000	41.802	-4.039	0.000
TANK53	Tank default (1.0000)	Tank default	0%	12.616	0.000	12.616	0.000	21.000	9.528	15.000
TANK52	Tank default (1.0000)	Tank default	0%	12.616	0.000	12.616	0.000	21.000	-9.528	15.000
TANK51	Tank default (1.0000)	Tank default	0%	12.071	0.000	12.071	0.000	19.500	9.448	15.000
TANK50	Tank default (1.0000)	Tank default	0%	12.071	0.000	12.071	0.000	19.500	-9.448	15.000
BoxTop			735.42	0.000	0.000			27.300	0.000	21.120
BoxBottom			735.42	0.000	0.000			27.300	0.000	17.270
BoxPort			118.965	0.000	0.000			27.300	-11.900	19.195
BoxStbd			118.965	0.000	0.000			27.300	11.900	19.195
BoxBottom			674.73	0.000	0.000			28.575	0.000	21.120
BoxPort			99.225	0.000	0.000			28.575	-11.900	22.870
BoxStbd			99.225	0.000	0.000			28.575	11.900	22.870
BoxTop			674.73	0.000	0.000			28.575	0.000	27.420
BoxPort			79.38	0.000	0.000			28.575	-11.900	26.020
BoxStbd			79.38	0.000	0.000			28.575	11.900	26.020
BoxTop			258.23	0.000	0.000			37.325	0.000	30.400
BoxPort			32.333	0.000	0.000			37.325	-11.900	28.910
BoxStbd			32.333	0.000	0.000			37.325	11.900	28.910
BoxTop			258.23	0.000	0.000			37.325	0.000	33.030
BoxPort			28.535	0.000	0.000			37.325	-11.900	31.715
BoxStbd			28.535	0.000	0.000			37.325	11.900	31.715
BoxTop			140.14	0.000	0.000			38.200	0.000	36.355
BoxPort			30.258	0.000	0.000			38.200	-7.700	34.692
BoxStbd			30.258	0.000	0.000			38.200	7.700	34.692
BoxTop			38.5	0.000	0.000			24.200	0.000	36.520
BoxPort			70.07	0.000	0.000			24.200	-2.500	31.970
BoxStbd			70.07	0.000	0.000			24.200	2.500	31.970

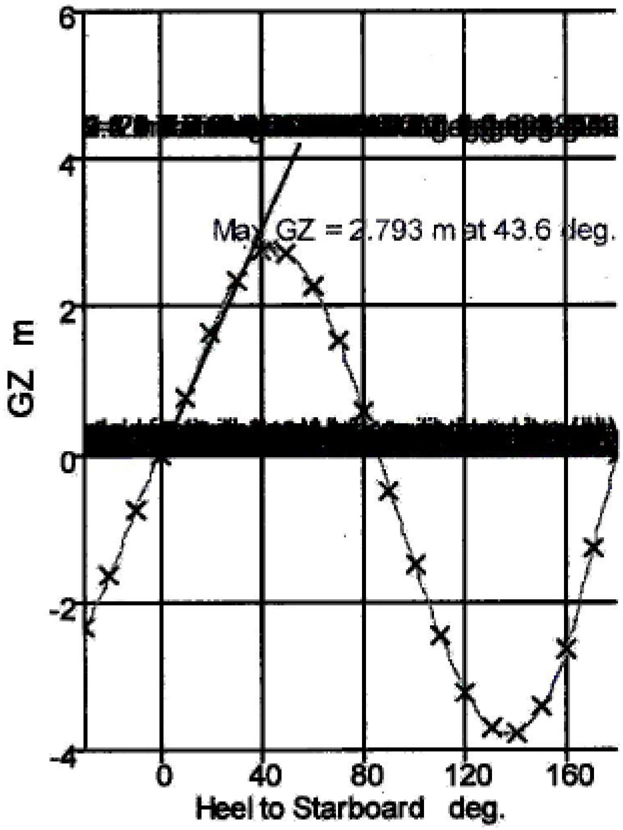


item			1	0.000	0.000			0.000	0.000	0.000
Total Loadcase					24006.040	12707.645	2155.450	78.688	0.000	10.438
FS correction										0.058
VCG fluid										10.497



Draft Amidships m	6.681
Displacement t	24006
Heel deg	0.0
Draft at FP m	6.569
Draft at AP m	6.794
Draft at LCF m	6.688
Trim (+ve by stern) m	0.226
WL Length m	162.110
Beam max extents on WL m	29.581
Wetted Area m^2	5484.296
Waterpl. Area m^2	4109.198
Prismatic coeff. (Cp)	0.797
Block coeff. (Cb)	0.770
Midship Sect. area coeff. (Cm)	0.967
Waterpl. area coeff. (Cwp)	0.903
LCB from aft perp. (+ve fwd) m	78.684
LCF from aft perp. (+ve fwd) m	72.501
KB m	3.552
KG fluid m	10.497
BMt m	11.268
BML m	299.277
GMt corrected m	4.324
GML m	292.333
KMt m	14.820
KML m	302.829
Immersion (TPc) tonne/cm	42.119
MTc tonne.m	456.261
RM at 1deg =	1811.46

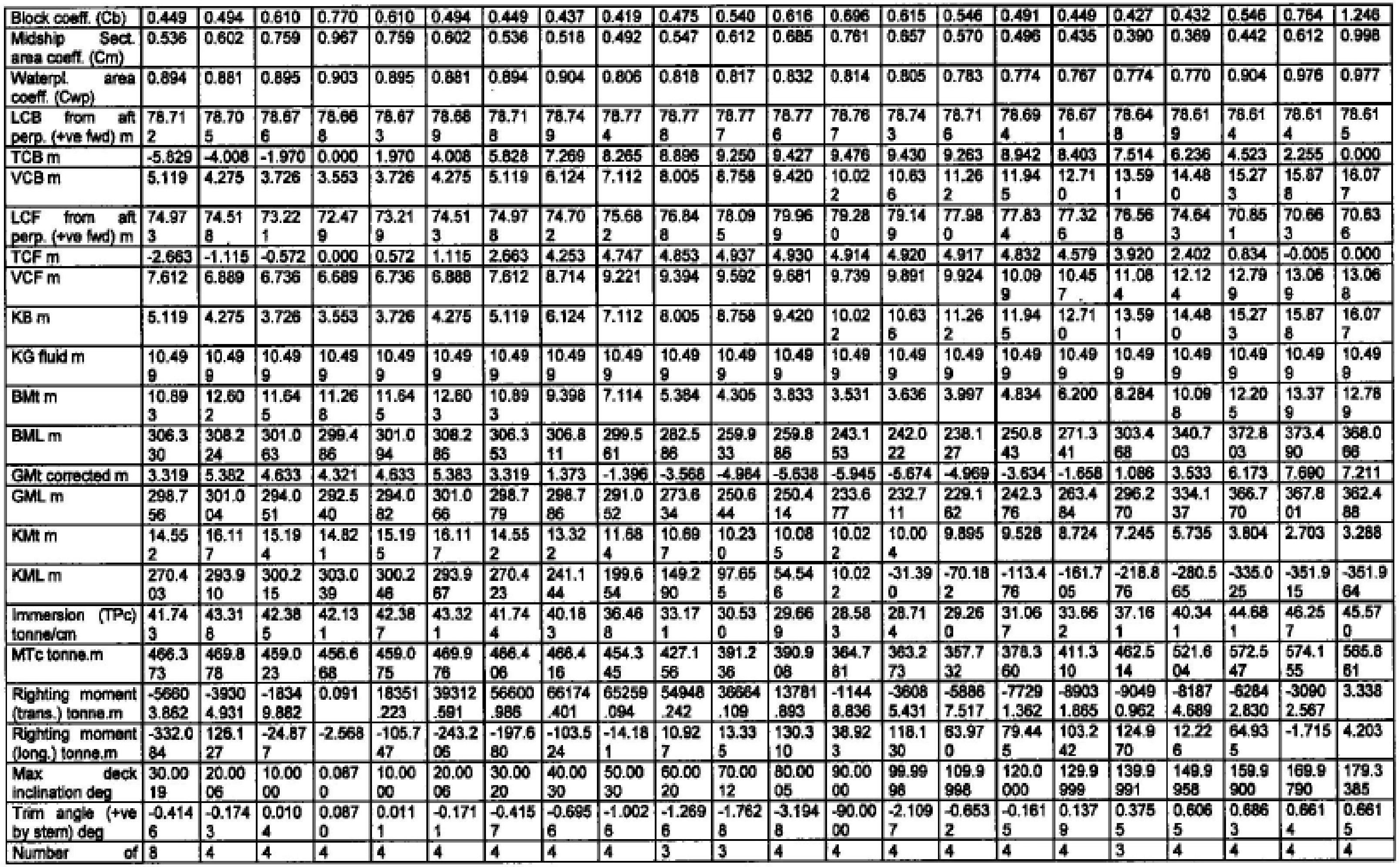
Table 36. Full Load Departure Equilibrium 3/3 – (Hydromax), (Maxsurf)



Picture 37. **Righting Lever Graph – FULL LOAD DEPARTURE –** (Hydromax), (Maxsurf)

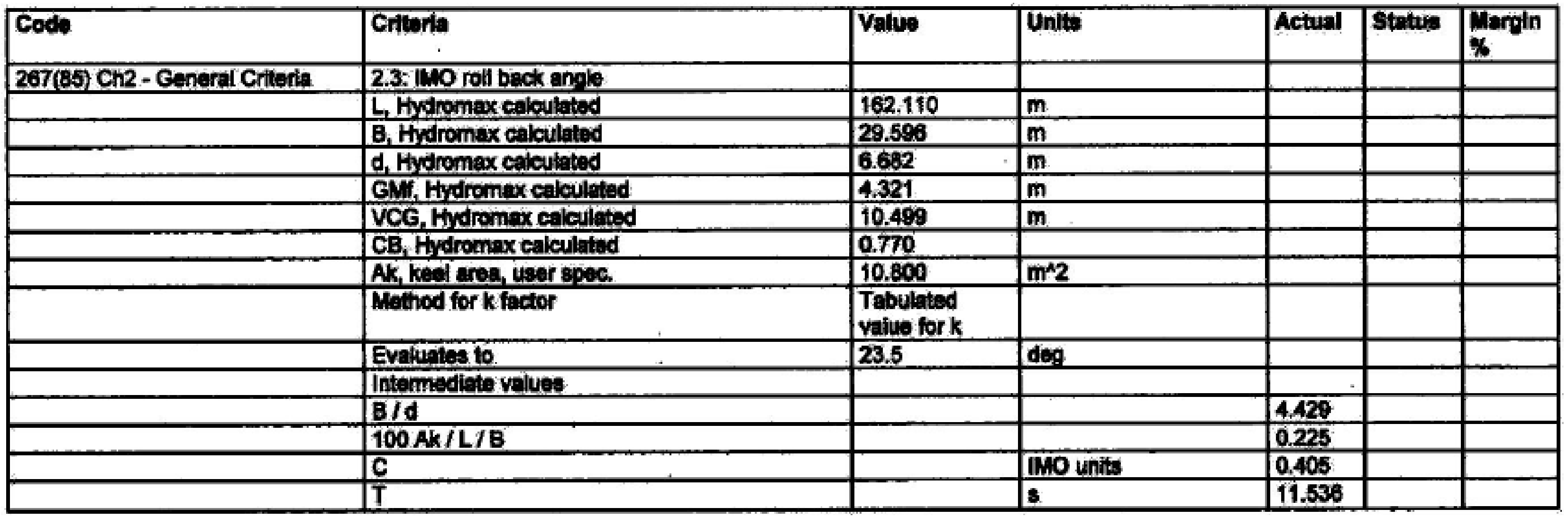
Heel to Starboard deg	-30.0	-20.0	-10.0	0.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100.0	110.0	120.0	130.0	140.0	150.0	160.0	170.0	180.0
GZ m	-2.357	-1.637	-0.764	0.000	0.764	1.637	2.357	2.756	2.718	2.289	1.527	0.574	-0.477	-1.503	-2.452	-3.219	-3.708	-3.769	-3.410	-2.617	-1.287	0.000
Area under GZ curve from zero heel m.deg	35.8447	15.7536	3.7261	0.0000	3.7311	15.7360	35.9222	61.8174	89.5427	114.8797	134.1768	144.8004	145.3130	135.3702	115.4937	86.9553	52.0204	14.2662	-21.9458	-52.5505	-72.2886	-78.6154
Displacement t	24011	24010	24010	24010	24010	24010	24010	24010	24010	24011	24009	24010	24010	24010	24010	24010	24010	24012	24010	24011	24010	24010
Volume (displaced) m^3	23424.888	23424.658	23424.638	23424.798	23424.818	23424.768	23424.684	23424.710	23424.833	23424.908	23422.977	23424.831	23424.830	23424.859	23424.843	23424.842	23424.849	23425.967	23424.826	23424.948	23424.850	23424.850
Draft at FP m	6.645	6.724	6.621	6.566	6.620	6.720	6.647	6.106	4.931	2.693	-1.641	-14.157	n/a	-35.042	-22.569	-18.255	-16.099	-14.879	-14.348	-14.096	-14.028	-14.028
Draft at AP m	5.532	6.256	6.649	6.799	6.650	6.260	5.531	4.239	2.239	-0.715	-6.375	-22.742	n/a	-40.708	-24.322	-18.688	-15.729	-13.871	-12.720	-12.254	-12.252	-12.252
Draft at LCF m	6.075	6.483	6.635	6.689	6.635	6.483	6.075	5.146	3.564	0.988	-3.972	-18.278	n/a	-37.793	-23.433	-18.469	-15.915	-14.373	-13.510	-13.102	-13.068	-13.068
Draft Amidships m	6.089	6.490	6.635	6.682	6.635	6.490	6.089	5.172	3.585	0.989	-4.008	-18.449	n/a	-37.875	-23.446	-18.471	-15.914	-14.375	-13.534	-13.175	-13.140	-13.140
Trim (+ve by stern) m	-1.113	-0.468	0.028	0.234	0.030	-0.459	-1.116	-1.867	-2.692	-3.409	-4.734	-8.585	n/a	-5.666	-1.754	-0.433	0.370	1.008	1.628	1.843	1.776	1.776
WL Length m	162.113	162.111	162.110	162.110	162.110	162.111	162.113	162.117	162.120	162.120	162.119	160.939	159.726	161.803	162.111	162.110	162.110	162.112	162.117	162.120	162.120	162.121
Beam max extents on WL m	29.602	31.188	30.033	29.581	30.033	31.187	29.602	28.201	28.713	25.715	23.699	22.614	22.270	22.614	23.699	25.467	27.838	30.458	33.241	31.351	30.053	29.596
Beam max on WL m	29.602	31.188	30.033	29.581	30.033	31.187	29.602	28.201	28.713	25.715	23.699	22.614	22.270	22.614	23.699	25.467	27.838	30.458	33.241	31.351	30.053	29.596
Beam extents on WL of station with max area m	29.602	31.113	30.033	29.581	30.033	31.112	29.602	26.867	28.683	25.715	23.699	22.614	22.270	22.614	23.699	25.467	27.838	30.458	33.241	31.351	30.053	29.596
Beam on WL of station with max area m	29.602	31.113	30.033	29.581	30.033	31.112	29.602	26.867	28.683	25.715	23.699	22.614	22.270	22.614	23.699	25.467	27.838	30.458	33.241	31.351	30.053	29.596
Beam extents on WL amidships m	29.113	31.076	29.979	29.524	29.979	31.076	29.113	26.867	22.544	19.942	18.378	17.536	17.270	17.536	18.378	19.825	21.589	23.672	24.517	27.683	29.979	29.524
Beam on WL amidships m	29.113	31.076	29.979	29.524	29.979	31.076	29.113	26.867	22.544	19.942	18.378	17.536	17.270	17.536	18.378	19.825	21.589	23.672	24.517	27.683	29.979	29.524
Wetted Area m^2	5402.527	5493.772	5475.824	5485.600	5476.278	5494.702	5403.625	5310.613	5323.179	5306.651	5287.362	5337.293	5311.294	5313.033	5310.738	5360.714	5458.861	5599.776	5814.781	6160.514	6370.416	6370.346
Waterpl. Area m^2	4072.474	4226.145	4135.171	4110.317	4135.313	4226.426	4072.543	3920.280	3557.865	3236.216	2978.491	2894.530	2788.546	2801.344	2854.665	3030.910	3284.080	3625.430	3935.755	4359.095	4512.886	4445.882
Prismatic coeff. (Cp)	0.838	0.821	0.803	0.797	0.803	0.821	0.838	0.843	0.853	0.867	0.884	0.899	0.914	0.936	0.959	0.990	1.033	1.095	1.170	1.237	1.249	1.249

Table 37. **Righting Lever Properties 1/2 – FULL LOAD DEPARTURE –** (Hydromax), (Maxsurf)



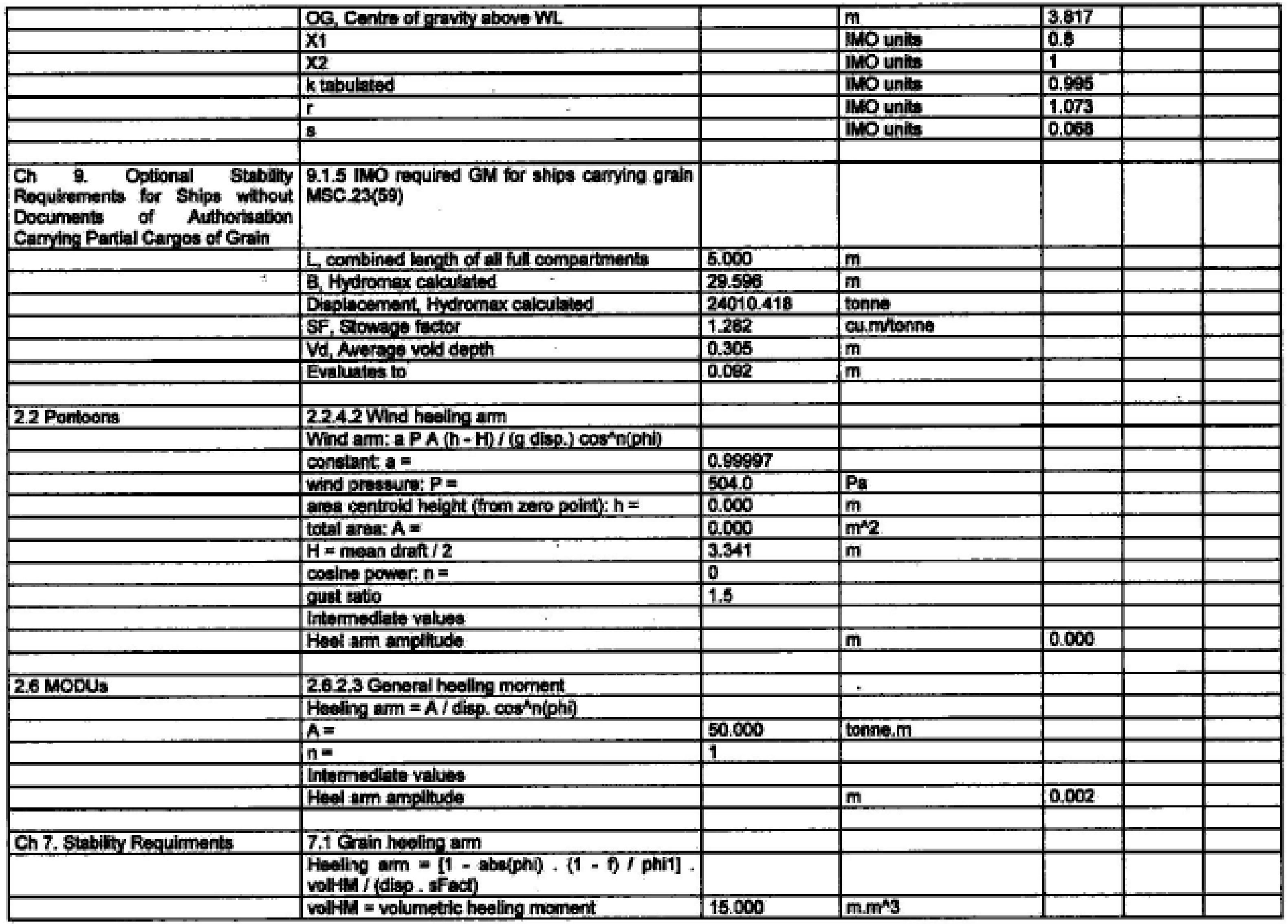
Block coeff. (Cb)	0.449	0.494	0.610	0.770	0.610	0.494	0.449	0.437	0.419	0.475	0.540	0.616	0.696	0.615	0.546	0.491	0.449	0.427	0.432	0.546	0.764	1.246
Midship Sect. area coeff. (Cm)	0.536	0.602	0.759	0.967	0.759	0.602	0.536	0.518	0.492	0.547	0.612	0.685	0.761	0.657	0.570	0.496	0.435	0.390	0.369	0.442	0.612	0.998
Waterpl. area coeff. (Cwp)	0.894	0.881	0.895	0.903	0.895	0.881	0.894	0.904	0.806	0.818	0.817	0.832	0.814	0.805	0.783	0.774	0.767	0.774	0.770	0.904	0.976	0.977
LCB from aft perp. (+ve fwd) m	78.712	78.705	78.676	78.668	78.673	78.689	78.718	78.749	78.774	78.778	78.777	78.776	78.767	78.743	78.716	78.694	78.671	78.648	78.619	78.614	78.614	78.615
TCB m	-5.829	-4.008	-1.970	0.000	1.970	4.008	5.828	7.269	8.265	8.896	9.250	9.427	9.476	9.430	9.263	8.942	8.403	7.514	6.236	4.523	2.255	0.000
VCB m	5.119	4.275	3.726	3.553	3.726	4.275	5.119	6.124	7.112	8.005	8.758	9.420	10.022	10.636	11.262	11.945	12.710	13.591	14.480	15.273	15.878	16.077
LCF from aft perp. (+ve fwd) m	74.973	74.518	73.221	72.479	73.219	74.513	74.978	74.702	75.682	76.848	78.095	79.969	79.280	79.149	77.980	77.834	77.326	76.568	74.643	70.851	70.663	70.636
TCF m	-2.663	-1.115	-0.572	0.000	0.572	1.115	2.663	4.253	4.747	4.853	4.937	4.930	4.914	4.920	4.917	4.832	4.579	3.920	2.402	0.834	-0.005	0.000
VCF m	7.612	6.889	6.736	6.689	6.736	6.888	7.612	8.714	9.221	9.394	9.592	9.681	9.739	9.891	9.924	10.099	10.457	11.084	12.124	12.799	13.069	13.068
KB m	5.119	4.275	3.726	3.553	3.726	4.275	5.119	6.124	7.112	8.005	8.758	9.420	10.022	10.636	11.262	11.945	12.710	13.591	14.480	15.273	15.878	16.077
KG fluid m	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499	10.499
BMt m	10.893	12.602	11.645	11.268	11.645	12.603	10.893	9.398	7.114	5.384	4.306	3.833	3.531	3.636	3.997	4.834	6.200	8.284	10.098	12.205	13.379	12.789
BML m	306.330	308.224	301.063	299.486	301.094	308.286	306.353	306.811	299.561	282.586	259.933	259.886	243.153	242.022	238.127	250.843	271.341	303.468	340.703	372.803	373.490	368.066
GMt corrected m	3.319	5.382	4.633	4.321	4.633	5.383	3.319	1.373	-1.396	-3.566	-4.984	-5.638	-5.945	-5.674	-4.969	-3.634	-1.658	1.086	3.533	6.173	7.690	7.211
GML m	298.756	301.004	294.051	292.540	294.082	301.066	298.779	298.786	291.052	273.634	250.644	250.414	233.677	232.711	229.162	242.376	263.484	296.270	334.137	366.770	367.801	362.488
KMt m	14.552	16.117	15.194	14.821	15.195	16.117	14.552	13.322	11.684	10.697	10.230	10.085	10.022	10.004	9.895	9.528	8.724	7.245	5.735	3.804	2.703	3.288
KML m	270.403	293.910	300.215	303.039	300.248	293.967	270.423	241.144	199.654	149.290	97.655	54.546	10.022	-31.390	-70.182	-113.476	-161.705	-218.876	-280.565	-335.025	-351.915	-351.964
Immersion (TPc) tonne/cm	41.743	43.318	42.385	42.131	42.387	43.321	41.744	40.183	36.468	33.171	30.530	29.669	28.583	28.714	29.260	31.067	33.662	37.161	40.341	44.681	46.257	45.570
MTc tonne.m	466.373	469.878	459.023	456.668	459.075	469.976	466.406	466.416	454.345	427.156	391.236	390.908	364.781	363.273	357.732	378.360	411.310	462.514	521.604	572.547	574.155	565.861
Righting moment (trans.) tonne.m	-56603.862	-39304.931	-18349.882	0.091	18351.223	39312.591	56600.986	66174.401	65259.094	54948.242	38664.109	13781.893	-11448.836	-36085.431	-58867.517	-77291.362	-89031.865	-90490.962	-81874.689	-62842.830	-30902.567	3.338
Righting moment (long.) tonne.m	-332.084	126.127	-24.877	-2.568	-105.747	-243.206	-197.680	-103.524	-14.181	10.927	13.335	130.310	38.923	118.130	63.970	79.445	103.242	124.970	12.226	64.935	-1.715	4.203
Max deck inclination deg	30.0019	20.0006	10.0000	0.0870	10.0000	20.0006	30.0020	40.0030	50.0030	60.0020	70.0012	80.0005	90.0000	99.9998	109.9998	120.0000	129.9999	139.9991	149.9958	159.9900	169.9790	179.3385
Trim angle (+ve by stern) deg	-0.4146	-0.1743	0.0104	0.0870	0.0111	-0.1711	-0.4157	-0.6956	-1.0026	-1.2696	-1.7628	-3.1948	-90.0000	-2.1097	-0.6532	-0.1615	0.1379	0.3755	0.6065	0.6863	0.6614	0.6615
Number of	8	4	4	4	4	4	4	4	4	3	3	4	4	4	4	4	4	3	4	4	4	4

Table 38. **Righting Lever Properties 2/2 – FULL LOAD DEPARTURE –** (Hydromax), (Maxsurf)



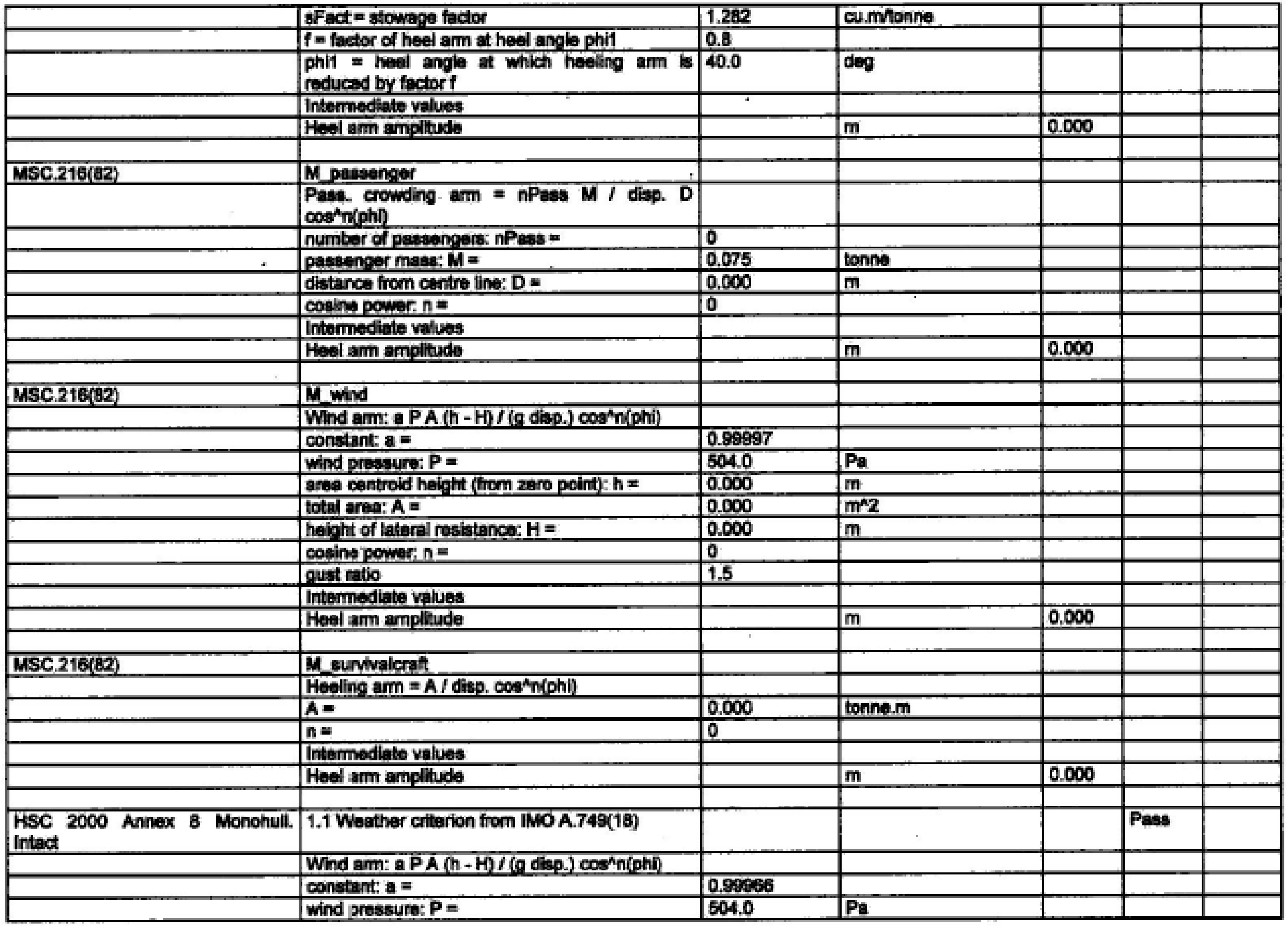
Code	Criteria	Value	Units	Actual	Status	Margin %
267(85) Ch2 - General Criteria	2.3: IMO roll back angle					
	L, Hydromax calculated	162.110	m			
	B, Hydromax calculated	29.596	m			
	d, Hydromax calculated	6.682	m			
	GMf, Hydromax calculated	4.321	m			
	VCG, Hydromax calculated	10.499	m			
	CB, Hydromax calculated	0.770				
	Ak, keel area, user spec.	10.800	m^2			
	Method for k factor	Tabulated value for k				
	Evaluates to	23.5	deg			
	Intermediate values					
	B / d			4.429		
	100 Ak / L / B			0.225		
	C		IMO units	0.405		
	T		s	11.536		

Table 39. Criteria – FULL LOAD DEPARTURE 1/23 – (Hydromax), (Maxsurf)



	OG, Centre of gravity above WL		m	3.817		
	X1		IMO units	0.8		
	X2		IMO units	1		
	k tabulated		IMO units	0.995		
	r		IMO units	1.073		
	s		IMO units	0.068		
Ch 9. Optional Stability Requirements for Ships without Documents of Authorisation Carrying Partial Cargos of Grain	9.1.5 IMO required GM for ships carrying grain MSC.23(59)					
	L, combined length of all full compartments	5.000	m			
	B, Hydromax calculated	29.596	m			
	Displacement, Hydromax calculated	24010.418	tonne			
	SF, Stowage factor	1.282	cu.m/tonne			
	Vd, Average void depth	0.305	m			
	Evaluates to	0.092	m			
2.2 Pontoons	2.2.4.2 Wind heeling arm					
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99997				
	wind pressure: P =	504.0	Pa			
	area centroid height (from zero point): h =	0.000	m			
	total area: A =	0.000	m^2			
	H = mean draft / 2	3.341	m			
	cosine power: n =	0				
	gust ratio	1.5				
	Intermediate values					
	Heel arm amplitude		m	0.000		
2.6 MODUs	2.6.2.3 General heeling moment					
	Heeling arm = A / disp. cos^n(phi)					
	A =	50.000	tonne.m			
	n =	1				
	Intermediate values					
	Heel arm amplitude		m	0.002		
Ch 7. Stability Requirments	7.1 Grain heeling arm					
	Heeling arm = [1 - abs(phi) . (1 - f) / phi1] . volHM / (disp . sFact)					
	volHM = volumetric heeling moment	15.000	m.m^3			

Table 40. Criteria – FULL LOAD DEPARTURE 2/23 – (Hydromax), (Maxsurf)

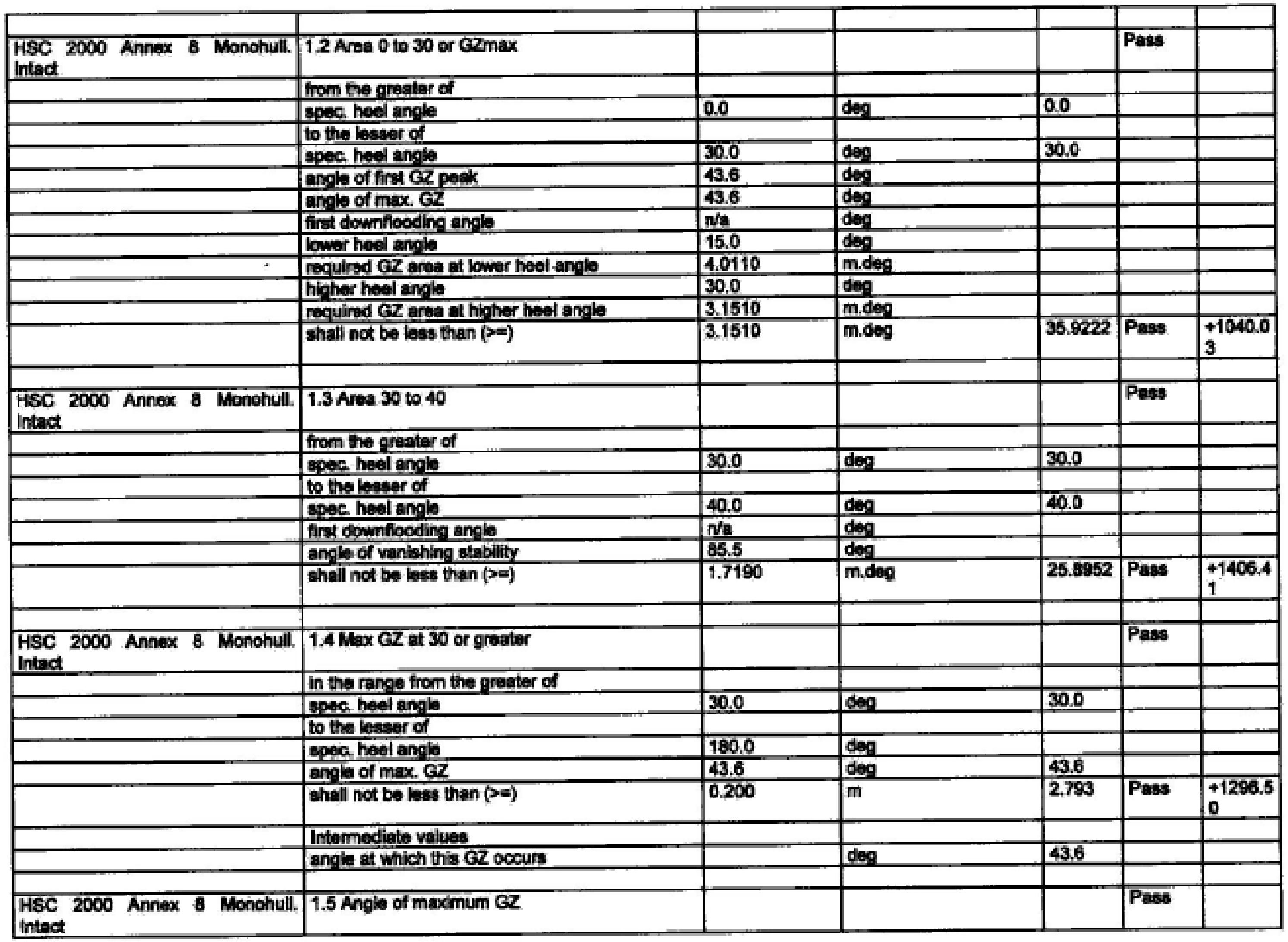


	sFact = stowage factor	1.282	cu.m/tonne			
	f = factor of heel arm at heel angle phi1	0.8				
	phi1 = heel angle at which heeling arm is reduced by factor f	40.0	deg			
	Intermediate values					
	Heel arm amplitude		m	0.000		
MSC.216(82)	M_passenger					
	Pass. crowding arm = nPass M / disp. D cos^n(phi)					
	number of passengers: nPass =	0				
	passenger mass: M =	0.075	tonne			
	distance from centre line: D =	0.000	m			
	cosine power: n =	0				
	Intermediate values					
	Heel arm amplitude		m	0.000		
MSC.216(82)	M_wind					
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99997				
	wind pressure: P =	504.0	Pa			
	area centroid height (from zero point): h =	0.000	m			
	total area: A =	0.000	m^2			
	height of lateral resistance: H =	0.000	m			
	cosine power: n =	0				
	gust ratio	1.5				
	Intermediate values					
	Heel arm amplitude		m	0.000		
MSC.216(82)	M_survivalcraft					
	Heeling arm = A / disp. cos^n(phi)					
	A =	0.000	tonne.m			
	n =	0				
	Intermediate values					
	Heel arm amplitude		m	0.000		
HSC 2000 Annex 8 Monohull. Intact	1.1 Weather criterion from IMO A.749(18)				Pass	
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99966				
	wind pressure: P =	504.0	Pa			

Table 41. **Criteria – FULL LOAD DEPARTURE 3/23 –** (Hydromax), (Maxsurf)

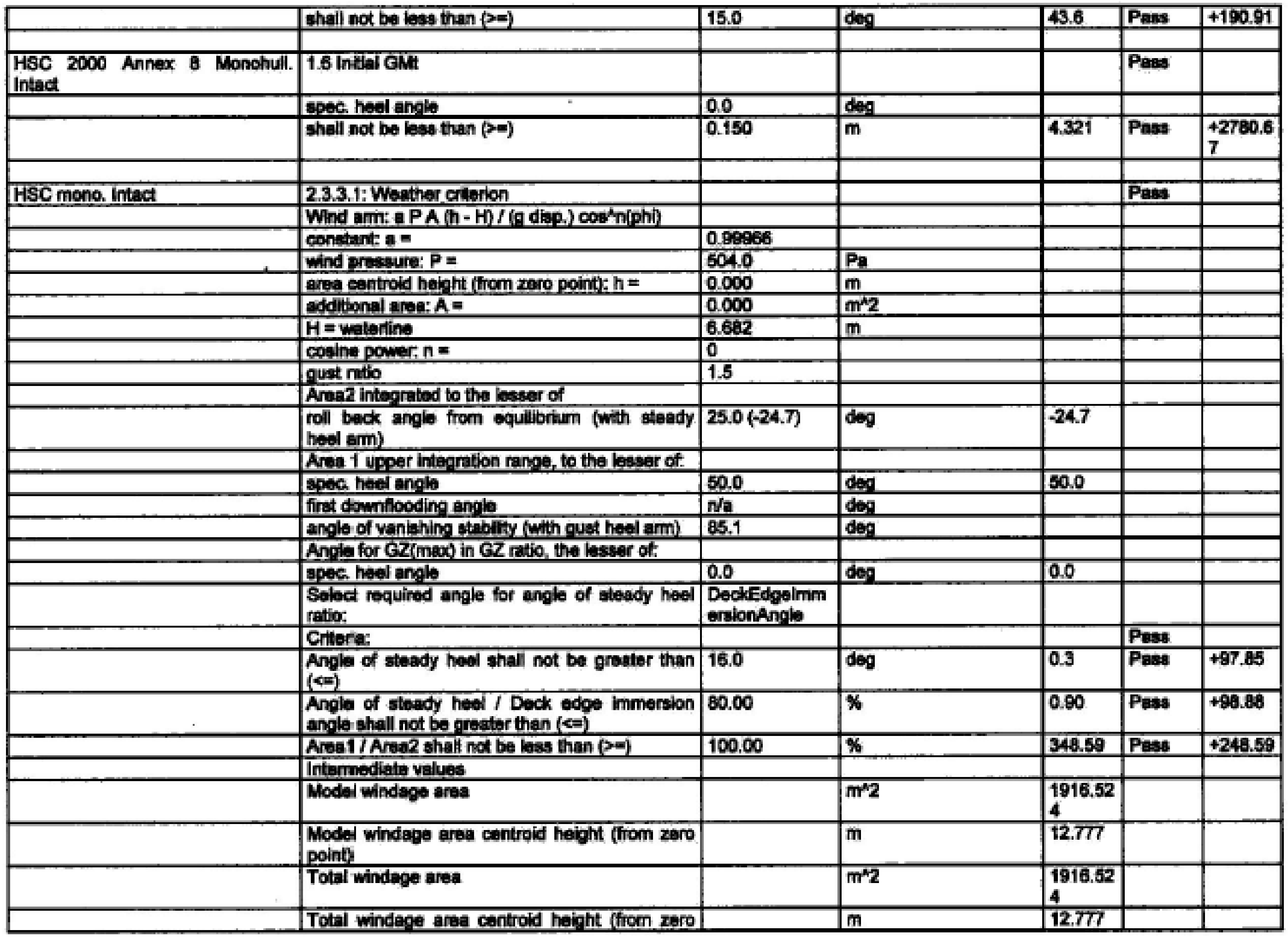
	area centroid height (from zero point): h =	0.000	m			
	additional area: A =	0.000	m^2			
	H = vert. centre of projected lat. u'water area	3.387	m			
	cosine power: n =	0				
	gust ratio	1.5				
	Area2 integrated to the lesser of					
	roll back angle from equilibrium (with steady heel arm)	25.0 (-24.5)	deg	-24.5		
	Area 1 upper integration range, to the lesser of:					
	spec. heel angle	50.0	deg	50.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with gust heel arm)	85.0	deg			
	Angle for GZ(max) in GZ ratio, the lesser of:					
	spec. heel angle	0.0	deg	0.0		
	Select required angle for angle of steady heel ratio:	MarginlineImmersionAngle				
	Criteria:				Pass	
	Angle of steady heel shall not be greater than (<=)	16.0	deg	0.5	Pass	+96.69
	Angle of steady heel / Marginline immersion angle shall be less than (<)	80.00	%	1.40	Pass	+98.25
	Area1 / Area2 shall not be less than (>=)	100.00	%	342.79	Pass	+242.79
	Intermediate values					
	Model windage area		m^2	1916.524		
	Model windage area centroid height (from zero point)		m	12.777		
	Total windage area		m^2	1916.524		
	Total windage area centroid height (from zero point)		m	12.777		
	Heel arm amplitude		m	0.039		
	Equilibrium angle with steady heel arm		deg	0.5		
	Equilibrium angle with gust heel arm		deg	0.8		
	Marginline immersion angle		deg	37.8		
	Area1 (under GZ), from 0.8 to 50.0 deg.		m.deg	89.5197		
	Area1 (under HA), from 0.8 to 50.0 deg.		m.deg	2.8423		
	Area1, from 0.8 to 50.0 deg.		m.deg	86.6774		
	Area2 (under GZ), from -24.5 to 0.8 deg.		m.deg	-23.8262		
	Area2 (under HA), from -24.5 to 0.8 deg.		m.deg	1.4594		
	Area2, from -24.5 to 0.8 deg.		m.deg	25.2856		

Table 42. Criteria – FULL LOAD DEPARTURE 4/23 – (Hydromax), (Maxsurf)



HSC 2000 Annex 8 Monohull. Intact	1.2 Area 0 to 30 or GZmax				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	30.0	deg	30.0		
	angle of first GZ peak	43.6	deg			
	angle of max. GZ	43.6	deg			
	first downflooding angle	n/a	deg			
	lower heel angle	15.0	deg			
	required GZ area at lower heel angle	4.0110	m.deg			
	higher heel angle	30.0	deg			
	required GZ area at higher heel angle	3.1510	m.deg			
	shall not be less than (>=)	3.1510	m.deg	35.9222	Pass	+1040.03
HSC 2000 Annex 8 Monohull. Intact	1.3 Area 30 to 40				Pass	
	from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	85.5	deg			
	shall not be less than (>=)	1.7190	m.deg	25.8952	Pass	+1406.41
HSC 2000 Annex 8 Monohull. Intact	1.4 Max GZ at 30 or greater				Pass	
	in the range from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	180.0	deg			
	angle of max. GZ	43.6	deg	43.6		
	shall not be less than (>=)	0.200	m	2.793	Pass	+1296.50
	Intermediate values					
	angle at which this GZ occurs		deg	43.6		
HSC 2000 Annex 8 Monohull. Intact	1.5 Angle of maximum GZ				Pass	

Table 43. **Criteria – FULL LOAD DEPARTURE 5/23 –** (Hydromax), (Maxsurf)

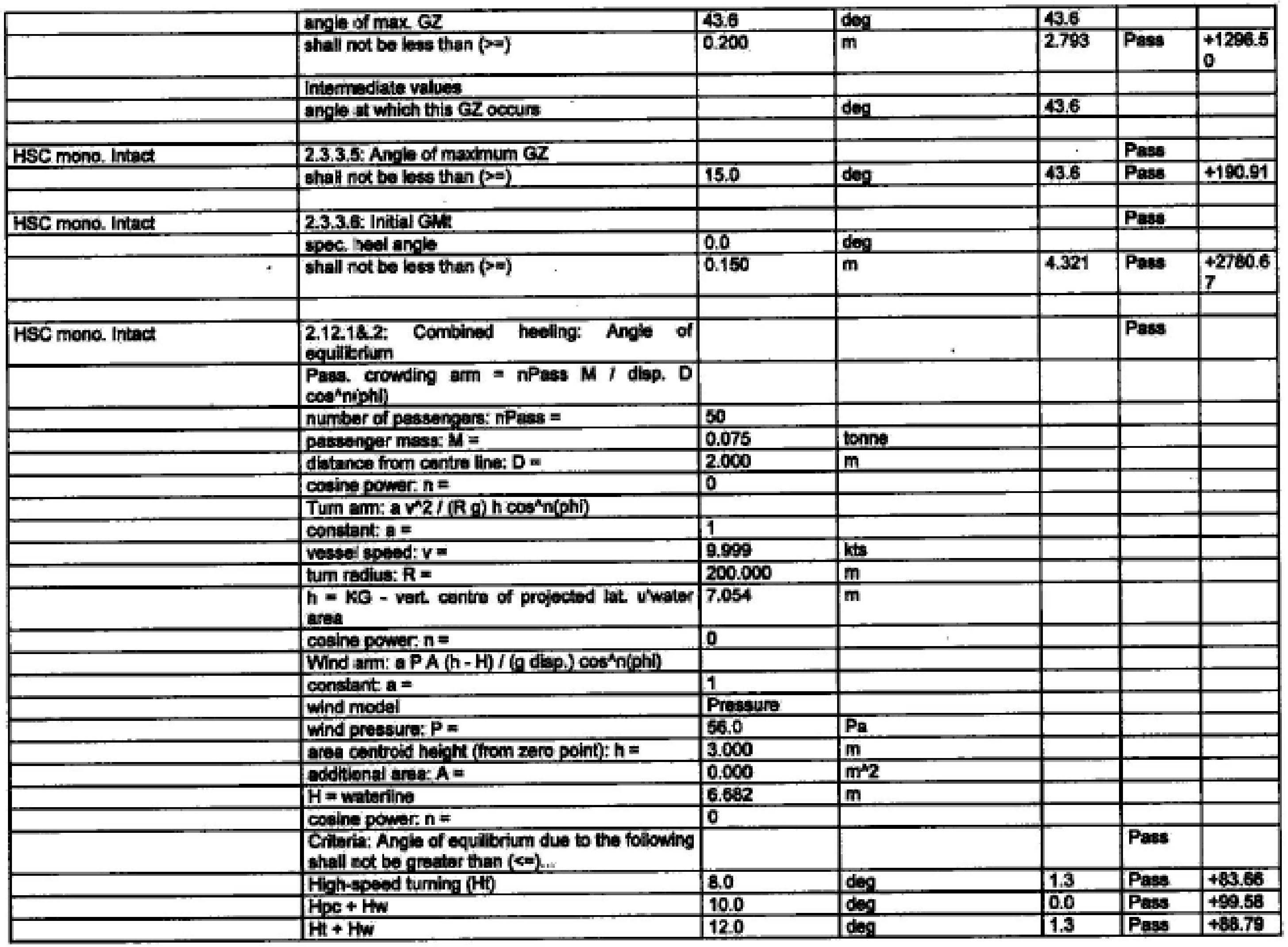


	shall not be less than (>=)	15.0	deg	43.6	Pass	+190.91
HSC 2000 Annex 8 Monohull. Intact	1.6 Initial GMt				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.150	m	4.321	Pass	+2780.6 7
HSC mono. Intact	2.3.3.1: Weather criterion				Pass	
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99966				
	wind pressure: P =	504.0	Pa			
	area centroid height (from zero point): h =	0.000	m			
	additional area: A =	0.000	m^2			
	H = waterline	6.682	m			
	cosine power: n =	0				
	gust ratio	1.5				
	Area2 integrated to the lesser of					
	roll back angle from equilibrium (with steady heel arm)	25.0 (-24.7)	deg	-24.7		
	Area 1 upper integration range, to the lesser of:					
	spec. heel angle	50.0	deg	50.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with gust heel arm)	85.1	deg			
	Angle for GZ(max) in GZ ratio, the lesser of:					
	spec. heel angle	0.0	deg	0.0		
	Select required angle for angle of steady heel ratio:	DeckEdgeImmersionAngle				
	Criteria:				Pass	
	Angle of steady heel shall not be greater than (<=)	16.0	deg	0.3	Pass	+97.85
	Angle of steady heel / Deck edge immersion angle shall not be greater than (<=)	80.00	%	0.90	Pass	+98.88
	Area1 / Area2 shall not be less than (>=)	100.00	%	348.59	Pass	+248.59
	Intermediate values					
	Model windage area		m^2	1916.52 4		
	Model windage area centroid height (from zero point)		m	12.777		
	Total windage area		m^2	1916.52 4		
	Total windage area centroid height (from zero		m	12.777		

Table 44. Criteria – FULL LOAD DEPARTURE 6/23 – (Hydromax), (Maxsurf)

	point)					
	Heel arm amplitude		m	0.025		
	Equilibrium angle with steady heel arm		deg	0.3		
	Equilibrium angle with gust heel arm		deg	0.5		
	Deck edge immersion angle		deg	38.0		
	Area1 (under GZ), from 0.5 to 50.0 deg.		m.deg	89.5330		
	Area1 (under HA), from 0.5 to 50.0 deg.		m.deg	1.8552		
	Area1, from 0.5 to 50.0 deg.		m.deg	87.6778		
	Area2 (under GZ), from -24.7 to 0.5 deg.		m.deg	-24.2081		
	Area2 (under HA), from -24.7 to 0.5 deg.		m.deg	0.9437		
	Area2, from -24.7 to 0.5 deg.		m.deg	25.1518		
HSC mono. Intact	2.3.3.2: Area 0 to 30 or GZmax				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	30.0	deg	30.0		
	first downflooding angle	n/a	deg			
	lower heel angle	15.0	deg			
	required GZ area at lower heel angle	4.0107	m.deg			
	higher heel angle	30.0	deg			
	required GZ area at higher heel angle	3.1513	m.deg			
	shall not be less than (>=)	3.1513	m.deg	35.9222	Pass	+1039.92
HSC mono. Intact	2.3.3.3: Area 30 to 40				Pass	
	from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	85.5	deg			
	shall not be less than (>=)	1.7189	m.deg	25.8952	Pass	+1406.50
HSC mono. Intact	2.3.3.4: Max GZ at 30 or greater				Pass	
	in the range from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	90.0	deg			

Table 45. **Criteria** – **FULL LOAD DEPARTURE 7/23** – (Hydromax), (Maxsurf)

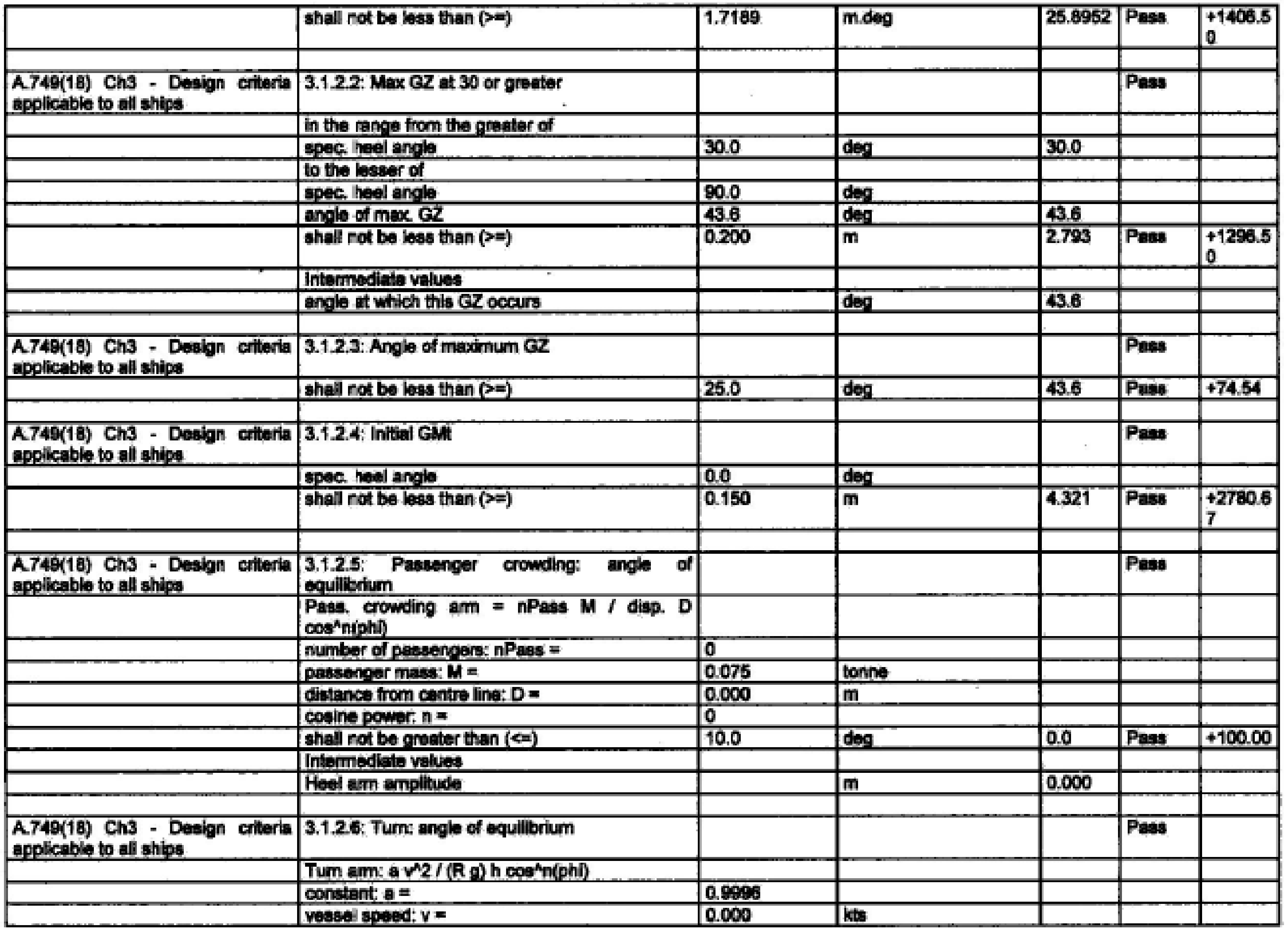


	angle of max. GZ	43.6	deg	43.6		
	shall not be less than (>=)	0.200	m	2.793	Pass	+1296.5 0
	Intermediate values					
	angle at which this GZ occurs		deg	43.6		
HSC mono. Intact	2.3.3.5: Angle of maximum GZ				Pass	
	shall not be less than (>=)	15.0	deg	43.6	Pass	+190.91
HSC mono. Intact	2.3.3.6: Initial GMt				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.150	m	4.321	Pass	+2780.6 7
HSC mono. Intact	2.12.1&2: Combined heeling: Angle of equilibrium				Pass	
	Pass. crowding arm = nPass M / disp. D cos^n(phi)					
	number of passengers: nPass =	50				
	passenger mass: M =	0.075	tonne			
	distance from centre line: D =	2.000	m			
	cosine power: n =	0				
	Turn arm: a v^2 / (R g) h cos^n(phi)					
	constant: a =	1				
	vessel speed: v =	9.999	kts			
	turn radius: R =	200.000	m			
	h = KG - vert. centre of projected lat. u'water area	7.054	m			
	cosine power: n =	0				
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	1				
	wind model	Pressure				
	wind pressure: P =	56.0	Pa			
	area centroid height (from zero point): h =	3.000	m			
	additional area: A =	0.000	m^2			
	H = waterline	6.682	m			
	cosine power: n =	0				
	Criteria: Angle of equilibrium due to the following shall not be greater than (<=)...				Pass	
	High-speed turning (Ht)	8.0	deg	1.3	Pass	+83.66
	Hpc + Hw	10.0	deg	0.0	Pass	+99.58
	Ht + Hw	12.0	deg	1.3	Pass	+88.79

Table 46. Criteria – FULL LOAD DEPARTURE 8/23 – (Hydromax), (Maxsurf)

	Intermediate values					
	Pass. crowding heel arm amplitude (Hpc)		m	0.000		
	Turning heel arm amplitude (Ht)		m	0.095		
	Model windage area		m^2	1916.524		
	Model windage area centroid height (from zero point)		m	12.777		
	Total windage area		m^2	1916.524		
	Total windage area centroid height (from zero point)		m	12.777		
	Wind heeling heel arm amplitude (Hw)		m	0.003		
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 0 to 30				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	30.0	deg	30.0		
	angle of vanishing stability	85.5	deg			
	shall not be less than (>=)	3.1513	m.deg	35.9222	Pass	+1039.92
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 0 to 40				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	85.5	deg			
	shall not be less than (>=)	5.1566	m.deg	61.8174	Pass	+1098.80
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 30 to 40				Pass	
	from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle cf vanishing stability	85.5	deg			

Table 47. **Criteria** – **FULL LOAD DEPARTURE 9/23** – (Hydromax), (Maxsurf)

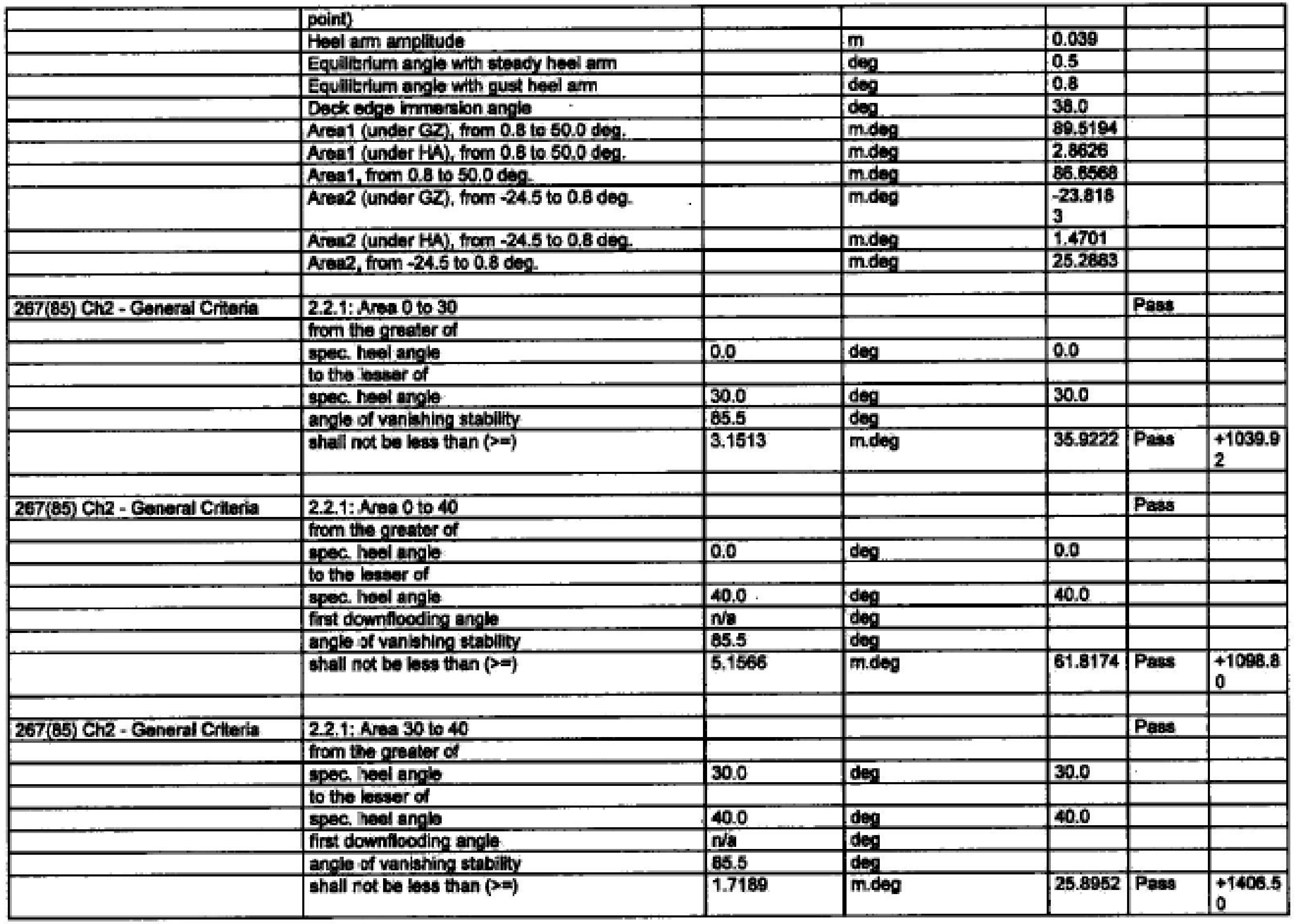


	shall not be less than (>=)	1.7189	m.deg	25.8952	Pass	+1406.50
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.2: Max GZ at 30 or greater				Pass	
	in the range from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	43.6	deg	43.6		
	shall not be less than (>=)	0.200	m	2.793	Pass	+1296.50
	Intermediate values					
	angle at which this GZ occurs		deg	43.6		
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.3: Angle of maximum GZ				Pass	
	shall not be less than (>=)	25.0	deg	43.6	Pass	+74.54
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.4: Initial GMt				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.150	m	4.321	Pass	+2780.67
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.5: Passenger crowding: angle of equilibrium				Pass	
	Pass. crowding arm = nPass M / disp. D cos^n(phi)					
	number of passengers: nPass =	0				
	passenger mass: M =	0.075	tonne			
	distance from centre line: D =	0.000	m			
	cosine power: n =	0				
	shall not be greater than (<=)	10.0	deg	0.0	Pass	+100.00
	Intermediate values					
	Heel arm amplitude		m	0.000		
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.6: Turn: angle of equilibrium				Pass	
	Turn arm: a v^2 / (R g) h cos^n(phi)					
	constant: a =	0.9996				
	vessel speed: v =	0.000	kts			

Table 48. **Criteria – FULL LOAD DEPARTURE 10/23 –** (Hydromax), (Maxsurf)

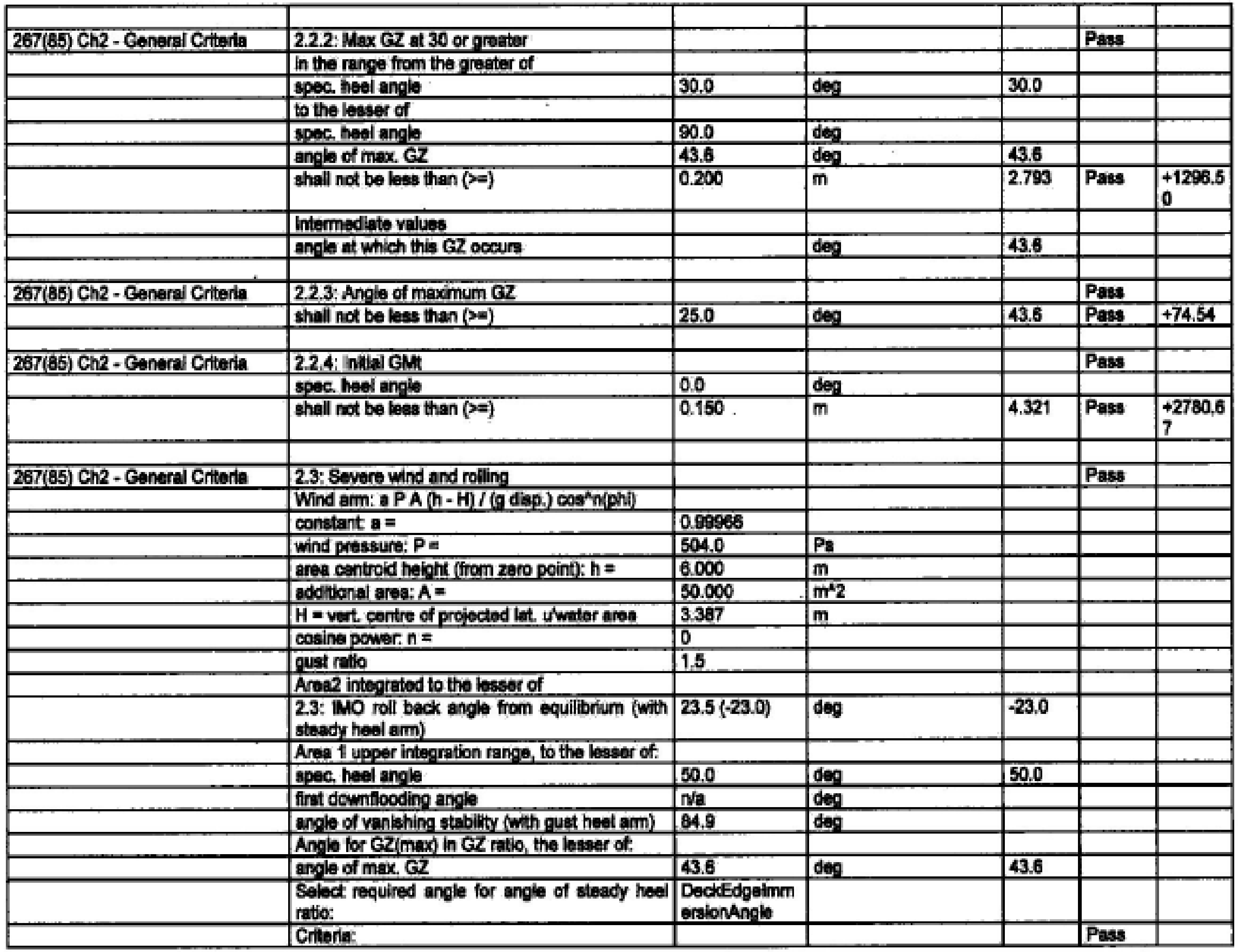
	turn radius, R, as percentage of Lwl	510.00	%			
	h = KG - mean draft / 2	7.100	m			
	cosine power: n =	0				
	shall not be greater than (<=)	10.0	deg	0.0	Pass	+100.00
	Intermediate values					
	Heel arm amplitude		m	0.000		
A.749(18) Ch3 - Design criteria applicable to all ships	3.2.2: Severe wind and rolling				Pass	
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99966				
	wind pressure: P =	504.0	Pa			
	area centroid height (from zero point): h =	6.000	m			
	additional area: A =	50.000	m^2			
	H = vert. centre of projected lat. u'water area	3.387	m			
	cosine power: n =	0				
	gust ratio	1.5				
	Area2 integrated to the lesser of					
	roll back angle from equilibrium (with steady heel arm)	25.0 (-24.5)	deg	-24.5		
	Area 1 upper integration range, to the lesser of:					
	spec. heel angle	50.0	deg	50.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with gust heel arm)	84.9	deg			
	Angle for GZ(max) in GZ ratio, the lesser of:					
	angle of max. GZ	43.6	deg	43.6		
	Select required angle for angle of steady heel ratio:	DeckEdgeImmersionAngle				
	Criteria:				Pass	
	Angle of steady heel shall not be greater than (<=)	16.0	deg	0.5	Pass	+96.67
	Angle of steady heel / Deck edge immersion angle shall not be greater than (<=)	80.00	%	1.40	Pass	+98.25
	Area1 / Area2 shall not be less than (>=)	100.00	%	342.67	Pass	+242.67
	Intermediate values					
	Model windage area		m^2	1916.524		
	Model windage area centroid height (from zero point)		m	12.777		
	Total windage area		m^2	1966.524		
	Total windage area centroid height (from zero		m	12.605		

Table 49. **Criteria** – **FULL LOAD DEPARTURE 11/23** – (Hydromax), (Maxsurf)



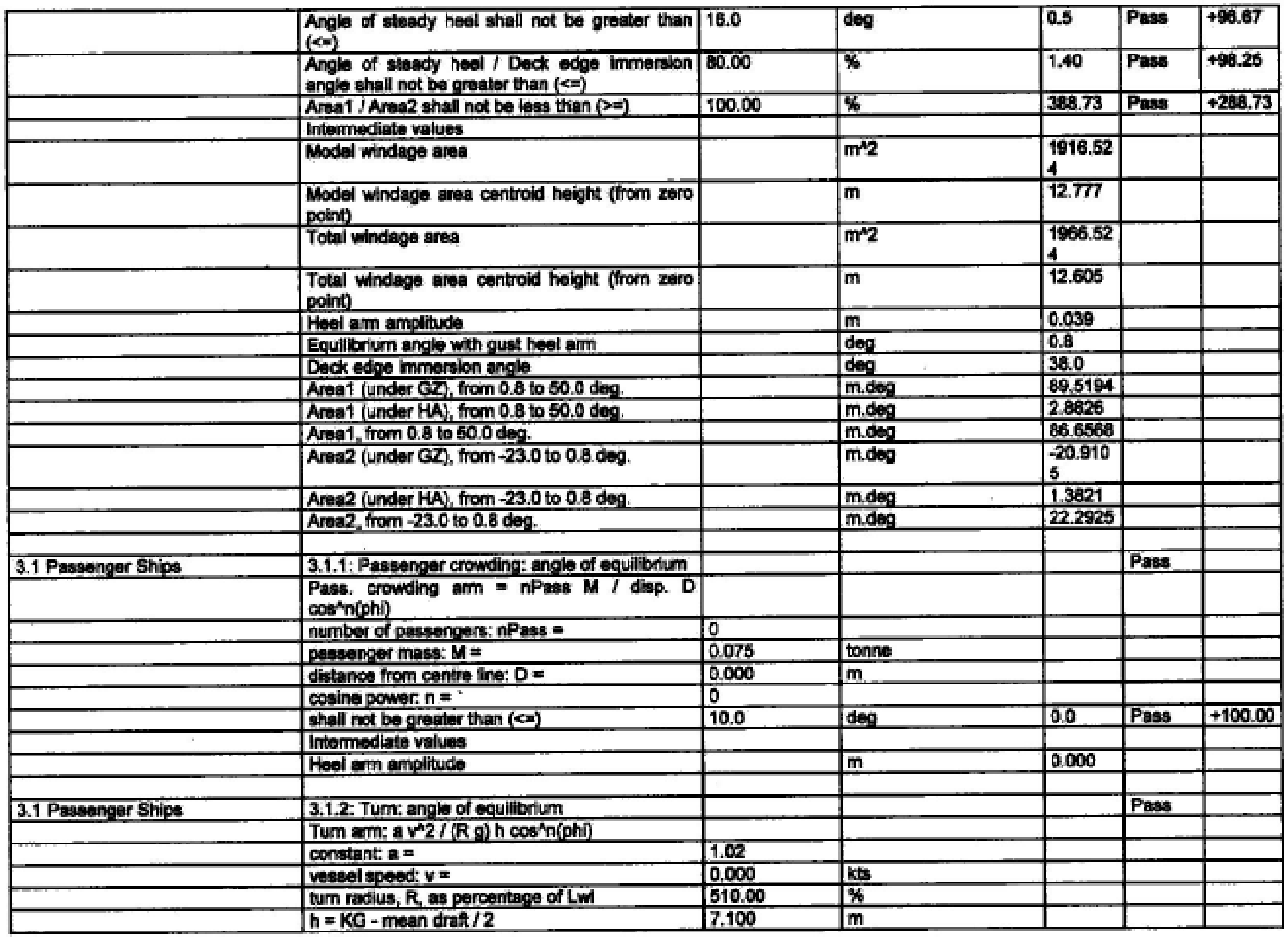
	point)					
	Heel arm amplitude		m	0.039		
	Equilibrium angle with steady heel arm		deg	0.5		
	Equilibrium angle with gust heel arm		deg	0.8		
	Deck edge immersion angle		deg	38.0		
	Area1 (under GZ), from 0.8 to 50.0 deg.		m.deg	89.5194		
	Area1 (under HA), from 0.8 to 50.0 deg.		m.deg	2.8626		
	Area1, from 0.8 to 50.0 deg.		m.deg	86.6568		
	Area2 (under GZ), from -24.5 to 0.8 deg.		m.deg	-23.818 3		
	Area2 (under HA), from -24.5 to 0.8 deg.		m.deg	1.4701		
	Area2, from -24.5 to 0.8 deg.		m.deg	25.2883		
267(85) Ch2 - General Criteria	2.2.1: Area 0 to 30				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	30.0	deg	30.0		
	angle of vanishing stability	85.5	deg			
	shall not be less than (>=)	3.1513	m.deg	35.9222	Pass	+1039.9 2
267(85) Ch2 - General Criteria	2.2.1: Area 0 to 40				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	85.5	deg			
	shall not be less than (>=)	5.1566	m.deg	61.8174	Pass	+1098.8 0
267(85) Ch2 - General Criteria	2.2.1: Area 30 to 40				Pass	
	from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	85.5	deg			
	shall not be less than (>=)	1.7189	m.deg	25.8952	Pass	+1406.5 0

Table 50. Criteria – FULL LOAD DEPARTURE 12/23 – (Hydromax), (Maxsurf)



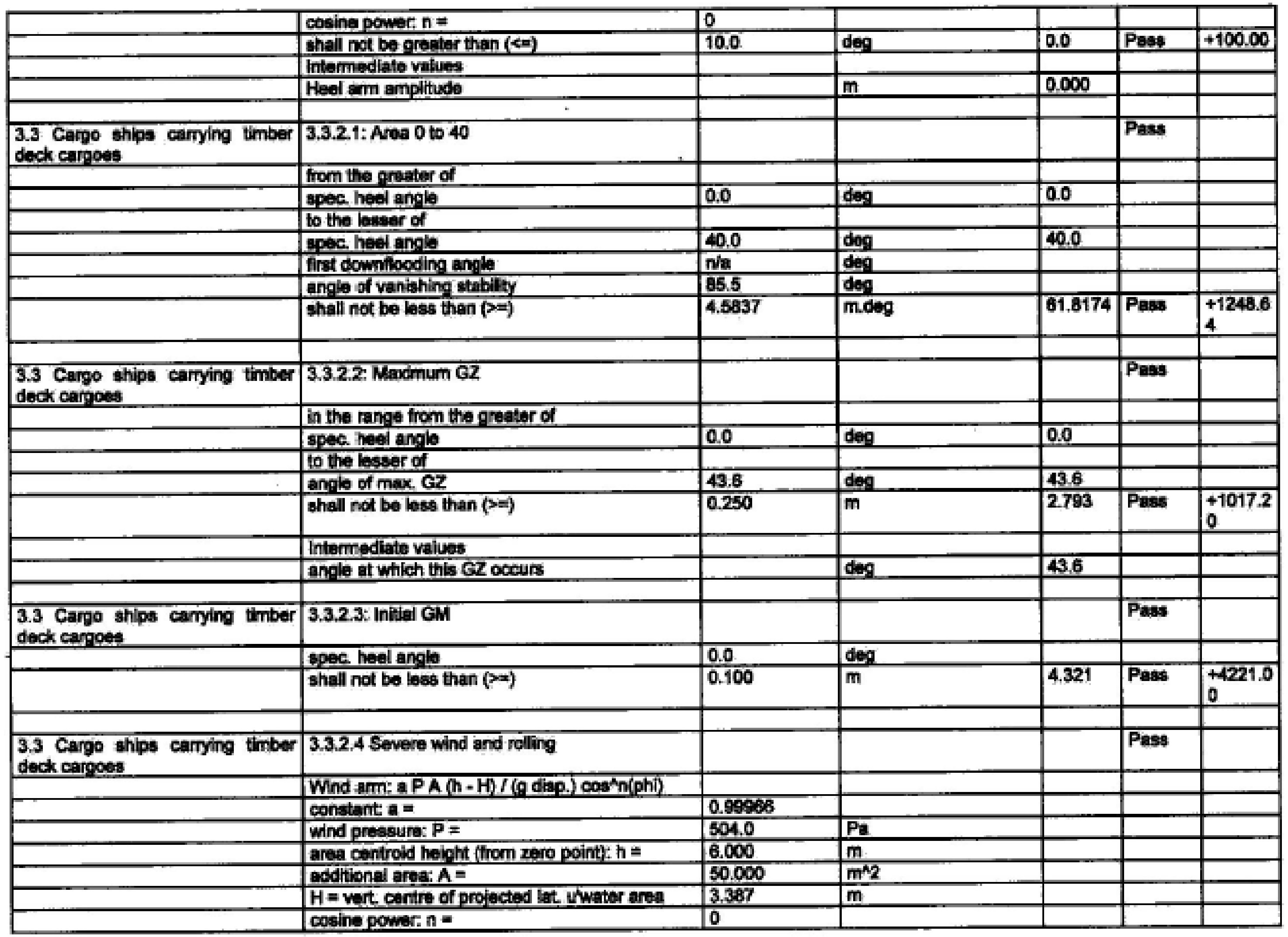
267(85) Ch2 - General Criteria	2.2.2: Max GZ at 30 or greater				Pass	
	in the range from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	43.6	deg	43.6		
	shall not be less than (>=)	0.200	m	2.793	Pass	+1296.50
	Intermediate values					
	angle at which this GZ occurs		deg	43.6		
267(85) Ch2 - General Criteria	2.2.3: Angle of maximum GZ				Pass	
	shall not be less than (>=)	25.0	deg	43.6	Pass	+74.54
267(85) Ch2 - General Criteria	2.2.4: Initial GMt				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.150	m	4.321	Pass	+2780.67
267(85) Ch2 - General Criteria	2.3: Severe wind and rolling				Pass	
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99966				
	wind pressure: P =	504.0	Pa			
	area centroid height (from zero point): h =	6.000	m			
	additional area: A =	50.000	m^2			
	H = vert. centre of projected lat. u/water area	3.387	m			
	cosine power: n =	0				
	gust ratio	1.5				
	Area2 integrated to the lesser of					
	2.3: IMO roll back angle from equilibrium (with steady heel arm)	23.5 (-23.0)	deg	-23.0		
	Area 1 upper integration range, to the lesser of:					
	spec. heel angle	50.0	deg	50.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with gust heel arm)	84.9	deg			
	Angle for GZ(max) in GZ ratio, the lesser of:					
	angle of max. GZ	43.6	deg	43.6		
	Select required angle for angle of steady heel ratio:	DeckEdgeImmersionAngle				
	Criteria:				Pass	

Table 51. **Criteria – FULL LOAD DEPARTURE 13/23 –** (Hydromax), (Maxsurf)



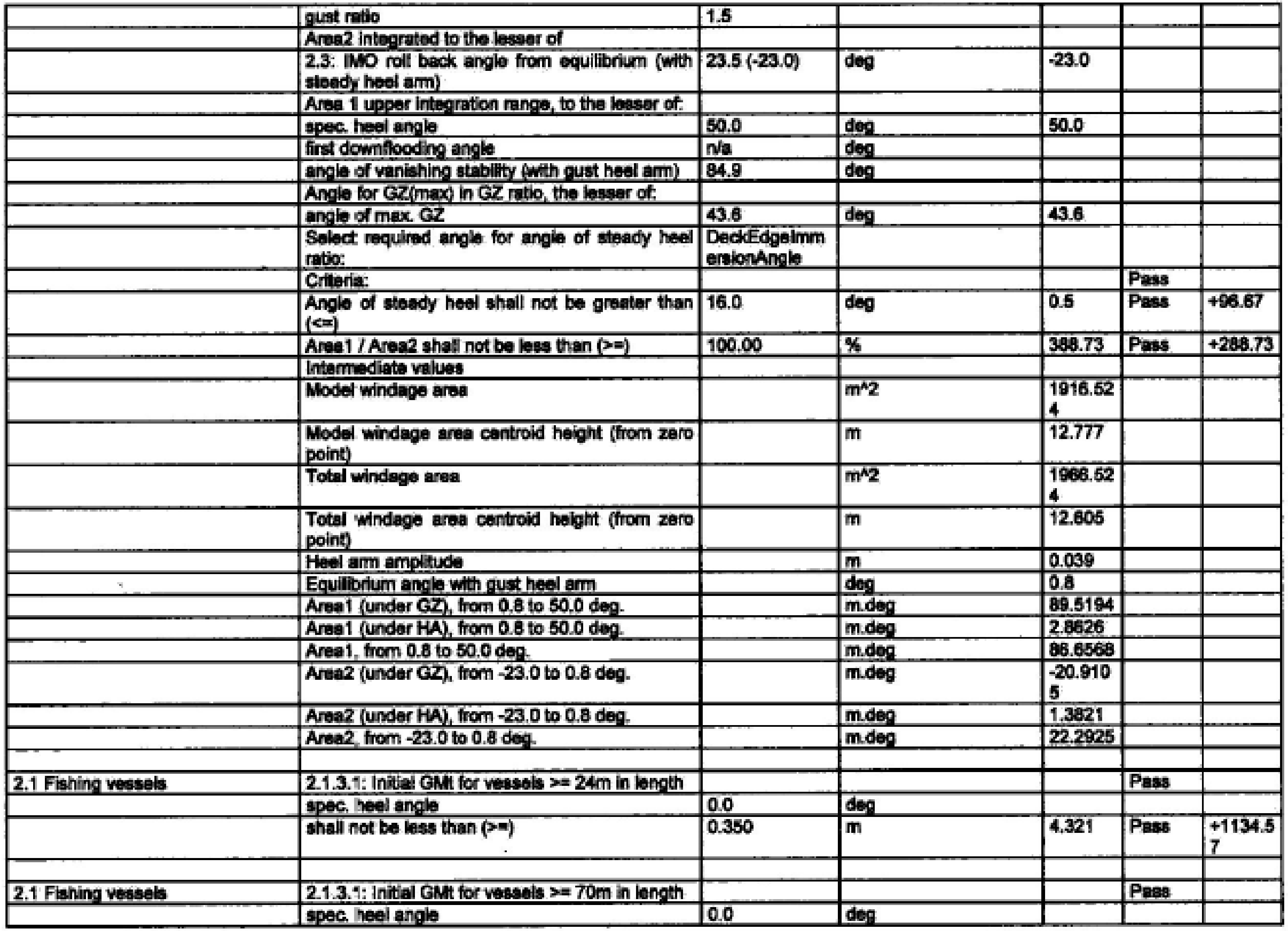
	Angle of steady heel shall not be greater than (<=)	16.0	deg	0.5	Pass	+96.87
	Angle of steady heel / Deck edge immersion angle shall not be greater than (<=)	80.00	%	1.40	Pass	+98.25
	Area1 / Area2 shall not be less than (>=)	100.00	%	388.73	Pass	+288.73
	Intermediate values					
	Model windage area		m^2	1916.52 4		
	Model windage area centroid height (from zero point)		m	12.777		
	Total windage area		m^2	1966.52 4		
	Total windage area centroid height (from zero point)		m	12.605		
	Heel arm amplitude		m	0.039		
	Equilibrium angle with gust heel arm		deg	0.8		
	Deck edge immersion angle		deg	38.0		
	Area1 (under GZ), from 0.8 to 50.0 deg.		m.deg	89.5194		
	Area1 (under HA), from 0.8 to 50.0 deg.		m.deg	2.8826		
	Area1, from 0.8 to 50.0 deg.		m.deg	86.6568		
	Area2 (under GZ), from -23.0 to 0.8 deg.		m.deg	-20.910 5		
	Area2 (under HA), from -23.0 to 0.8 deg.		m.deg	1.3821		
	Area2, from -23.0 to 0.8 deg.		m.deg	22.2925		
3.1 Passenger Ships	3.1.1: Passenger crowding: angle of equilibrium				Pass	
	Pass. crowding arm = nPass M / disp. D cos^n(phi)					
	number of passengers: nPass =	0				
	passenger mass: M =	0.075	tonne			
	distance from centre line: D =	0.000	m			
	cosine power: n =	0				
	shall not be greater than (<=)	10.0	deg	0.0	Pass	+100.00
	Intermediate values					
	Heel arm amplitude		m	0.000		
3.1 Passenger Ships	3.1.2: Turn: angle of equilibrium				Pass	
	Turn arm: a v^2 / (R g) h cos^n(phi)					
	constant: a =	1.02				
	vessel speed: v =	0.000	kts			
	turn radius, R, as percentage of Lwl	510.00	%			
	h = KG - mean draft / 2	7.100	m			

Table 52. Criteria – FULL LOAD DEPARTURE 14/23 – (Hydromax), (Maxsurf)



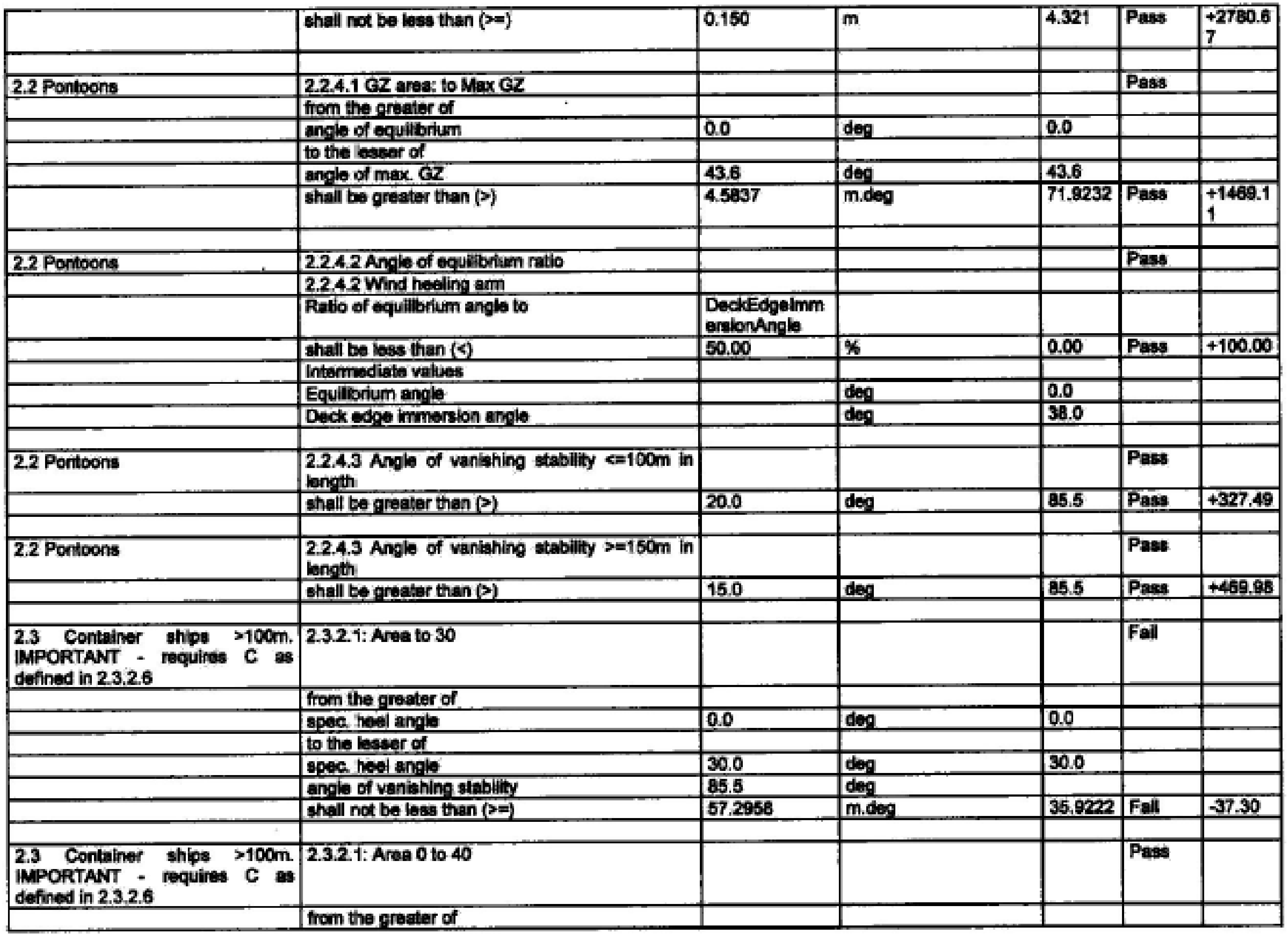
	cosine power: n =	0				
	shall not be greater than (<=)	10.0	deg	0.0	Pass	+100.00
	Intermediate values					
	Heel arm amplitude		m	0.000		
3.3 Cargo ships carrying timber deck cargoes	3.3.2.1: Area 0 to 40				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	85.5	deg			
	shall not be less than (>=)	4.5837	m.deg	61.8174	Pass	+1248.64
3.3 Cargo ships carrying timber deck cargoes	3.3.2.2: Maximum GZ				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	angle of max. GZ	43.6	deg	43.6		
	shall not be less than (>=)	0.250	m	2.793	Pass	+1017.20
	Intermediate values					
	angle at which this GZ occurs		deg	43.6		
3.3 Cargo ships carrying timber deck cargoes	3.3.2.3: Initial GM				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.100	m	4.321	Pass	+4221.00
3.3 Cargo ships carrying timber deck cargoes	3.3.2.4 Severe wind and rolling				Pass	
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99966				
	wind pressure: P =	504.0	Pa			
	area centroid height (from zero point): h =	6.000	m			
	additional area: A =	50.000	m^2			
	H = vert. centre of projected lat. u/water area	3.387	m			
	cosine power: n =	0				

Table 53. Criteria – FULL LOAD DEPARTURE 15/23 – (Hydromax), (Maxsurf)



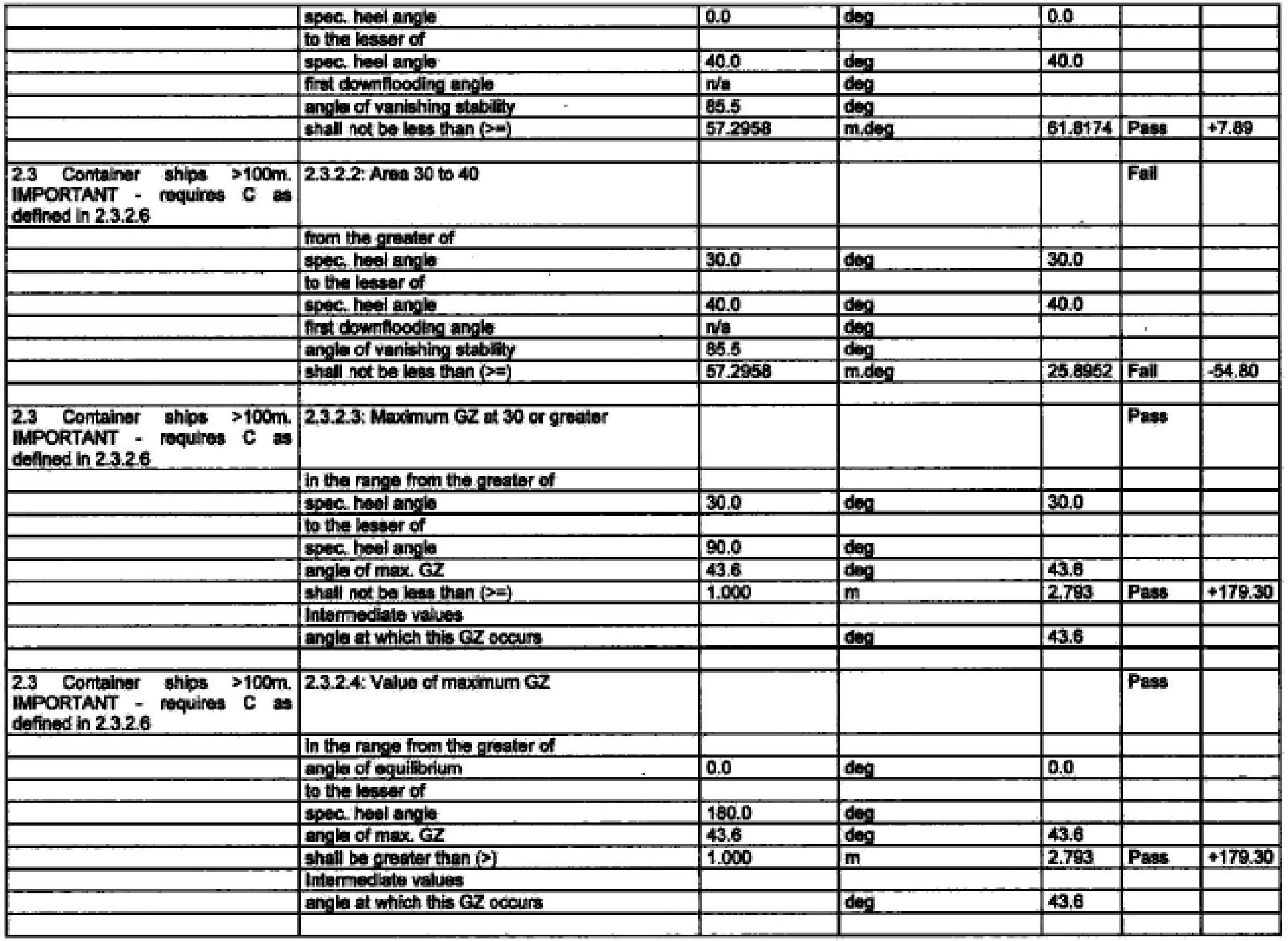
	gust ratio	1.5				
	Area2 integrated to the lesser of					
	2.3: IMO roll back angle from equilibrium (with steady heel arm)	23.5 (-23.0)	deg	-23.0		
	Area 1 upper integration range, to the lesser of:					
	spec. heel angle	50.0	deg	50.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with gust heel arm)	84.9	deg			
	Angle for GZ(max) in GZ ratio, the lesser of:					
	angle of max. GZ	43.6	deg	43.6		
	Select required angle for angle of steady heel ratio:	DeckEdgeImmersionAngle				
	Criteria:				Pass	
	Angle of steady heel shall not be greater than (<=)	16.0	deg	0.5	Pass	+96.67
	Area1 / Area2 shall not be less than (>=)	100.00	%	388.73	Pass	+288.73
	Intermediate values					
	Model windage area		m^2	1916.524		
	Model windage area centroid height (from zero point)		m	12.777		
	Total windage area		m^2	1966.524		
	Total windage area centroid height (from zero point)		m	12.605		
	Heel arm amplitude		m	0.039		
	Equilibrium angle with gust heel arm		deg	0.8		
	Area1 (under GZ), from 0.8 to 50.0 deg.		m.deg	89.5194		
	Area1 (under HA), from 0.8 to 50.0 deg.		m.deg	2.8626		
	Area1, from 0.8 to 50.0 deg.		m.deg	86.6568		
	Area2 (under GZ), from -23.0 to 0.8 deg.		m.deg	-20.9105		
	Area2 (under HA), from -23.0 to 0.8 deg.		m.deg	1.3821		
	Area2, from -23.0 to 0.8 deg.		m.deg	22.2925		
2.1 Fishing vessels	2.1.3.1: Initial GMt for vessels >= 24m in length				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.350	m	4.321	Pass	+1134.57
2.1 Fishing vessels	2.1.3.1: Initial GMt for vessels >= 70m in length				Pass	
	spec. heel angle	0.0	deg			

Table 54. Criteria – FULL LOAD DEPARTURE 16/23 – (Hydromax), (Maxsurf)



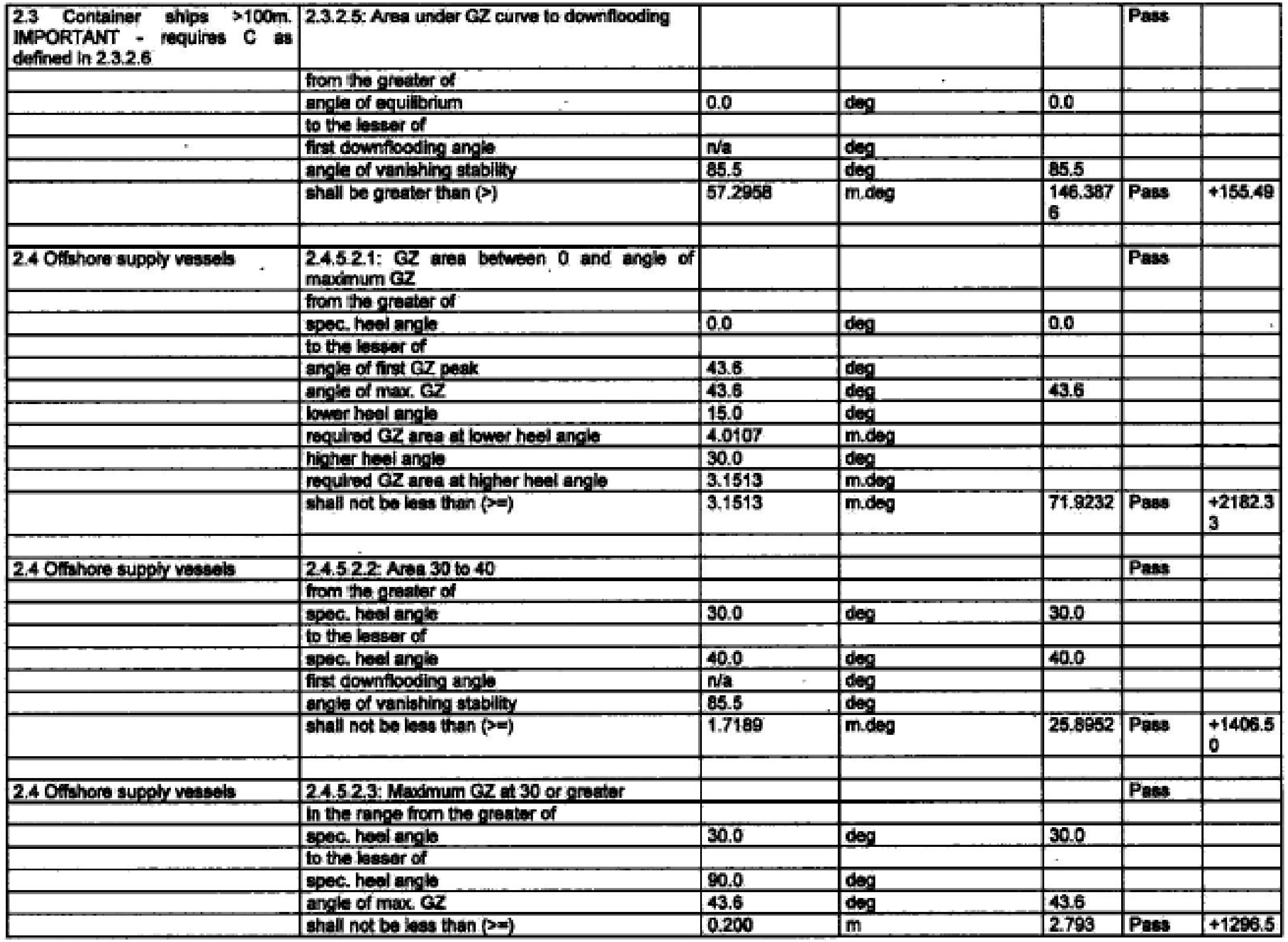
	shall not be less than (>=)	0.150	m	4.321	Pass	+2780.6 7
2.2 Pontoons	2.2.4.1 GZ area: to Max GZ				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	angle of max. GZ	43.6	deg	43.6		
	shall be greater than (>)	4.5837	m.deg	71.9232	Pass	+1469.1 1
2.2 Pontoons	2.2.4.2 Angle of equilibrium ratio				Pass	
	2.2.4.2 Wind heeling arm					
	Ratio of equilibrium angle to	DeckEdgeImm ersionAngle				
	shall be less than (<)	50.00	%	0.00	Pass	+100.00
	Intermediate values					
	Equilibrium angle		deg	0.0		
	Deck edge immersion angle		deg	38.0		
2.2 Pontoons	2.2.4.3 Angle of vanishing stability <=100m in length				Pass	
	shall be greater than (>)	20.0	deg	85.5	Pass	+327.49
2.2 Pontoons	2.2.4.3 Angle of vanishing stability >=150m in length				Pass	
	shall be greater than (>)	15.0	deg	85.5	Pass	+469.98
2.3 Container ships >100m. IMPORTANT - requires C as defined in 2.3.2.6	2.3.2.1: Area to 30				Fail	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	30.0	deg	30.0		
	angle of vanishing stability	85.5	deg			
	shall not be less than (>=)	57.2958	m.deg	35.9222	Fail	-37.30
2.3 Container ships >100m. IMPORTANT - requires C as defined in 2.3.2.6	2.3.2.1: Area 0 to 40				Pass	
	from the greater of					

Table 55. **Criteria** – **FULL LOAD DEPARTURE 17/23** – (Hydromax), (Maxsurf)



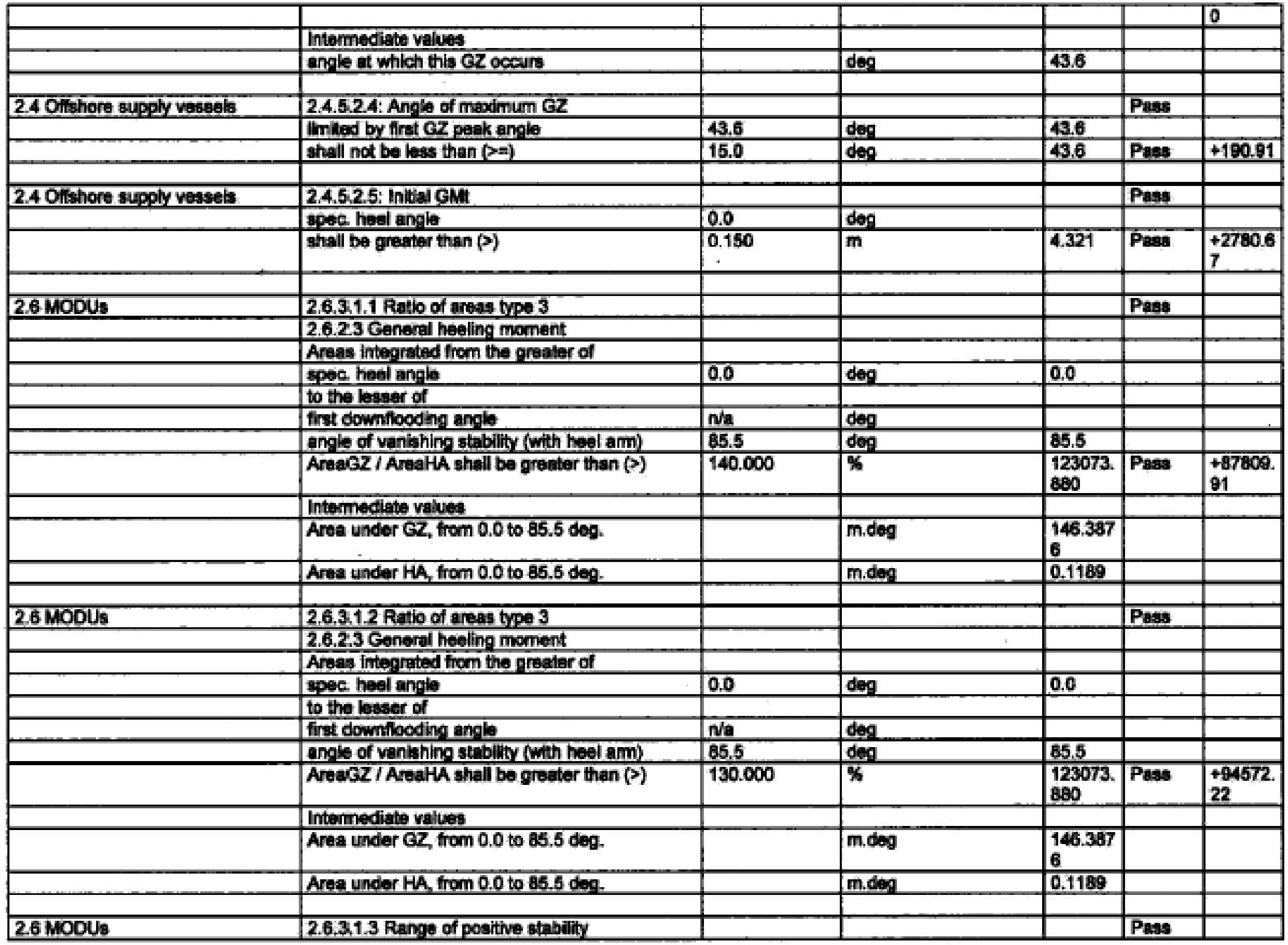
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	85.5	deg			
	shall not be less than (>=)	57.2958	m.deg	61.8174	Pass	+7.89
2.3 Container ships >100m. IMPORTANT - requires C as defined in 2.3.2.6	2.3.2.2: Area 30 to 40				Fail	
	from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	85.5	deg			
	shall not be less than (>=)	57.2958	m.deg	25.8952	Fail	-54.80
2.3 Container ships >100m. IMPORTANT - requires C as defined in 2.3.2.6	2.3.2.3: Maximum GZ at 30 or greater				Pass	
	in the range from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	43.6	deg	43.6		
	shall not be less than (>=)	1.000	m	2.793	Pass	+179.30
	Intermediate values					
	angle at which this GZ occurs		deg	43.6		
2.3 Container ships >100m. IMPORTANT - requires C as defined in 2.3.2.6	2.3.2.4: Value of maximum GZ				Pass	
	in the range from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	180.0	deg			
	angle of max. GZ	43.6	deg	43.6		
	shall be greater than (>)	1.000	m	2.793	Pass	+179.30
	Intermediate values					
	angle at which this GZ occurs		deg	43.6		

Table 56. Criteria – FULL LOAD DEPARTURE 18/23 – (Hydromax), (Maxsurf)



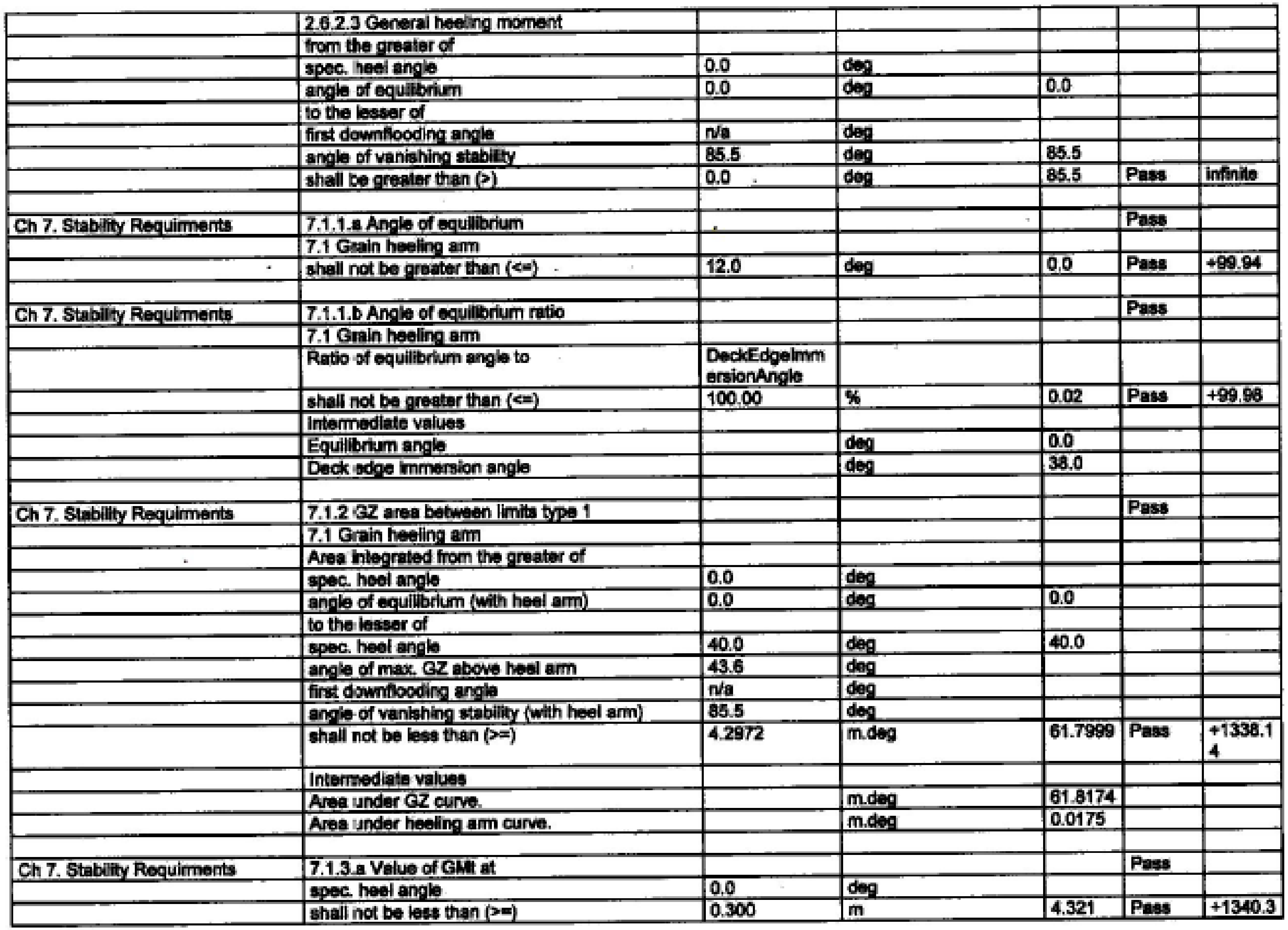
2.3 Container ships >100m. IMPORTANT - requires C as defined in 2.3.2.6	2.3.2.5: Area under GZ curve to downflooding				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	n/a	deg			
	angle of vanishing stability	85.5	deg	85.5		
	shall be greater than (>)	57.2958	m.deg	146.3876	Pass	+155.49
2.4 Offshore supply vessels	2.4.5.2.1: GZ area between 0 and angle of maximum GZ				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	angle of first GZ peak	43.6	deg			
	angle of max. GZ	43.6	deg	43.6		
	lower heel angle	15.0	deg			
	required GZ area at lower heel angle	4.0107	m.deg			
	higher heel angle	30.0	deg			
	required GZ area at higher heel angle	3.1513	m.deg			
	shall not be less than (>=)	3.1513	m.deg	71.9232	Pass	+2182.33
2.4 Offshore supply vessels	2.4.5.2.2: Area 30 to 40				Pass	
	from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	85.5	deg			
	shall not be less than (>=)	1.7189	m.deg	25.8952	Pass	+1406.50
2.4 Offshore supply vessels	2.4.5.2.3: Maximum GZ at 30 or greater				Pass	
	in the range from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	43.6	deg	43.6		
	shall not be less than (>=)	0.200	m	2.793	Pass	+1296.5

Table 57. **Criteria** – **FULL LOAD DEPARTURE 19/23 –** (Hydromax), (Maxsurf)



						0
	Intermediate values					
	angle at which this GZ occurs		deg	43.6		
2.4 Offshore supply vessels	2.4.5.2.4: Angle of maximum GZ				Pass	
	limited by first GZ peak angle	43.6	deg	43.6		
	shall not be less than (>=)	15.0	deg	43.6	Pass	+190.91
2.4 Offshore supply vessels	2.4.5.2.5: Initial GMt				Pass	
	spec. heel angle	0.0	deg			
	shall be greater than (>)	0.150	m	4.321	Pass	+2780.6 7
2.6 MODUs	2.6.3.1.1 Ratio of areas type 3				Pass	
	2.6.2.3 General heeling moment					
	Areas integrated from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with heel arm)	85.5	deg	85.5		
	AreaGZ / AreaHA shall be greater than (>)	140.000	%	123073. 880	Pass	+87809. 91
	Intermediate values					
	Area under GZ, from 0.0 to 85.5 deg.		m.deg	146.387 6		
	Area under HA, from 0.0 to 85.5 deg.		m.deg	0.1189		
2.6 MODUs	2.6.3.1.2 Ratio of areas type 3				Pass	
	2.6.2.3 General heeling moment					
	Areas integrated from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with heel arm)	85.5	deg	85.5		
	AreaGZ / AreaHA shall be greater than (>)	130.000	%	123073. 880	Pass	+94572. 22
	Intermediate values					
	Area under GZ, from 0.0 to 85.5 deg.		m.deg	146.387 6		
	Area under HA, from 0.0 to 85.5 deg.		m.deg	0.1189		
2.6 MODUs	2.6.3.1.3 Range of positive stability				Pass	

Table 58. **Criteria – FULL LOAD DEPARTURE 20/23 –** (Hydromax), (Maxsurf)



	2.6.2.3 General heeling moment					
	from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	n/a	deg			
	angle of vanishing stability	85.5	deg	85.5		
	shall be greater than (>)	0.0	deg	85.5	Pass	infinite
Ch 7. Stability Requirments	7.1.1.a Angle of equilibrium				Pass	
	7.1 Grain heeling arm					
	shall not be greater than (<=)	12.0	deg	0.0	Pass	+99.94
Ch 7. Stability Requirments	7.1.1.b Angle of equilibrium ratio				Pass	
	7.1 Grain heeling arm					
	Ratio of equilibrium angle to	DeckEdgeImmersionAngle				
	shall not be greater than (<=)	100.00	%	0.02	Pass	+99.98
	Intermediate values					
	Equilibrium angle		deg	0.0		
	Deck edge immersion angle		deg	38.0		
Ch 7. Stability Requirments	7.1.2 GZ area between limits type 1				Pass	
	7.1 Grain heeling arm					
	Area integrated from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium (with heel arm)	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	angle of max. GZ above heel arm	43.6	deg			
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with heel arm)	85.5	deg			
	shall not be less than (>=)	4.2972	m.deg	61.7999	Pass	+1338.14
	Intermediate values					
	Area under GZ curve.		m.deg	61.8174		
	Area under heeling arm curve.		m.deg	0.0175		
Ch 7. Stability Requirments	7.1.3.a Value of GMt at				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.300	m	4.321	Pass	+1340.3

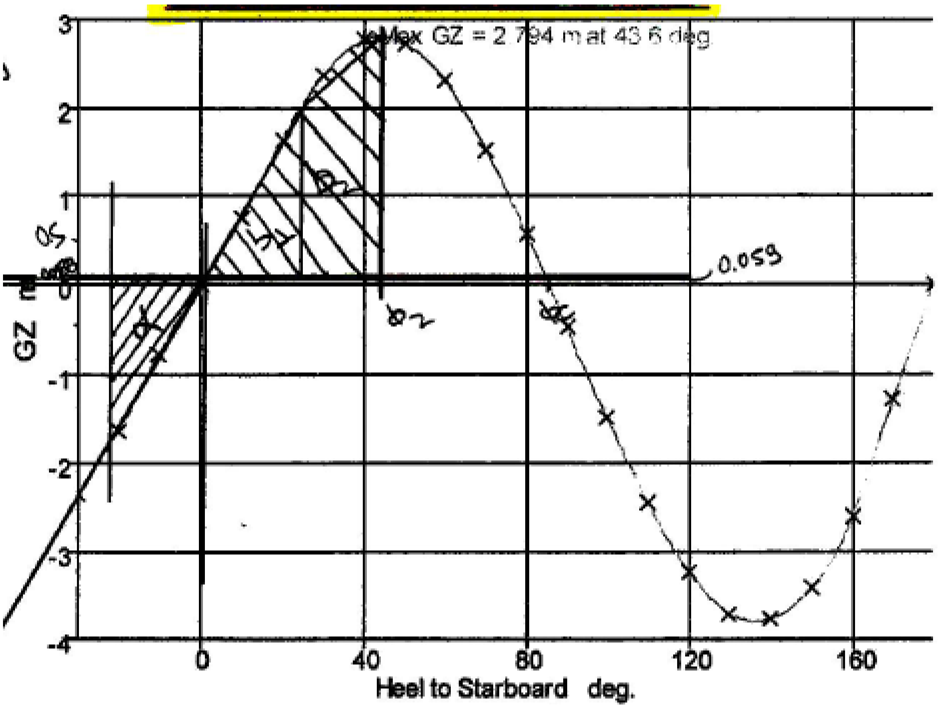
Table 59. **Criteria – FULL LOAD DEPARTURE 21/23 –** (Hydromax), (Maxsurf)

						3
Ch 9. Optional Stability Requirements for Ships without Documents of Authorisation Carrying Partial Cargos of Grain	9.1.5 Value of GMt at				Pass	
	spec. heel angle	0.0	deg			
	9.1.5 IMO required GM for ships carrying grain MSC.23(59)	0.092	m	0.092		
	shall not be less than (>=)	0.092	m	4.321	Pass	+4621.67
MSC.216(82)	Probabilistic Damage Subdivision Index s-factor MSC.216(82)				Fail	
	Vessel type	Passenger				
	Lower angle of range: greater of					
	angle of equilibrium	0.0	deg	0.0		
	Upper angle of range: lesser of					
	first downflooding angle	n/a	deg			
	angle of vanishing stability	85.5	deg	85.5		
	s Final					
	max. GZ limit	0.120	m			
	range limit	16.0	deg			
	K-factor min. heel	7.0	deg			
	K-factor max. heel	15.0	deg			
	s Intermediate					
	max. GZ limit	0.050	m			
	range limit	7.0	deg			
	max. allowable equilibrium heel angle	15.0	deg			
	s Moment					
	intact displacement at subdivision draft	0.000	tonne			
	GZ reduction	0.040	m			
	M_passenger		tonne.m	0.000		
	M_wind		tonne.m	0.000		
	M_survivalcraft		tonne.m	0.000		
	angle of equilibrium must be less than immersion angle of PotentialDfloodingPoints	n/a	deg	n/a		
	angle of equilibrium must be less than immersion angle of DeckEdge	38.0	deg	Pass		
	shall be greater than (>)	0.0000		0.0000	Fail	infinite
	Intermediate values					
	angle of equilibrium		deg	0.0		

Table 60. Criteria – FULL LOAD DEPARTURE 22/23 – (Hydromax), (Maxsurf)

	max. GZ		m	2.793		
	angle of max. GZ		deg	43.6		
	range of stability		deg	85.5		
	K (equil: 0.0 deg)			1.0000		
	max. heel moment		tonne.m	0.000		
	s Final			1.0000		
	s Intermediate			1.0000		
	s Moment			0.0000		
MSC.19(58)	Probabilistic Damage Subdivision Index s-factor MSC.19(58)				Pass	
	Max. GZ in the range from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	n/a	deg			
	angle of vanishing stability	85.5	deg	85.5		
	Apply upper limit to max. GZ	0.100	m			
	Apply upper limit to range of positive stability	20.0	deg			
	shall be greater than (>)	0.0000		1.0000	Pass	infinite
	Intermediate values					
	angle at which max. GZ occurs		deg	43.6		
	C - value (equil: 0.0 deg)			1.000		
	Actual value of max. GZ		m	2.793		
	Effective value of max. GZ		m	0.100		
	Actual value of range of positive stability		deg	85.5		
	Effective value of range of positive stability		deg	20.0		

Table 61. **Criteria** – **FULL LOAD DEPARTURE 23/23 –** (Hydromax), (Maxsurf)



Picture 38. **Weather Criterion Application – Full Load Departure – (Hydromax), (Maxsurf) – Personal Estimation**

According to bibliographical source: (ANNEX 2 RESOLUTION MSC.267(85) (adopted on 4 December 2008) MSC 85/26/Add.1), the weather criterion will be applied for Full Load Departure condition.

A=projected lateral area of the portion of the ship and deck cargo above the waterline (m2)=2350

Z=vertical distance from the center of A to the center of the underwater lateral area or approximately to a point at one half the mean draught (m)=11.7

θfd=36deg, θf=44deg, GM=4.324m, Displ.=24008t, P=504Pa

lw1=(P*A*Z)/(1000*g*Displ.)=(504*2350*11.7)/(1000*9.81*24008)=0.059m

lw2=1.5*lw1=1.5*0.059=0.088m

Lwl=162.11m

Φc=85.6deg

Φ0=1.6deg<min(16deg,0.8*36deg)=min(16deg,28.8deg)=16deg (Ok)

Φ1=109*K*X1*X2*sqrt(r*S)[deg]

Φ2=min(θf,50deg, Φc)=min(44,50,85.6)=44deg

B/d=29.58/6.68=4.428->X1=0.8

Cb=0.77->X2=1.00

Ak=0->K=1.00

OG=KG-d=10.497-6.68=3.817m

r=0.73+0.6*OG/d=0.73+0.6*3.817/6.68=1.073m

C=0.373+0.023*B/d-0.043*(Lwl/100)=0.373+0.023*4.428-0.043*(162.11/100)=0.405

T=(2*C*B)/sqrt(GM)=(2*0.405*29.58)/sqrt(4.324)=11.52sec->S=0.0684

Φc=85.6deg->φ2=min(44deg,50deg,85.6deg)=44deg

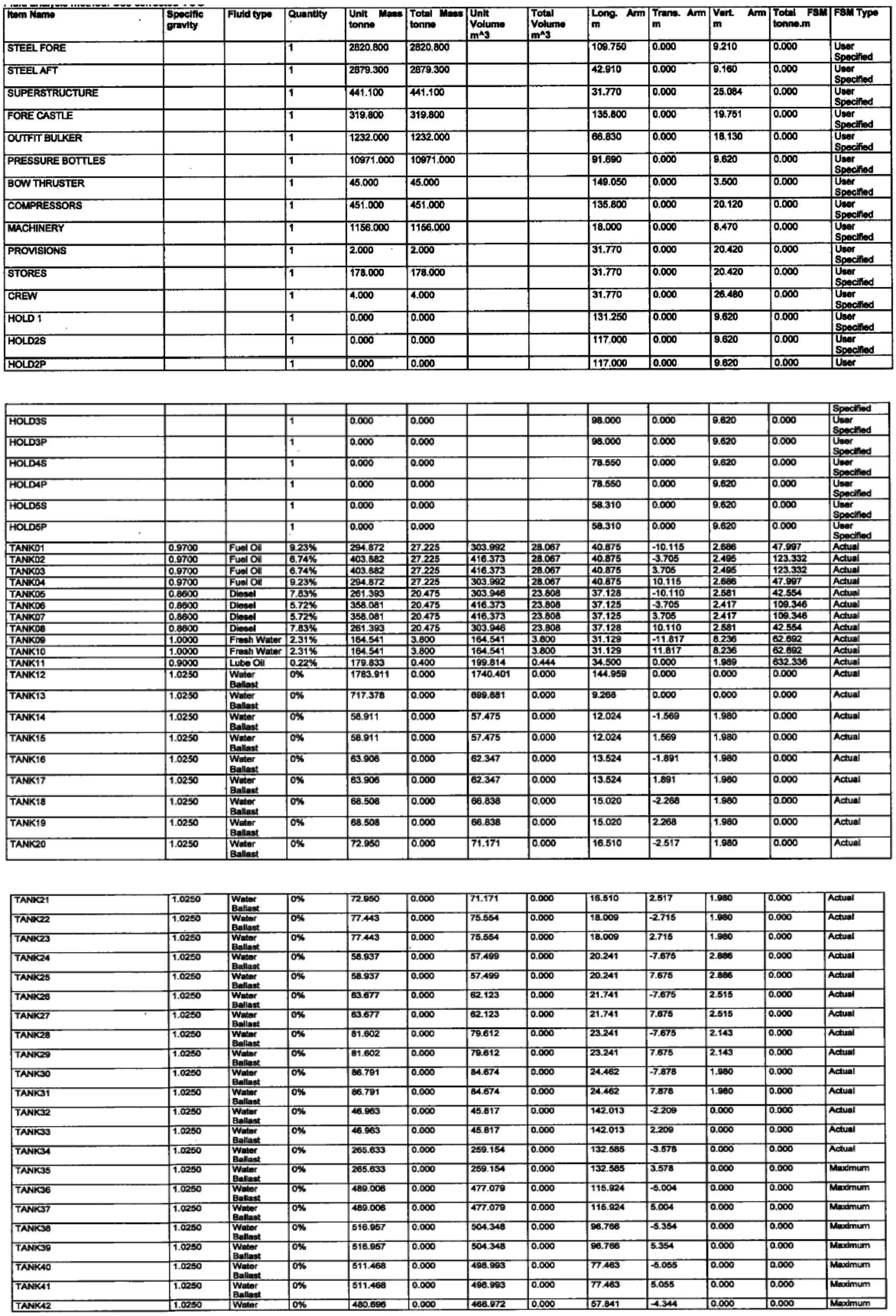
Φ1=109*1.0*0.8*1.0*sqrt(1.073*0.0684)=23.62deg

a=20.56deg*m

b=b1+b2=0.5*24*1.85+0.5*19.2*(1.92+2.64)=65.98deg

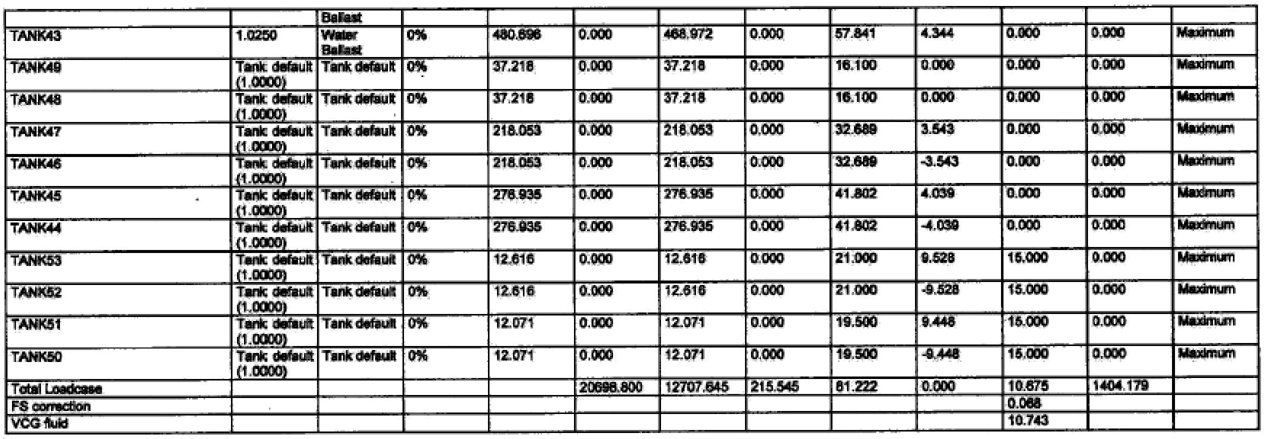
b>a->(OK)

Equation 3. **Weather Criterion Application – Full Load Departure** (ANNEX 2 RESOLUTION MSC.267(85) (adopted on 4 December 2008) MSC 85/26/Add.1)



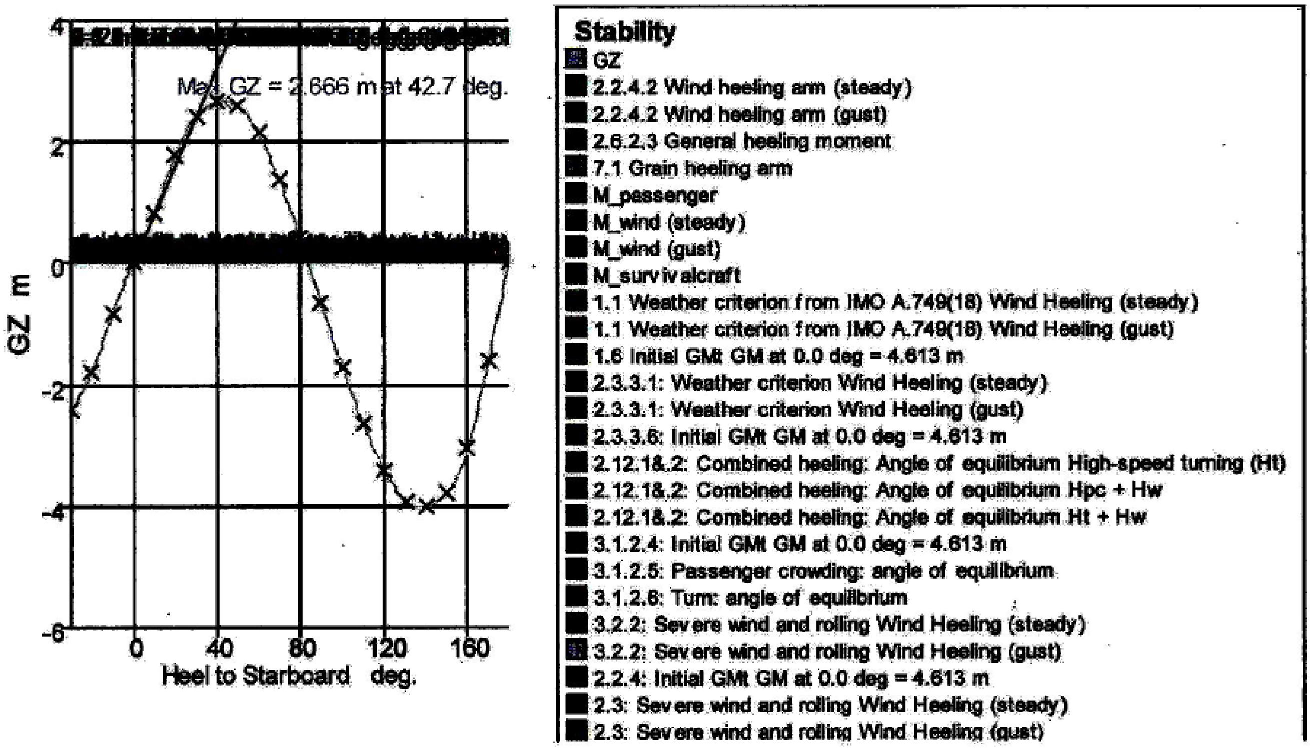
Item Name	Specific gravity	Fluid type	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
STEEL FORE			1	2820.800	2820.800			109.750	0.000	9.210	0.000	User Specified
STEEL AFT			1	2879.300	2879.300			42.910	0.000	9.160	0.000	User Specified
SUPERSTRUCTURE			1	441.100	441.100			31.770	0.000	25.084	0.000	User Specified
FORE CASTLE			1	319.800	319.800			135.800	0.000	19.751	0.000	User Specified
OUTFIT BULKER			1	1232.000	1232.000			66.830	0.000	18.130	0.000	User Specified
PRESSURE BOTTLES			1	10971.000	10971.000			91.690	0.000	9.620	0.000	User Specified
BOW THRUSTER			1	45.000	45.000			149.050	0.000	3.500	0.000	User Specified
COMPRESSORS			1	451.000	451.000			135.800	0.000	20.120	0.000	User Specified
MACHINERY			1	1156.000	1156.000			18.000	0.000	8.470	0.000	User Specified
PROVISIONS			1	2.000	2.000			31.770	0.000	20.420	0.000	User Specified
STORES			1	178.000	178.000			31.770	0.000	20.420	0.000	User Specified
CREW			1	4.000	4.000			31.770	0.000	26.480	0.000	User Specified
HOLD 1			1	0.000	0.000			131.250	0.000	9.620	0.000	User Specified
HOLD2S			1	0.000	0.000			117.000	0.000	9.620	0.000	User Specified
HOLD2P			1	0.000	0.000			117.000	0.000	9.620	0.000	User Specified
HOLD3S			1	0.000	0.000			98.000	0.000	9.620	0.000	User Specified
HOLD3P			1	0.000	0.000			98.000	0.000	9.620	0.000	User Specified
HOLD4S			1	0.000	0.000			78.550	0.000	9.620	0.000	User Specified
HOLD4P			1	0.000	0.000			78.550	0.000	9.620	0.000	User Specified
HOLD5S			1	0.000	0.000			58.310	0.000	9.620	0.000	User Specified
HOLD5P			1	0.000	0.000			58.310	0.000	9.620	0.000	User Specified
TANK01	0.9700	Fuel Oil	9.23%	294.872	27.225	303.992	28.067	40.875	-10.115	2.686	47.997	Actual
TANK02	0.9700	Fuel Oil	6.74%	403.882	27.225	416.373	28.067	40.875	-3.705	2.495	123.332	Actual
TANK03	0.9700	Fuel Oil	6.74%	403.882	27.225	416.373	28.067	40.875	3.705	2.495	123.332	Actual
TANK04	0.9700	Fuel Oil	9.23%	294.872	27.225	303.992	28.067	40.875	10.115	2.686	47.997	Actual
TANK05	0.8600	Diesel	7.83%	261.393	20.475	303.946	23.808	37.128	-10.110	2.581	42.554	Actual
TANK06	0.8600	Diesel	5.72%	358.081	20.475	416.373	23.808	37.125	-3.705	2.417	109.346	Actual
TANK07	0.8600	Diesel	5.72%	358.081	20.475	416.373	23.808	37.125	3.705	2.417	109.346	Actual
TANK08	0.8600	Diesel	7.83%	261.393	20.475	303.946	23.808	37.128	10.110	2.581	42.554	Actual
TANK09	1.0000	Fresh Water	2.31%	164.541	3.800	164.541	3.800	31.129	-11.817	8.236	62.692	Actual
TANK10	1.0000	Fresh Water	2.31%	164.541	3.800	164.541	3.800	31.129	11.817	8.236	62.692	Actual
TANK11	0.9000	Lube Oil	0.22%	179.833	0.400	199.814	0.444	34.500	0.000	1.989	632.336	Actual
TANK12	1.0250	Water Ballast	0%	1783.911	0.000	1740.401	0.000	144.959	0.000	0.000	0.000	Actual
TANK13	1.0250	Water Ballast	0%	717.378	0.000	699.881	0.000	9.268	0.000	0.000	0.000	Actual
TANK14	1.0250	Water Ballast	0%	58.911	0.000	57.475	0.000	12.024	-1.569	1.980	0.000	Actual
TANK15	1.0250	Water Ballast	0%	58.911	0.000	57.475	0.000	12.024	1.569	1.980	0.000	Actual
TANK16	1.0250	Water Ballast	0%	63.906	0.000	62.347	0.000	13.524	-1.891	1.980	0.000	Actual
TANK17	1.0250	Water Ballast	0%	63.906	0.000	62.347	0.000	13.524	1.891	1.980	0.000	Actual
TANK18	1.0250	Water Ballast	0%	68.508	0.000	66.838	0.000	15.020	-2.268	1.980	0.000	Actual
TANK19	1.0250	Water Ballast	0%	68.508	0.000	66.838	0.000	15.020	2.268	1.980	0.000	Actual
TANK20	1.0250	Water Ballast	0%	72.950	0.000	71.171	0.000	16.510	-2.517	1.980	0.000	Actual
TANK21	1.0250	Water Ballast	0%	72.950	0.000	71.171	0.000	16.510	2.517	1.980	0.000	Actual
TANK22	1.0250	Water Ballast	0%	77.443	0.000	75.554	0.000	18.009	-2.715	1.980	0.000	Actual
TANK23	1.0250	Water Ballast	0%	77.443	0.000	75.554	0.000	18.009	2.715	1.980	0.000	Actual
TANK24	1.0250	Water Ballast	0%	58.937	0.000	57.499	0.000	20.241	-7.675	2.886	0.000	Actual
TANK25	1.0250	Water Ballast	0%	58.937	0.000	57.499	0.000	20.241	7.675	2.886	0.000	Actual
TANK26	1.0250	Water Ballast	0%	63.677	0.000	62.123	0.000	21.741	-7.675	2.515	0.000	Actual
TANK27	1.0250	Water Ballast	0%	63.677	0.000	62.123	0.000	21.741	7.675	2.515	0.000	Actual
TANK28	1.0250	Water Ballast	0%	81.602	0.000	79.612	0.000	23.241	-7.675	2.143	0.000	Actual
TANK29	1.0250	Water Ballast	0%	81.602	0.000	79.612	0.000	23.241	7.675	2.143	0.000	Actual
TANK30	1.0250	Water Ballast	0%	86.791	0.000	84.674	0.000	24.462	-7.878	1.980	0.000	Actual
TANK31	1.0250	Water Ballast	0%	86.791	0.000	84.674	0.000	24.462	7.878	1.980	0.000	Actual
TANK32	1.0250	Water Ballast	0%	46.963	0.000	45.817	0.000	142.013	-2.209	0.000	0.000	Actual
TANK33	1.0250	Water Ballast	0%	46.963	0.000	45.817	0.000	142.013	2.209	0.000	0.000	Actual
TANK34	1.0250	Water Ballast	0%	265.633	0.000	259.154	0.000	132.585	-3.578	0.000	0.000	Actual
TANK35	1.0250	Water Ballast	0%	265.633	0.000	259.154	0.000	132.585	3.578	0.000	0.000	Maximum
TANK36	1.0250	Water Ballast	0%	489.006	0.000	477.079	0.000	115.924	-5.004	0.000	0.000	Maximum
TANK37	1.0250	Water Ballast	0%	489.006	0.000	477.079	0.000	115.924	5.004	0.000	0.000	Maximum
TANK38	1.0250	Water Ballast	0%	516.957	0.000	504.348	0.000	96.766	-5.354	0.000	0.000	Maximum
TANK39	1.0250	Water Ballast	0%	516.957	0.000	504.348	0.000	96.766	5.354	0.000	0.000	Maximum
TANK40	1.0250	Water Ballast	0%	511.468	0.000	498.993	0.000	77.463	-5.055	0.000	0.000	Maximum
TANK41	1.0250	Water Ballast	0%	511.468	0.000	498.993	0.000	77.463	5.055	0.000	0.000	Maximum
TANK42	1.0250	Water	0%	480.696	0.000	468.972	0.000	57.841	-4.344	0.000	0.000	Maximum

Table 62. Water Ballast Arrival Equilibrium 1/2 – (Hydromax), (Maxsurf)

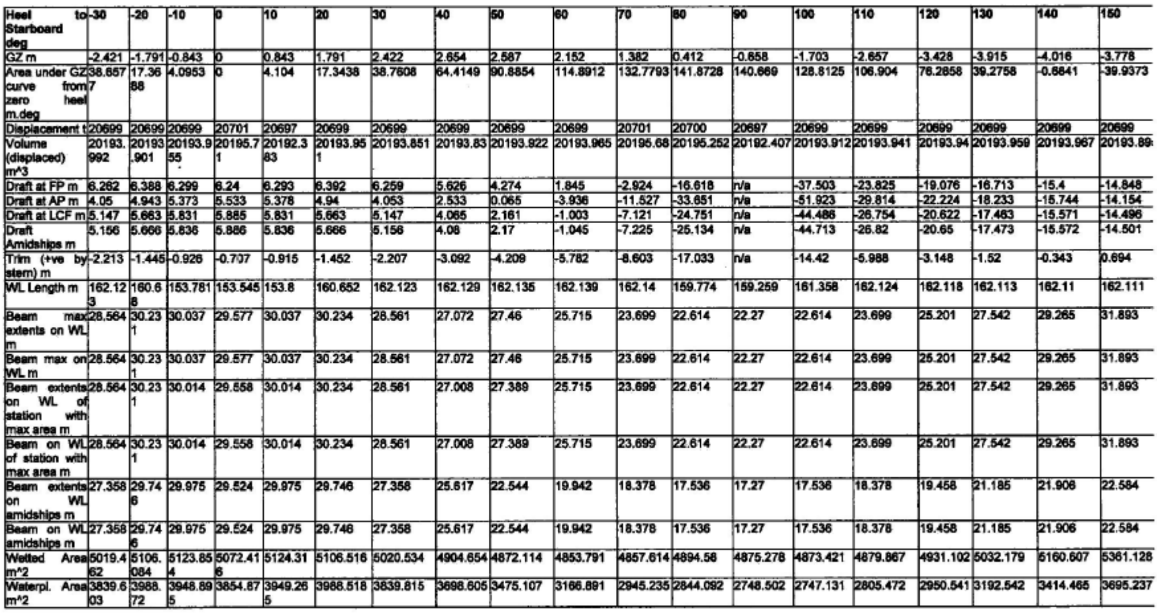


		Ballast											
TANK43	1.0250	Water Ballast	0%	480.696	0.000	468.972	0.000	57.841	4.344	0.000	0.000	Maximum
TANK49	Tank default (1.0000)	Tank default	0%	37.218	0.000	37.218	0.000	16.100	0.000	0.000	0.000	Maximum
TANK48	Tank default (1.0000)	Tank default	0%	37.218	0.000	37.218	0.000	16.100	0.000	0.000	0.000	Maximum
TANK47	Tank default (1.0000)	Tank default	0%	218.053	0.000	218.053	0.000	32.689	3.543	0.000	0.000	Maximum
TANK46	Tank default (1.0000)	Tank default	0%	218.053	0.000	218.053	0.000	32.689	-3.543	0.000	0.000	Maximum
TANK45	Tank default (1.0000)	Tank default	0%	276.935	0.000	276.935	0.000	41.802	4.039	0.000	0.000	Maximum
TANK44	Tank default (1.0000)	Tank default	0%	276.935	0.000	276.935	0.000	41.802	-4.039	0.000	0.000	Maximum
TANK53	Tank default (1.0000)	Tank default	0%	12.616	0.000	12.616	0.000	21.000	9.528	15.000	0.000	Maximum
TANK52	Tank default (1.0000)	Tank default	0%	12.616	0.000	12.616	0.000	21.000	-9.528	15.000	0.000	Maximum
TANK51	Tank default (1.0000)	Tank default	0%	12.071	0.000	12.071	0.000	19.500	9.448	15.000	0.000	Maximum
TANK50	Tank default (1.0000)	Tank default	0%	12.071	0.000	12.071	0.000	19.500	-9.448	15.000	0.000	Maximum
Total Loadcase					20698.800	12707.645	215.545	81.222	0.000	10.675	1404.179	
FS correction										0.068		
VCG fluid										10.743		

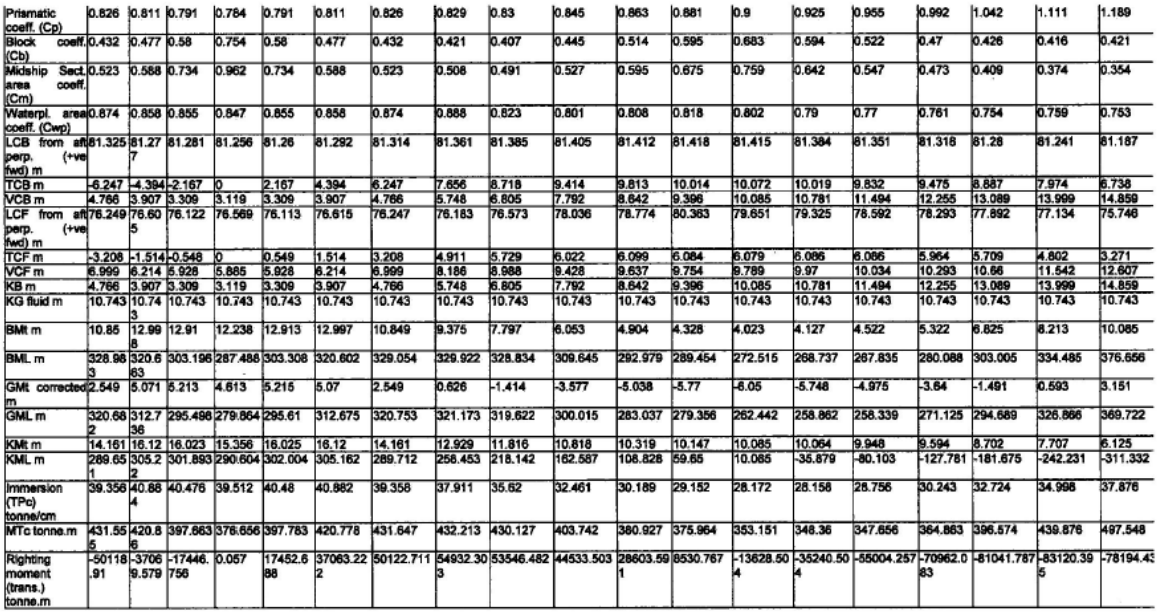
Table 63. Water Ballast Arrival Equilibrium 2/2 (Hydromax), (Maxsurf)



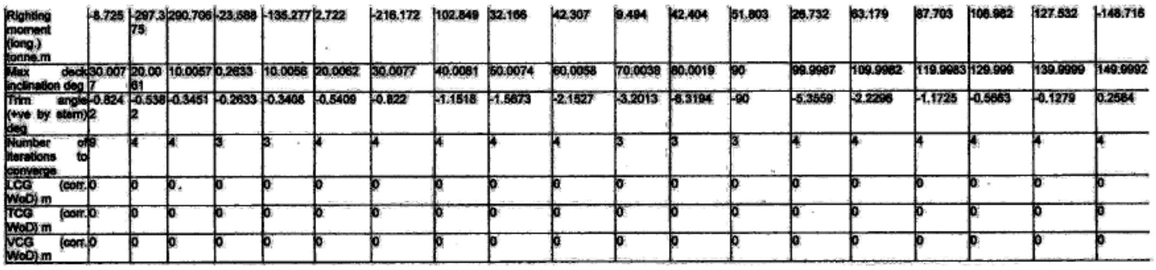
Picture 39. Righting Lever Properties – Water Ballast Arrival – (Hydromax), (Maxsurf)



Heel to Starboard deg	-30	-20	-10	0	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150
GZ m	-2.421	-1.791	-0.843	0	0.843	1.791	2.422	2.654	2.587	2.152	1.382	0.412	-0.858	-1.703	-2.657	-3.428	-3.915	-4.016	-3.778
Area under GZ curve from zero heel m.deg	38.6577	17.3688	4.0953	0	4.104	17.3438	38.7608	64.4149	90.8854	114.8912	132.7793	141.8728	140.669	128.8125	106.904	76.2858	39.2758	-0.6841	-39.9373
Displacement t	20699	20699	20699	20701	20697	20699	20699	20699	20699	20699	20701	20700	20697	20699	20699	20699	20699	20699	20699
Volume (displaced) m^3	20193.992	20193.901	20193.955	20195.71	20192.383	20193.951	20193.851	20193.83	20193.922	20193.965	20195.68	20195.252	20192.407	20193.912	20193.941	20193.94	20193.959	20193.967	20193.89
Draft at FP m	6.262	6.388	6.299	6.24	6.293	6.392	6.259	5.626	4.274	1.845	-2.924	-16.618	n/a	-37.503	-23.825	-19.076	-16.713	-15.4	-14.848
Draft at AP m	4.05	4.943	5.373	5.533	5.378	4.94	4.053	2.533	0.065	-3.936	-11.527	-33.651	n/a	-51.923	-29.814	-22.224	-18.233	-15.744	-14.154
Draft at LCF m	5.147	5.663	5.831	5.885	5.831	5.663	5.147	4.065	2.161	-1.003	-7.121	-24.751	n/a	-44.486	-26.754	-20.622	-17.463	-15.571	-14.496
Draft Amidships m	5.156	5.666	5.836	5.886	5.836	5.666	5.156	4.08	2.17	-1.045	-7.225	-25.134	n/a	-44.713	-26.82	-20.65	-17.473	-15.572	-14.501
Trim (+ve by stern) m	-2.213	-1.445	-0.926	-0.707	-0.915	-1.452	-2.207	-3.092	-4.209	-5.782	-8.603	-17.033	n/a	-14.42	-5.988	-3.148	-1.52	-0.343	0.694
WL Length m	162.123	160.68	153.781	153.545	153.8	160.652	162.123	162.129	162.135	162.139	162.14	159.774	159.259	161.358	162.124	162.118	162.113	162.11	162.111
Beam max extents on WL m	28.564	30.231	30.037	29.577	30.037	30.234	28.561	27.072	27.46	25.715	23.699	22.614	22.27	22.614	23.699	25.201	27.542	29.265	31.893
Beam max on WL m	28.564	30.231	30.037	29.577	30.037	30.234	28.561	27.072	27.46	25.715	23.699	22.614	22.27	22.614	23.699	25.201	27.542	29.265	31.893
Beam extents on WL of station with max area m	28.564	30.231	30.014	29.558	30.014	30.234	28.561	27.008	27.389	25.715	23.699	22.614	22.27	22.614	23.699	25.201	27.542	29.265	31.893
Beam on WL of station with max area m	28.564	30.231	30.014	29.558	30.014	30.234	28.561	27.008	27.389	25.715	23.699	22.614	22.27	22.614	23.699	25.201	27.542	29.265	31.893
Beam extents on WL amidships m	27.358	29.746	29.975	29.524	29.975	29.746	27.358	25.617	22.544	19.942	18.378	17.536	17.27	17.536	18.378	19.458	21.185	21.906	22.584
Beam on WL amidships m	27.358	29.746	29.975	29.524	29.975	29.746	27.358	25.617	22.544	19.942	18.378	17.536	17.27	17.536	18.378	19.458	21.185	21.906	22.584
Wetted Area m^2	5019.462	5106.084	5123.854	5072.416	5124.31	5106.516	5020.534	4904.654	4872.114	4853.791	4857.614	4894.58	4875.278	4873.421	4879.867	4931.102	5032.179	5160.607	5361.128
Waterpl. Area m^2	3839.603	3988.72	3948.895	3854.87	3949.265	3988.518	3839.815	3698.605	3475.107	3166.891	2945.235	2844.092	2748.502	2747.131	2805.472	2950.541	3192.542	3414.465	3695.237

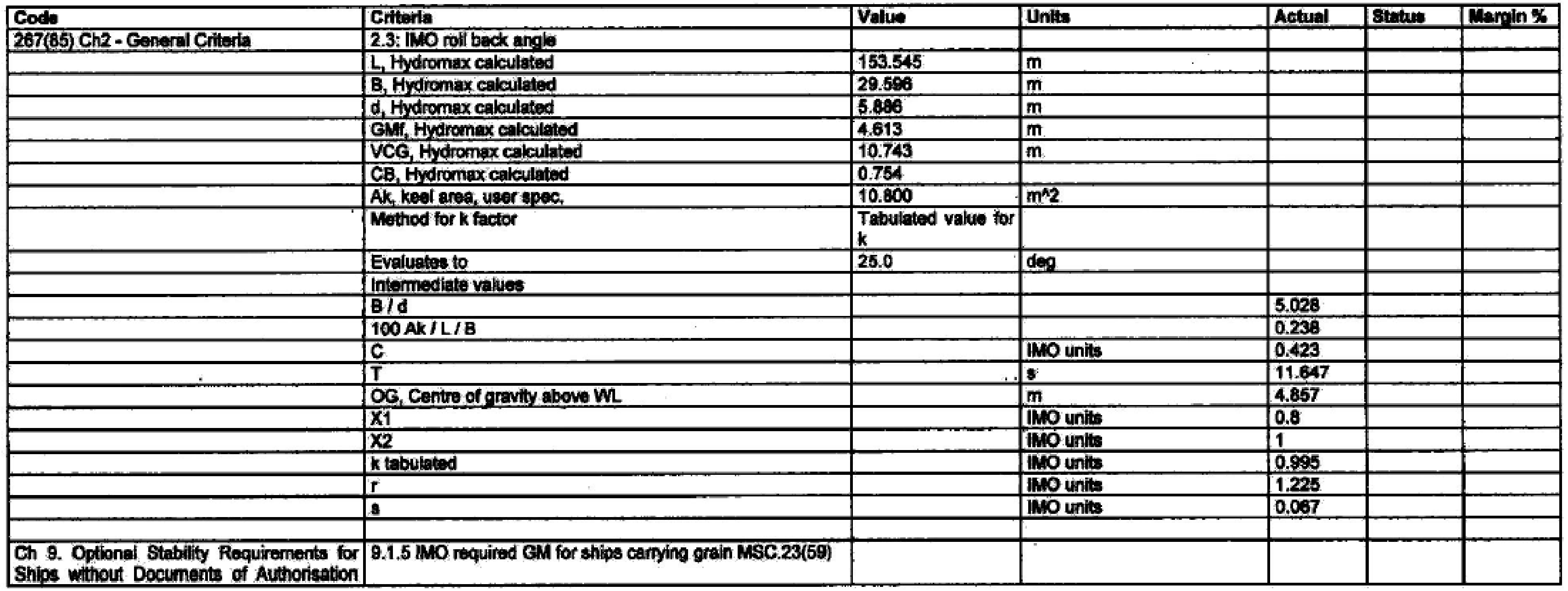


Prismatic coeff. (Cp)	0.826	0.811	0.791	0.784	0.791	0.811	0.826	0.829	0.83	0.845	0.863	0.881	0.9	0.925	0.955	0.992	1.042	1.111	1.189
Block coeff. (Cb)	0.432	0.477	0.58	0.754	0.58	0.477	0.432	0.421	0.407	0.445	0.514	0.595	0.683	0.594	0.522	0.47	0.426	0.416	0.421
Midship Sect. area coeff. (Cm)	0.523	0.588	0.734	0.962	0.734	0.588	0.523	0.508	0.491	0.527	0.595	0.675	0.759	0.642	0.547	0.473	0.409	0.374	0.354
Waterpl. area coeff. (Cwp)	0.874	0.858	0.855	0.847	0.855	0.858	0.874	0.888	0.823	0.801	0.808	0.818	0.802	0.79	0.77	0.761	0.754	0.759	0.753
LCB from aft perp. (+ve fwd) m	81.325	81.277	81.281	81.256	81.26	81.292	81.314	81.361	81.385	81.405	81.412	81.418	81.415	81.384	81.351	81.318	81.28	81.241	81.187
TCB m	-6.247	-4.394	-2.167	0	2.167	4.394	6.247	7.656	8.718	9.414	9.813	10.014	10.072	10.019	9.832	9.475	8.887	7.974	6.738
VCB m	4.766	3.907	3.309	3.119	3.309	3.907	4.766	5.748	6.805	7.792	8.642	9.396	10.085	10.781	11.494	12.255	13.089	13.999	14.859
LCF from aft perp. (+ve fwd) m	76.249	76.605	76.122	76.569	76.113	76.615	76.247	76.183	76.573	78.036	78.774	80.363	79.651	79.325	78.592	78.293	77.892	77.134	75.746
TCF m	-3.208	-1.514	-0.548	0	0.549	1.514	3.208	4.911	5.729	6.022	6.099	6.084	6.079	6.086	6.086	5.964	5.709	4.802	3.271
VCF m	6.999	6.214	5.928	5.885	5.928	6.214	6.999	8.186	8.988	9.428	9.637	9.754	9.789	9.97	10.034	10.293	10.66	11.542	12.607
KB m	4.766	3.907	3.309	3.119	3.309	3.907	4.766	5.748	6.805	7.792	8.642	9.396	10.085	10.781	11.494	12.255	13.089	13.999	14.859
KG fluid m	10.743	10.743	10.743	10.743	10.743	10.743	10.743	10.743	10.743	10.743	10.743	10.743	10.743	10.743	10.743	10.743	10.743	10.743	10.743
BMt m	10.85	12.998	12.91	12.238	12.913	12.997	10.849	9.375	7.797	6.053	4.904	4.328	4.023	4.127	4.522	5.322	6.825	8.213	10.085
BML m	328.983	320.663	303.196	287.488	303.308	320.602	329.054	329.922	328.834	309.645	292.979	289.454	272.515	268.737	267.835	280.088	303.005	334.485	376.656
GMt corrected m	2.549	5.071	5.213	4.613	5.215	5.07	2.549	0.626	-1.414	-3.577	-5.038	-5.77	-6.05	-5.748	-4.975	-3.64	-1.491	0.593	3.151
GML m	320.682	312.736	295.498	279.864	295.61	312.675	320.753	321.173	319.622	300.015	283.037	279.356	262.442	258.862	258.339	271.125	294.689	326.866	369.722
KMt m	14.161	16.12	16.023	15.356	16.025	16.12	14.161	12.929	11.816	10.818	10.319	10.147	10.085	10.064	9.948	9.594	8.702	7.707	6.125
KML m	289.651	305.22	301.893	290.604	302.004	305.162	289.712	256.453	218.142	162.587	108.828	59.65	10.085	-35.879	-80.103	-127.781	-181.675	-242.231	-311.332
Immersion (TPc) tonne/cm	39.356	40.884	40.476	39.512	40.48	40.882	39.358	37.911	35.62	32.461	30.189	29.152	28.172	28.158	28.756	30.243	32.724	34.998	37.876
MTc tonne.m	431.555	420.86	397.863	376.656	397.783	420.778	431.647	432.213	430.127	403.742	380.927	375.964	353.151	348.36	347.656	364.863	396.574	439.876	497.548
Righting moment (trans.) tonne.m	-50118.91	-37069.579	-17446.756	0.057	17452.688	37063.222	50122.711	54932.303	53546.482	44533.503	28603.591	8530.767	-13628.504	-35240.504	-55004.257	-70962.083	-81041.787	-83120.395	-78194.43



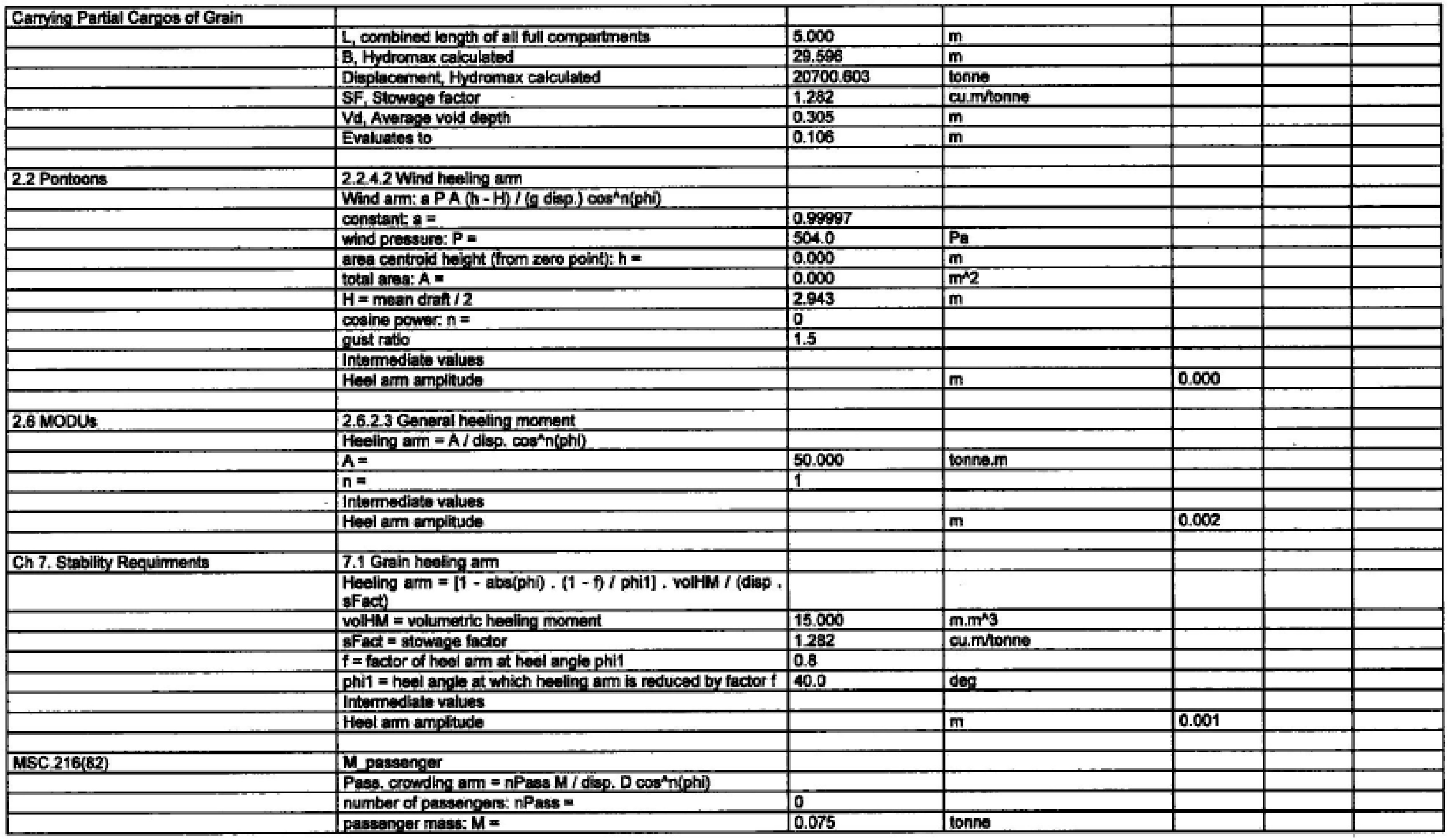
Righting moment (long.) tonne.m	-8.725	-297.375	290.706	-23.588	-135.277	2.722	-216.172	102.849	32.166	42.307	9.494	42.404	51.803	26.732	63.179	87.703	106.982	127.532	-148.716
Max deck inclination deg	30.0077	20.0061	10.0057	0.2633	10.0056	20.0062	30.0077	40.0081	50.0074	60.0058	70.0038	80.0019	90	99.9987	109.9982	119.9983	129.999	139.9999	149.9992
Trim angle (+ve by stern) deg	-0.8242	-0.5382	-0.3451	-0.2633	-0.3408	-0.5409	-0.822	-1.1518	-1.5673	-2.1527	-3.2013	-6.3194	-90	-5.3559	-2.2296	-1.1725	-0.5663	-0.1279	0.2584
Number of iterations to converge	9	4	4	3	3	4	4	4	4	4	3	3	3	4	4	4	4	4	4
LCG (corr. WoD) m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TCG (corr. WoD) m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
VCG (corr. WoD) m	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 64. **Righting Lever Properties – Water Ballast Arrival – (Hydromax), (Maxsurf)**



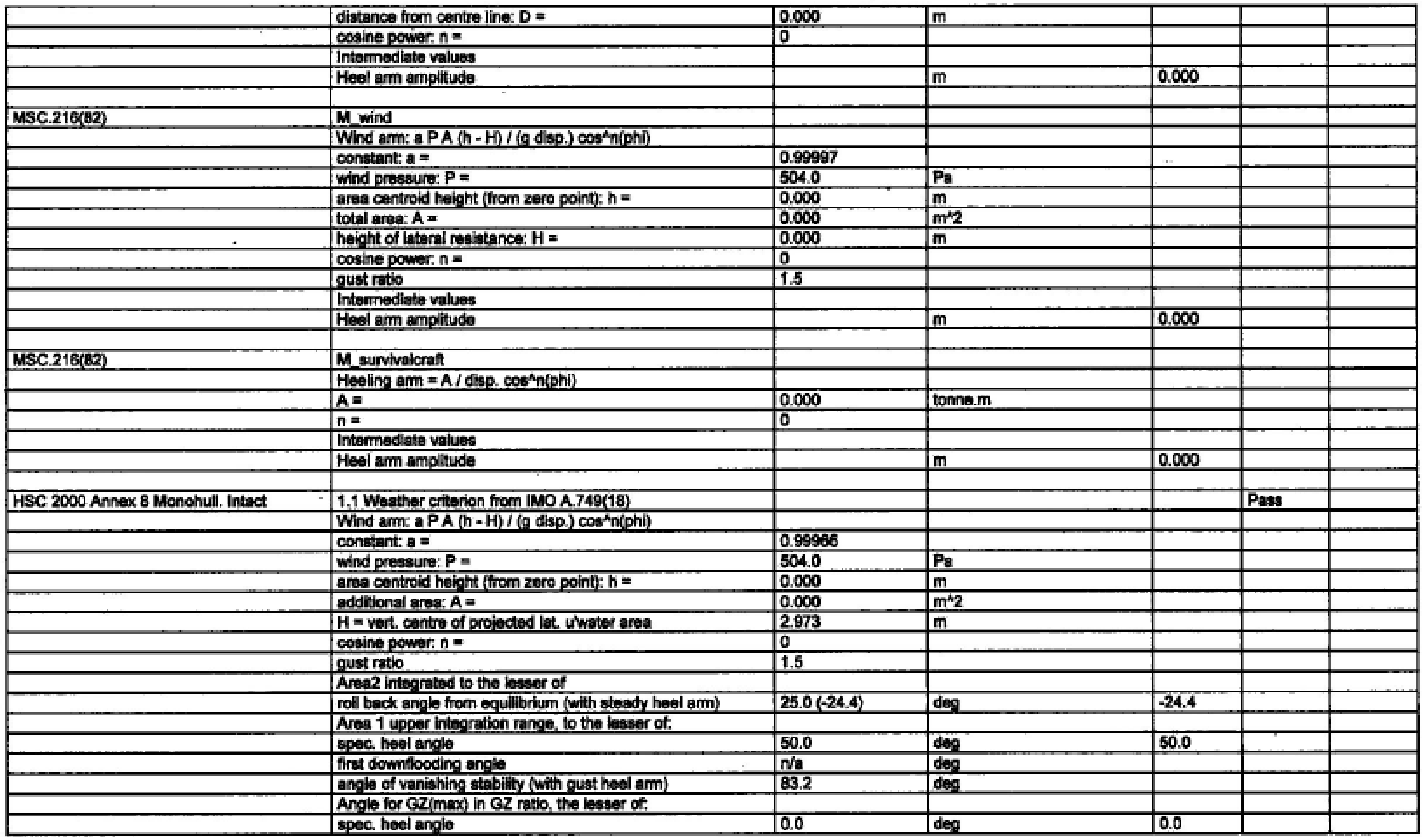
Code	Criteria	Value	Units	Actual	Status	Margin %
267(85) Ch2 - General Criteria	2.3: IMO roll back angle					
	L, Hydromax calculated	153.545	m			
	B, Hydromax calculated	29.596	m			
	d, Hydromax calculated	5.886	m			
	GMf, Hydromax calculated	4.613	m			
	VCG, Hydromax calculated	10.743	m			
	CB, Hydromax calculated	0.754				
	Ak, keel area, user spec.	10.800	m^2			
	Method for k factor	Tabulated value for k				
	Evaluates to	25.0	deg			
	Intermediate values					
	B / d			5.028		
	100 Ak / L / B			0.238		
	C		IMO units	0.423		
	T		s	11.647		
	OG, Centre of gravity above WL		m	4.857		
	X1		IMO units	0.8		
	X2		IMO units	1		
	k tabulated		IMO units	0.995		
	r		IMO units	1.225		
	s		IMO units	0.067		
Ch 9. Optional Stability Requirements for Ships without Documents of Authorisation	9.1.5 IMO required GM for ships carrying grain MSC.23(59)					

Table 65. Criteria – WATER BALLAST ARRIVAL 1/20 – (Hydromax), (Maxsurf)



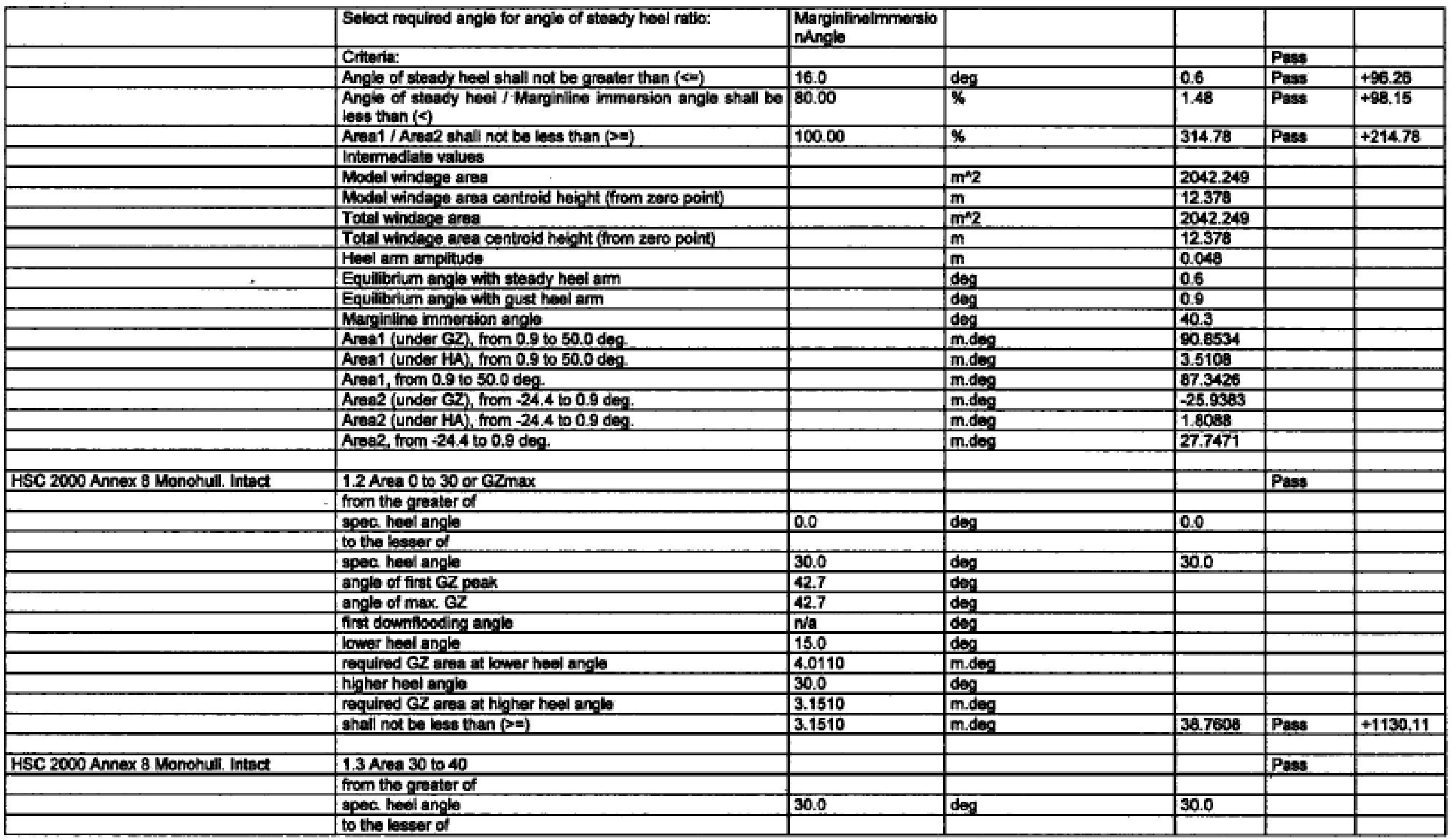
Carrying Partial Cargos of Grain						
	L, combined length of all full compartments	5.000	m			
	B, Hydromax calculated	29.596	m			
	Displacement, Hydromax calculated	20700.603	tonne			
	SF, Stowage factor	1.282	cu.m/tonne			
	Vd, Average void depth	0.305	m			
	Evaluates to	0.106	m			
2.2 Pontoons	2.2.4.2 Wind heeling arm					
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99997				
	wind pressure: P =	504.0	Pa			
	area centroid height (from zero point): h =	0.000	m			
	total area: A =	0.000	m^2			
	H = mean draft / 2	2.943	m			
	cosine power: n =	0				
	gust ratio	1.5				
	Intermediate values					
	Heel arm amplitude		m	0.000		
2.6 MODUs	2.6.2.3 General heeling moment					
	Heeling arm = A / disp. cos^n(phi)					
	A =	50.000	tonne.m			
	n =	1				
	Intermediate values					
	Heel arm amplitude		m	0.002		
Ch 7. Stability Requirments	7.1 Grain heeling arm					
	Heeling arm = [1 - abs(phi) . (1 - f) / phi1] . volHM / (disp . sFact)					
	volHM = volumetric heeling moment	15.000	m.m^3			
	sFact = stowage factor	1.282	cu.m/tonne			
	f = factor of heel arm at heel angle phi1	0.8				
	phi1 = heel angle at which heeling arm is reduced by factor f	40.0	deg			
	Intermediate values					
	Heel arm amplitude		m	0.001		
MSC.216(82)	M_passenger					
	Pass. crowding arm = nPass M / disp. D cos^n(phi)					
	number of passengers: nPass =	0				
	passenger mass: M =	0.075	tonne			

Table 66. Criteria – WATER BALLAST ARRIVAL 2/20 – (Hydromax), (Maxsurf)



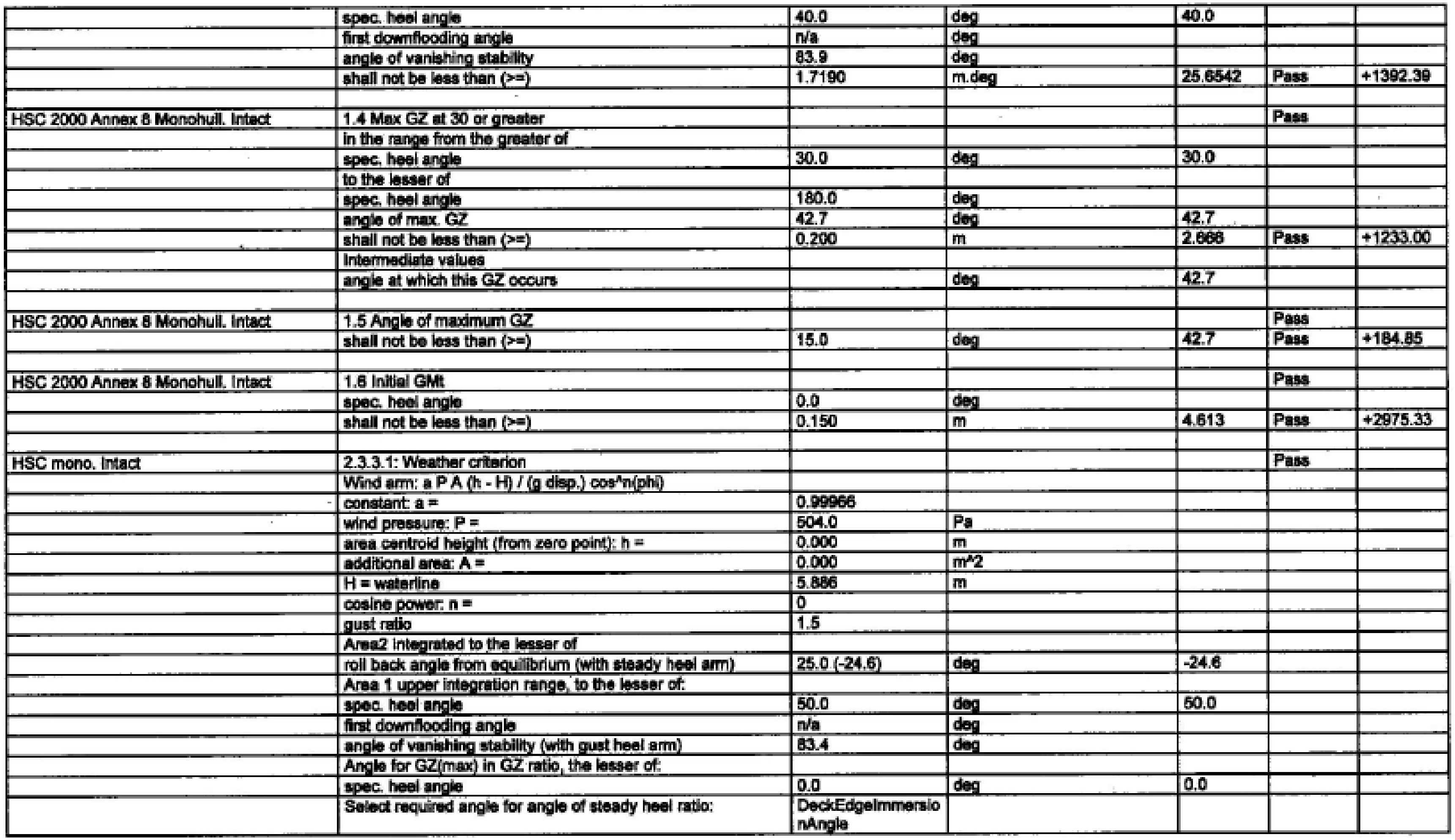
	distance from centre line: D =	0.000	m			
	cosine power: n =	0				
	Intermediate values					
	Heel arm amplitude		m	0.000		
MSC.216(82)	M_wind					
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99997				
	wind pressure: P =	504.0	Pa			
	area centroid height (from zero point): h =	0.000	m			
	total area: A =	0.000	m^2			
	height of lateral resistance: H =	0.000	m			
	cosine power: n =	0				
	gust ratio	1.5				
	Intermediate values					
	Heel arm amplitude		m	0.000		
MSC.216(82)	M_survivalcraft					
	Heeling arm = A / disp. cos^n(phi)					
	A =	0.000	tonne.m			
	n =	0				
	Intermediate values					
	Heel arm amplitude		m	0.000		
HSC 2000 Annex 8 Monohull. Intact	1.1 Weather criterion from IMO A.749(18)				Pass	
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99966				
	wind pressure: P =	504.0	Pa			
	area centroid height (from zero point): h =	0.000	m			
	additional area: A =	0.000	m^2			
	H = vert. centre of projected lat. u'water area	2.973	m			
	cosine power: n =	0				
	gust ratio	1.5				
	Area2 integrated to the lesser of					
	roll back angle from equilibrium (with steady heel arm)	25.0 (-24.4)	deg	-24.4		
	Area 1 upper integration range, to the lesser of:					
	spec. heel angle	50.0	deg	50.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with gust heel arm)	83.2	deg			
	Angle for GZ(max) in GZ ratio, the lesser of:					
	spec. heel angle	0.0	deg	0.0		

Table 67. Criteria – WATER BALLAST ARRIVAL 3/20 – (Hydromax), (Maxsurf)



	Select required angle for angle of steady heel ratio:	MarginlineImmersionAngle				
	Criteria:				Pass	
	Angle of steady heel shall not be greater than (<=)	16.0	deg	0.6	Pass	+96.26
	Angle of steady heel / Marginline immersion angle shall be less than (<)	80.00	%	1.48	Pass	+98.15
	Area1 / Area2 shall not be less than (>=)	100.00	%	314.78	Pass	+214.78
	Intermediate values					
	Model windage area		m^2	2042.249		
	Model windage area centroid height (from zero point)		m	12.378		
	Total windage area		m^2	2042.249		
	Total windage area centroid height (from zero point)		m	12.378		
	Heel arm amplitude		m	0.048		
	Equilibrium angle with steady heel arm		deg	0.6		
	Equilibrium angle with gust heel arm		deg	0.9		
	Marginline immersion angle		deg	40.3		
	Area1 (under GZ), from 0.9 to 50.0 deg.		m.deg	90.8534		
	Area1 (under HA), from 0.9 to 50.0 deg.		m.deg	3.5108		
	Area1, from 0.9 to 50.0 deg.		m.deg	87.3426		
	Area2 (under GZ), from -24.4 to 0.9 deg.		m.deg	-25.9383		
	Area2 (under HA), from -24.4 to 0.9 deg.		m.deg	1.8088		
	Area2, from -24.4 to 0.9 deg.		m.deg	27.7471		
HSC 2000 Annex 8 Monohull. Intact	1.2 Area 0 to 30 or GZmax				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	30.0	deg	30.0		
	angle of first GZ peak	42.7	deg			
	angle of max. GZ	42.7	deg			
	first downflooding angle	n/a	deg			
	lower heel angle	15.0	deg			
	required GZ area at lower heel angle	4.0110	m.deg			
	higher heel angle	30.0	deg			
	required GZ area at higher heel angle	3.1510	m.deg			
	shall not be less than (>=)	3.1510	m.deg	38.7608	Pass	+1130.11
HSC 2000 Annex 8 Monohull. Intact	1.3 Area 30 to 40				Pass	
	from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					

Table 68. Criteria – WATER BALLAST ARRIVAL 4/20 – (Hydromax), (Maxsurf)



	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	83.9	deg			
	shall not be less than (>=)	1.7190	m.deg	25.6542	Pass	+1392.39
HSC 2000 Annex 8 Monohull. Intact	1.4 Max GZ at 30 or greater				Pass	
	in the range from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	180.0	deg			
	angle of max. GZ	42.7	deg	42.7		
	shall not be less than (>=)	0.200	m	2.666	Pass	+1233.00
	Intermediate values					
	angle at which this GZ occurs		deg	42.7		
HSC 2000 Annex 8 Monohull. Intact	1.5 Angle of maximum GZ				Pass	
	shall not be less than (>=)	15.0	deg	42.7	Pass	+184.85
HSC 2000 Annex 8 Monohull. Intact	1.6 Initial GMt				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.150	m	4.613	Pass	+2975.33
HSC mono. Intact	2.3.3.1: Weather criterion				Pass	
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99966				
	wind pressure: P =	504.0	Pa			
	area centroid height (from zero point): h =	0.000	m			
	additional area: A =	0.000	m^2			
	H = waterline	5.886	m			
	cosine power: n =	0				
	gust ratio	1.5				
	Area2 integrated to the lesser of					
	roll back angle from equilibrium (with steady heel arm)	25.0 (-24.6)	deg	-24.6		
	Area 1 upper integration range, to the lesser of:					
	spec. heel angle	50.0	deg	50.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with gust heel arm)	83.4	deg			
	Angle for GZ(max) in GZ ratio, the lesser of:					
	spec. heel angle	0.0	deg	0.0		
	Select required angle for angle of steady heel ratio:	DeckEdgeImmersionAngle				

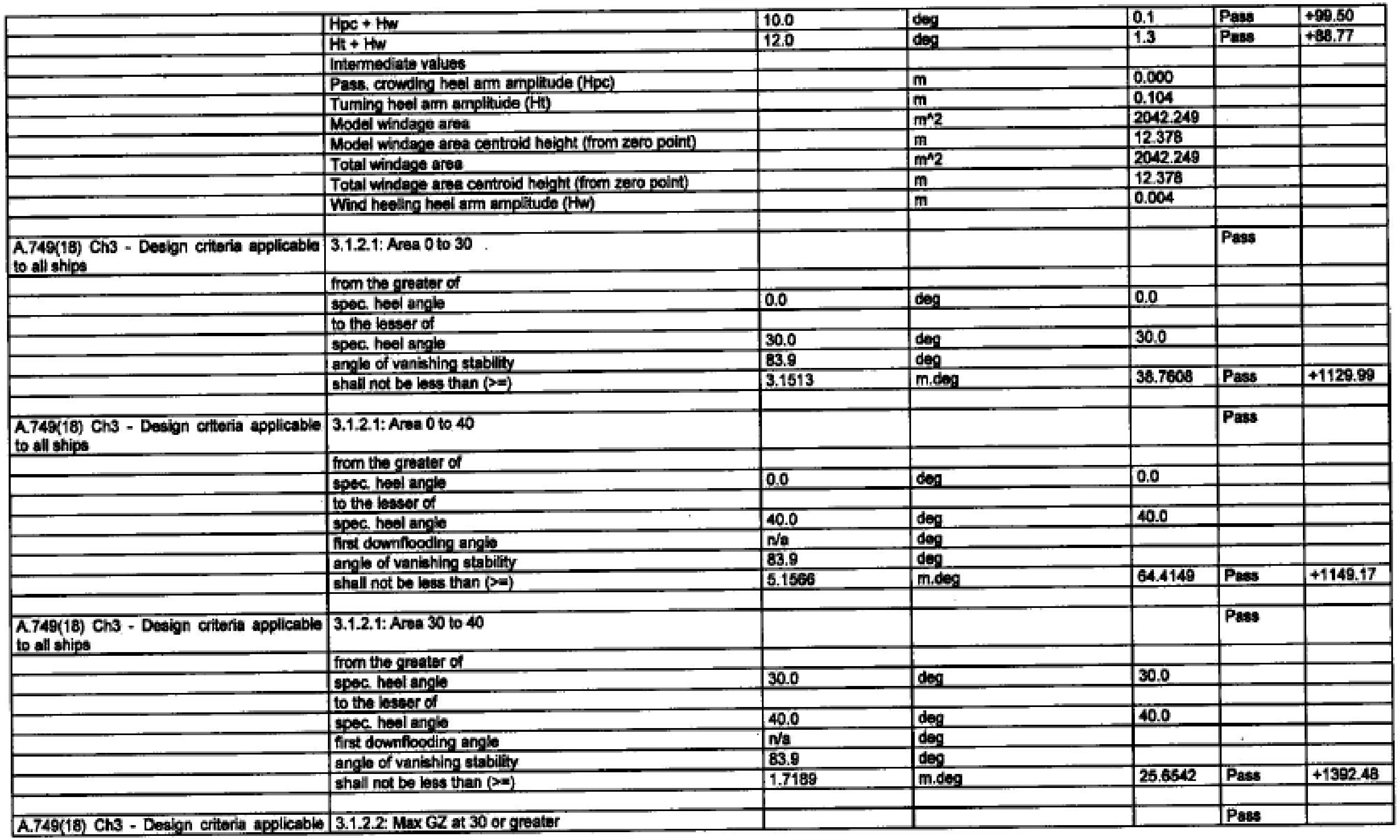
Table 69. **Criteria – WATER BALLAST ARRIVAL 5/20 – (Hydromax), (Maxsurf)**

	Criteria:				Pass	
	Angle of steady heel shall not be greater than (<=)	16.0	deg	0.4	Pass	+97.42
	Angle of steady heel / Deck edge immersion angle shall not be greater than (<=)	80.00	%	1.02	Pass	+98.72
	Area1 / Area2 shall not be less than (>=)	100.00	%	320.53	Pass	+220.53
	Intermediate values					
	Model windage area		m^2	2042.249		
	Model windage area centroid height (from zero point)		m	12.378		
	Total windage area		m^2	2042.249		
	Total windage area centroid height (from zero point)		m	12.378		
	Heel arm amplitude		m	0.033		
	Equilibrium angle with steady heel arm		deg	0.4		
	Equilibrium angle with gust heel arm		deg	0.6		
	Deck edge immersion angle		deg	40.6		
	Area1 (under GZ), from 0.6 to 50.0 deg.		m.deg	90.8702		
	Area1 (under HA), from 0.6 to 50.0 deg.		m.deg	2.4370		
	Area1, from 0.6 to 50.0 deg.		m.deg	88.4331		
	Area2 (under GZ), from -24.6 to 0.6 deg.		m.deg	-26.3458		
	Area2 (under HA), from -24.6 to 0.6 deg.		m.deg	1.2440		
	Area2, from -24.6 to 0.6 deg.		m.deg	27.5897		
HSC mono. Intact	2.3.3.2: Area 0 to 30 or GZmax				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	30.0	deg	30.0		
	first downflooding angle	n/a	deg			
	lower heel angle	15.0	deg			
	required GZ area at lower heel angle	4.0107	m.deg			
	higher heel angle	30.0	deg			
	required GZ area at higher heel angle	3.1513	m.deg			
	shall not be less than (>=)	3.1513	m.deg	38.7608	Pass	+1129.99
HSC mono. Intact	2.3.3.3: Area 30 to 40				Pass	
	from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	83.9	deg			
	shall not be less than (>=)	1.7189	m.deg	25.6542	Pass	+1392.48

Table 70. **Criteria – WATER BALLAST ARRIVAL 6/20 – (Hydromax), (Maxsurf)**

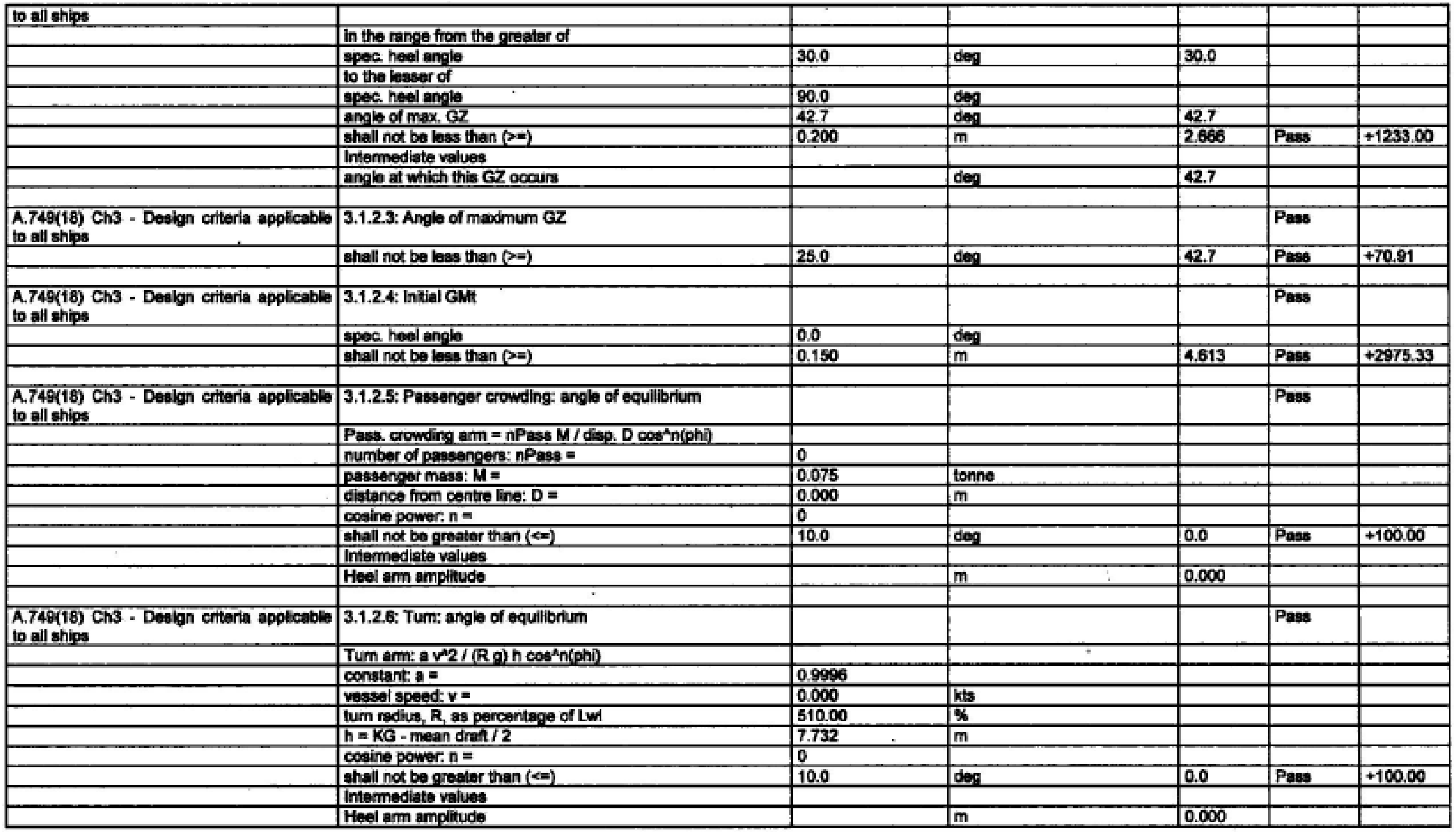
HSC mono. intact	2.3.3.4: Max GZ at 30 or greater				Pass	
	in the range from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	42.7	deg	42.7		
	shall not be less than (>=)	0.200	m	2.666	Pass	+1233.00
	Intermediate values					
	angle at which this GZ occurs		deg	42.7		
HSC mono. intact	2.3.3.5: Angle of maximum GZ				Pass	
	shall not be less than (>=)	15.0	deg	42.7	Pass	+184.85
HSC mono. intact	2.3.3.6: Initial GMt				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.150	m	4.613	Pass	+2975.33
HSC mono. intact	2.12.1&2: Combined heeling: Angle of equilibrium				Pass	
	Pass. crowding arm = nPass M / disp. D cos^n(phi)					
	number of passengers: nPass =	50				
	passenger mass: M =	0.075	tonne			
	distance from centre line: D =	2.000	m			
	cosine power: n =	0				
	Turn arm: a v^2 / (R g) h cos^n(phi)					
	constant: a =	1				
	vessel speed: v =	9.999	kts			
	turn radius: R =	200.000	m			
	h = KG - vert. centre of projected lat. u'water area	7.702	m			
	cosine power: n =	0				
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	1				
	wind model	Pressure				
	wind pressure: P =	56.0	Pa			
	area centroid height (from zero point): h =	3.000	m			
	additional area: A =	0.000	m^2			
	H = waterline	5.886	m			
	cosine power: n =	0				
	Criteria: Angle of equilibrium due to the following shall not be greater than (<=)...				Pass	
	High-speed turning (Ht)	8.0	deg	1.3	Pass	+83.73

Table 71. Criteria – WATER BALLAST ARRIVAL 7/20 – (Hydromax), (Maxsurf)



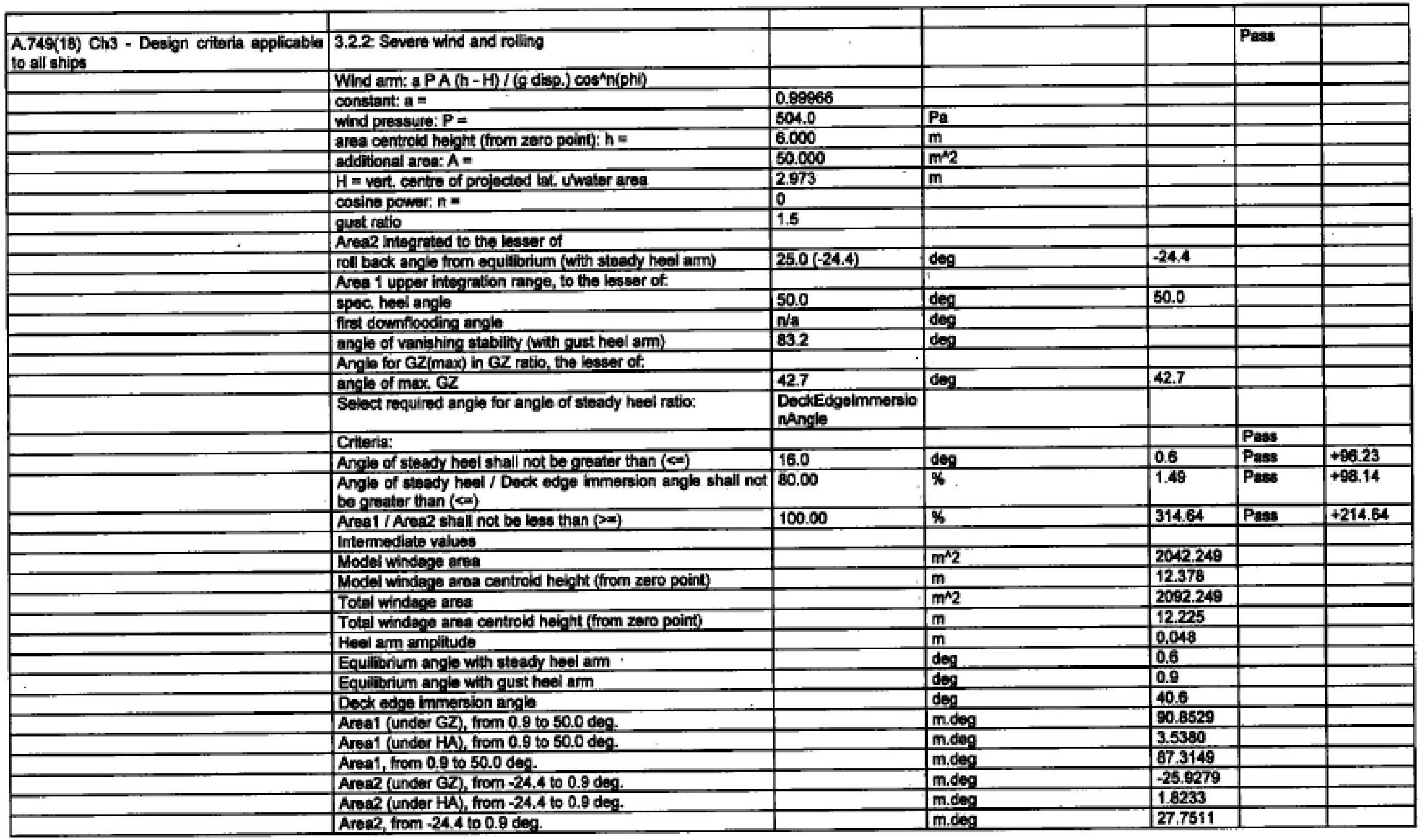
	Hpc + Hw	10.0	deg	0.1	Pass	+99.50
	Ht + Hw	12.0	deg	1.3	Pass	+88.77
	Intermediate values					
	Pass. crowding heel arm amplitude (Hpc)		m	0.000		
	Turning heel arm amplitude (Ht)		m	0.104		
	Model windage area		m^2	2042.249		
	Model windage area centroid height (from zero point)		m	12.378		
	Total windage area		m^2	2042.249		
	Total windage area centroid height (from zero point)		m	12.378		
	Wind heeling heel arm amplitude (Hw)		m	0.004		
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 0 to 30				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	30.0	deg	30.0		
	angle of vanishing stability	83.9	deg			
	shall not be less than (>=)	3.1513	m.deg	38.7608	Pass	+1129.99
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 0 to 40				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	83.9	deg			
	shall not be less than (>=)	5.1566	m.deg	64.4149	Pass	+1149.17
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.1: Area 30 to 40				Pass	
	from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	83.9	deg			
	shall not be less than (>=)	1.7189	m.deg	25.6542	Pass	+1392.48
A.749(18) Ch3 - Design criteria applicable	3.1.2.2: Max GZ at 30 or greater				Pass	

Table 72. Criteria – WATER BALLAST ARRIVAL 8/20 – (Hydromax), (Maxsurf)



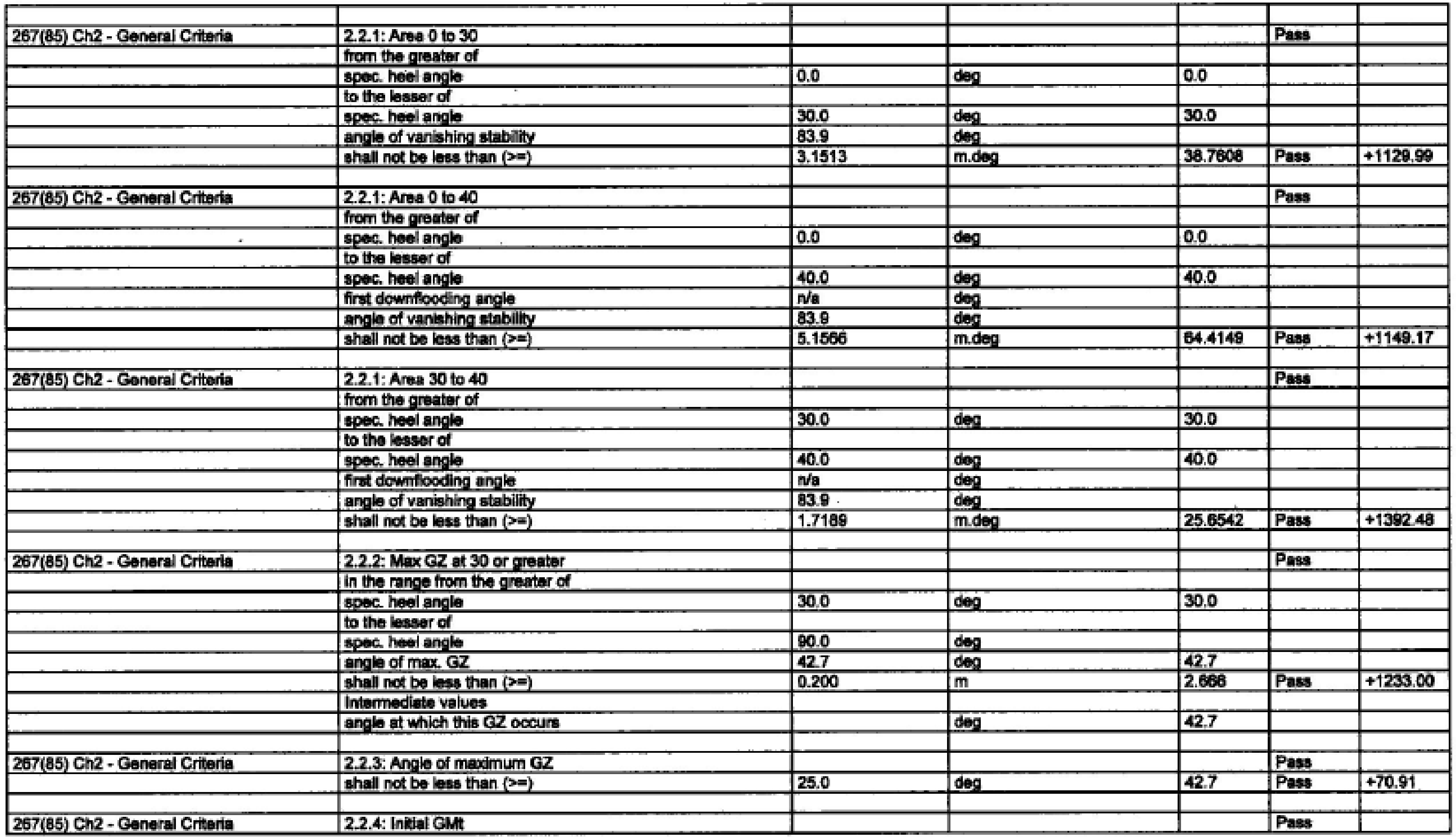
to all ships						
	In the range from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	42.7	deg	42.7		
	shall not be less than (>=)	0.200	m	2.666	Pass	+1233.00
	Intermediate values					
	angle at which this GZ occurs		deg	42.7		
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.3: Angle of maximum GZ				Pass	
	shall not be less than (>=)	25.0	deg	42.7	Pass	+70.91
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.4: Initial GMt				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.150	m	4.613	Pass	+2975.33
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.5: Passenger crowding: angle of equilibrium				Pass	
	Pass. crowding arm = nPass M / disp. D cos^n(phi)					
	number of passengers: nPass =	0				
	passenger mass: M =	0.075	tonne			
	distance from centre line: D =	0.000	m			
	cosine power: n =	0				
	shall not be greater than (<=)	10.0	deg	0.0	Pass	+100.00
	Intermediate values					
	Heel arm amplitude		m	0.000		
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.6: Turn: angle of equilibrium				Pass	
	Turn arm: a v^2 / (R g) h cos^n(phi)					
	constant: a =	0.9996				
	vessel speed: v =	0.000	kts			
	turn radius, R, as percentage of Lwl	510.00	%			
	h = KG - mean draft / 2	7.732	m			
	cosine power: n =	0				
	shall not be greater than (<=)	10.0	deg	0.0	Pass	+100.00
	Intermediate values					
	Heel arm amplitude		m	0.000		

Table 73. Criteria – WATER BALLAST ARRIVAL 9/20 – (Hydromax), (Maxsurf)



A.749(18) Ch3 - Design criteria applicable to all ships	3.2.2: Severe wind and rolling				Pass	
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99966				
	wind pressure: P =	504.0	Pa			
	area centroid height (from zero point): h =	6.000	m			
	additional area: A =	50.000	m^2			
	H = vert. centre of projected lat. u'water area	2.973	m			
	cosine power: n =	0				
	gust ratio	1.5				
	Area2 integrated to the lesser of					
	roll back angle from equilibrium (with steady heel arm)	25.0 (-24.4)	deg	-24.4		
	Area 1 upper integration range, to the lesser of:					
	spec. heel angle	50.0	deg	50.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with gust heel arm)	83.2	deg			
	Angle for GZ(max) in GZ ratio, the lesser of:					
	angle of max. GZ	42.7	deg	42.7		
	Select required angle for angle of steady heel ratio:	DeckEdgeImmersionAngle				
	Criteria:				Pass	
	Angle of steady heel shall not be greater than (<=)	16.0	deg	0.6	Pass	+96.23
	Angle of steady heel / Deck edge immersion angle shall not be greater than (<=)	80.00	%	1.49	Pass	+98.14
	Area1 / Area2 shall not be less than (>=)	100.00	%	314.64	Pass	+214.64
	Intermediate values					
	Model windage area		m^2	2042.249		
	Model windage area centroid height (from zero point)		m	12.378		
	Total windage area		m^2	2092.249		
	Total windage area centroid height (from zero point)		m	12.225		
	Heel arm amplitude		m	0.048		
	Equilibrium angle with steady heel arm		deg	0.6		
	Equilibrium angle with gust heel arm		deg	0.9		
	Deck edge immersion angle		deg	40.6		
	Area1 (under GZ), from 0.9 to 50.0 deg.		m.deg	90.8529		
	Area1 (under HA), from 0.9 to 50.0 deg.		m.deg	3.5380		
	Area1, from 0.9 to 50.0 deg.		m.deg	87.3149		
	Area2 (under GZ), from -24.4 to 0.9 deg.		m.deg	-25.9279		
	Area2 (under HA), from -24.4 to 0.9 deg.		m.deg	1.8233		
	Area2, from -24.4 to 0.9 deg.		m.deg	27.7511		

Table 74. **Criteria – WATER BALLAST ARRIVAL 10/20 – (Hydromax), (Maxsurf)**

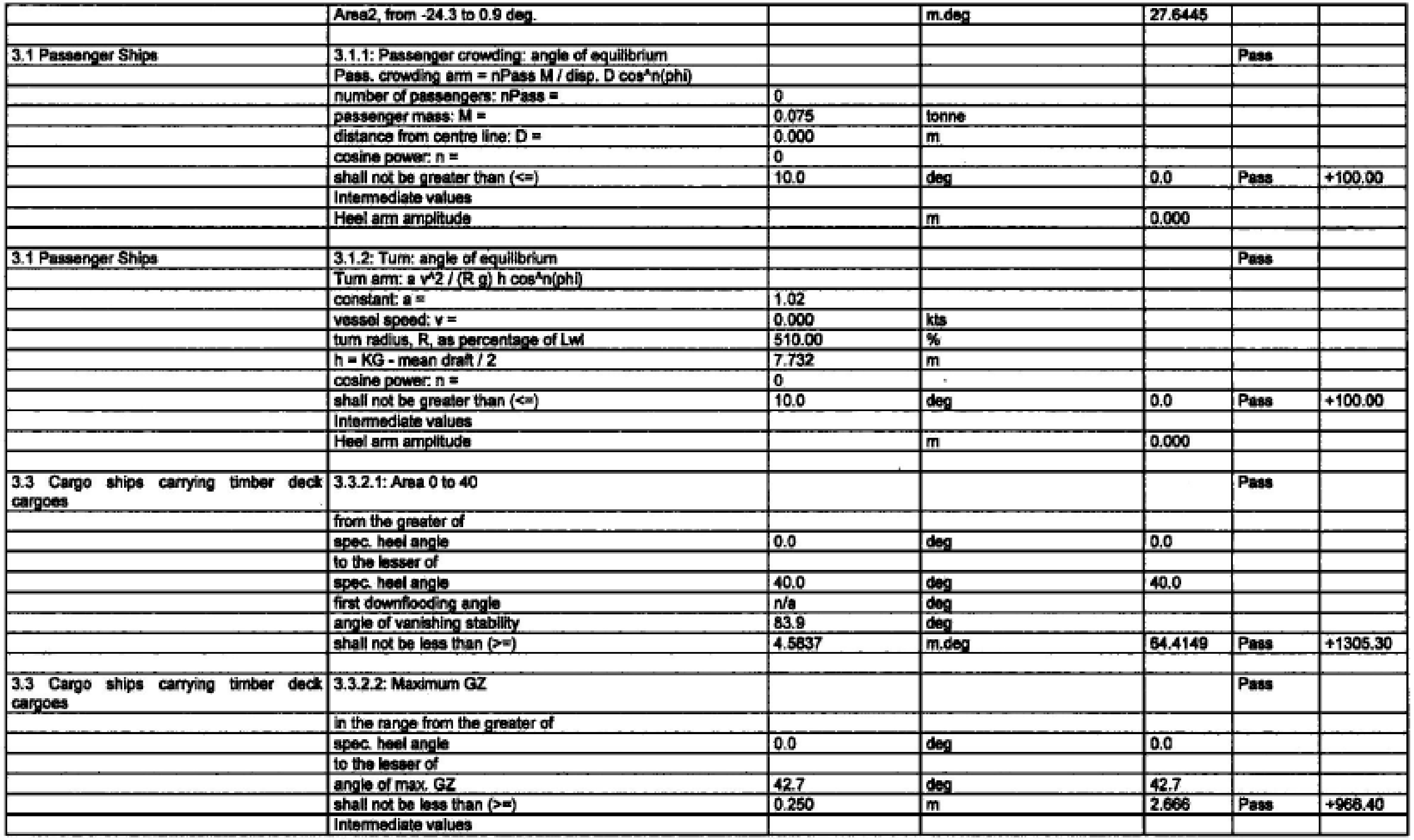


267(85) Ch2 - General Criteria	2.2.1: Area 0 to 30				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	30.0	deg	30.0		
	angle of vanishing stability	83.9	deg			
	shall not be less than (>=)	3.1513	m.deg	38.7608	Pass	+1129.99
267(85) Ch2 - General Criteria	2.2.1: Area 0 to 40				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	83.9	deg			
	shall not be less than (>=)	5.1566	m.deg	64.4149	Pass	+1149.17
267(85) Ch2 - General Criteria	2.2.1: Area 30 to 40				Pass	
	from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	83.9	deg			
	shall not be less than (>=)	1.7189	m.deg	25.6542	Pass	+1392.48
267(85) Ch2 - General Criteria	2.2.2: Max GZ at 30 or greater				Pass	
	in the range from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	42.7	deg	42.7		
	shall not be less than (>=)	0.200	m	2.666	Pass	+1233.00
	Intermediate values					
	angle at which this GZ occurs		deg	42.7		
267(85) Ch2 - General Criteria	2.2.3: Angle of maximum GZ				Pass	
	shall not be less than (>=)	25.0	deg	42.7	Pass	+70.91
267(85) Ch2 - General Criteria	2.2.4: Initial GMt				Pass	

Table 75. **Criteria – WATER BALLAST ARRIVAL 11/20 – (Hydromax), (Maxsurf)**

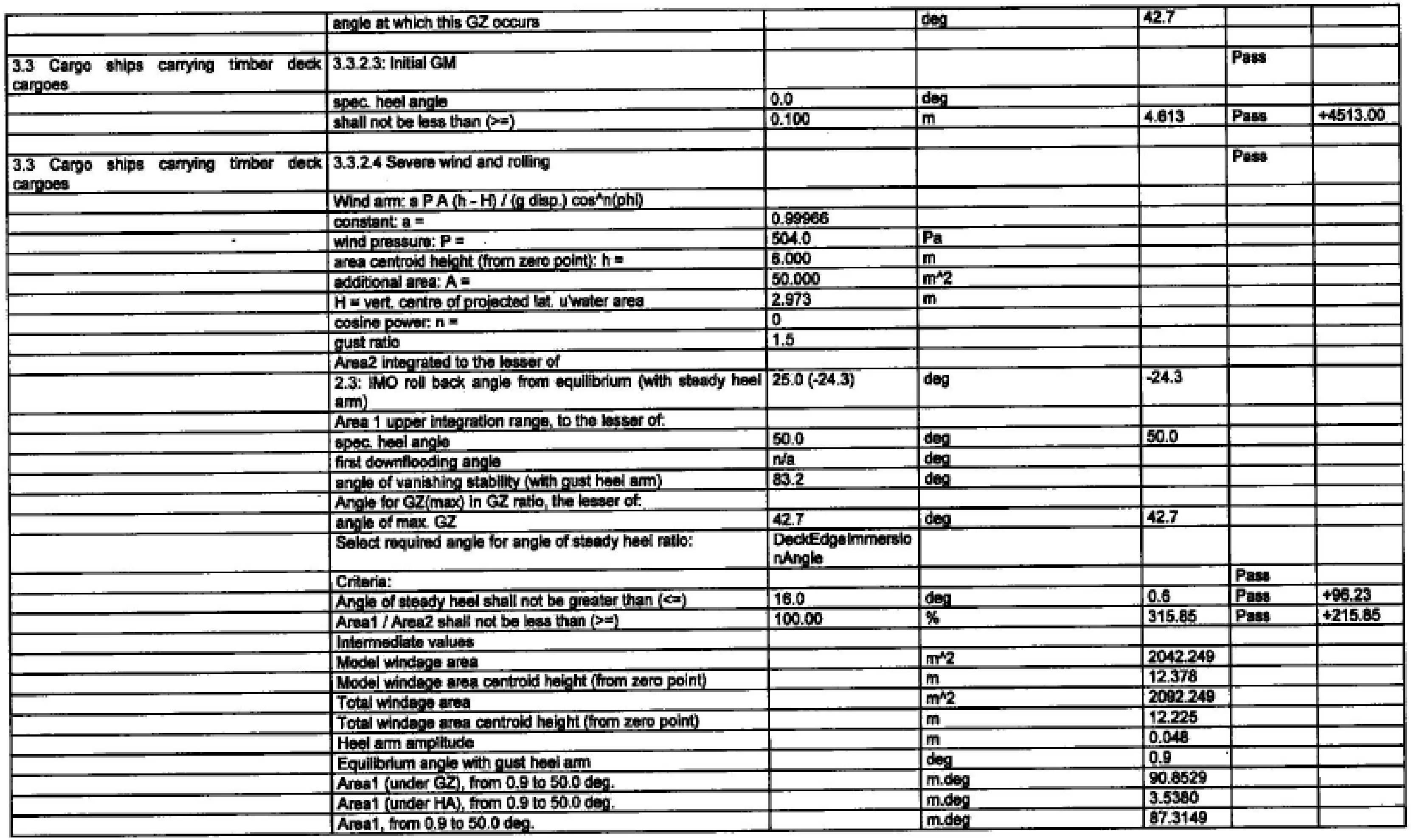
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.150	m	4.613	Pass	+2975.33
267(85) Ch2 - General Criteria	2.3: Severe wind and rolling				Pass	
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99966				
	wind pressure: P =	504.0	Pa			
	area centroid height (from zero point): h =	6.000	m			
	additional area: A =	50.000	m^2			
	H = vert. centre of projected lat. u'water area	2.973	m			
	cosine power: n =	0				
	gust ratio	1.5				
	Area2 integrated to the lesser of					
	2.3: IMO roll back angle from equilibrium (with steady heel arm)	25.0 (-24.3)	deg	-24.3		
	Area 1 upper integration range, to the lesser of:					
	spec. heel angle	50.0	deg	50.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with gust heel arm)	83.2	deg			
	Angle for GZ(max) in GZ ratio, the lesser of:					
	angle of max. GZ	42.7	deg	42.7		
	Select required angle for angle of steady heel ratio:	DeckEdgeImmersionAngle				
	Criteria:				Pass	
	Angle of steady heel shall not be greater than (<=)	16.0	deg	0.6	Pass	+96.23
	Angle of steady heel / Deck edge immersion angle shall not be greater than (<=)	80.00	%	1.49	Pass	+98.14
	Area1 / Area2 shall not be less than (>=)	100.00	%	315.85	Pass	+215.85
	Intermediate values					
	Model windage area		m^2	2042.249		
	Model windage area centroid height (from zero point)		m	12.378		
	Total windage area		m^2	2092.249		
	Total windage area centroid height (from zero point)		m	12.225		
	Heel arm amplitude		m	0.048		
	Equilibrium angle with gust heel arm		deg	0.9		
	Deck edge immersion angle		deg	40.6		
	Area1 (under GZ), from 0.9 to 50.0 deg.		m.deg	90.8529		
	Area1 (under HA), from 0.9 to 50.0 deg.		m.deg	3.5380		
	Area1, from 0.9 to 50.0 deg.		m.deg	87.3149		
	Area2 (under GZ), from -24.3 to 0.9 deg.		m.deg	-25.8248		
	Area2 (under HA), from -24.3 to 0.9 deg.		m.deg	1.8197		

Table 76. Criteria – WATER BALLAST ARRIVAL 12/20 – (Hydromax), (Maxsurf)



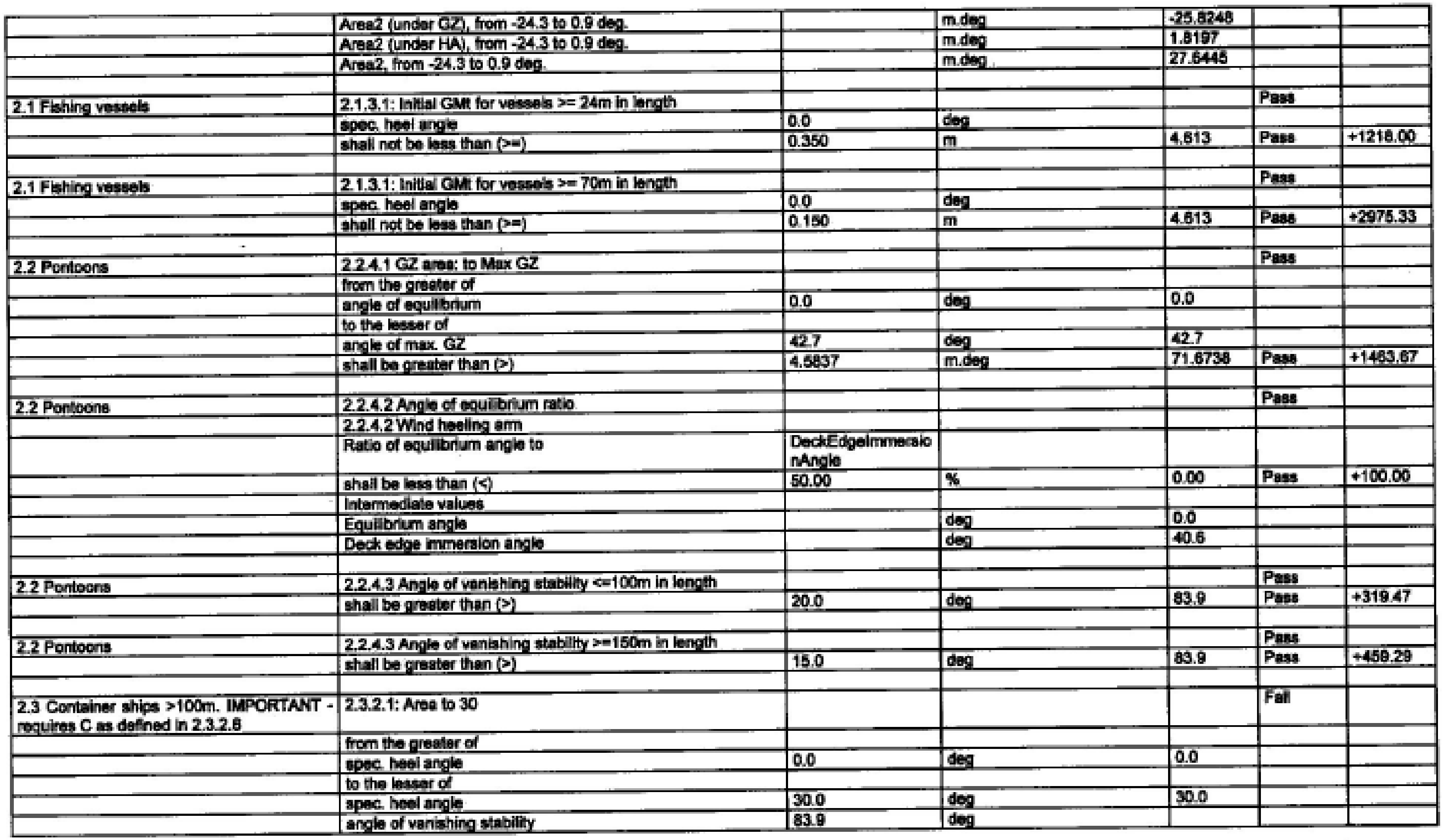
	Area2, from -24.3 to 0.9 deg.		m.deg	27.6445		
3.1 Passenger Ships	3.1.1: Passenger crowding: angle of equilibrium				Pass	
	Pass. crowding arm = nPass M / disp. D cos^n(phi)					
	number of passengers: nPass =	0				
	passenger mass: M =	0.075	tonne			
	distance from centre line: D =	0.000	m			
	cosine power: n =	0				
	shall not be greater than (<=)	10.0	deg	0.0	Pass	+100.00
	Intermediate values					
	Heel arm amplitude		m	0.000		
3.1 Passenger Ships	3.1.2: Turn: angle of equilibrium				Pass	
	Turn arm: a v^2 / (R g) h cos^n(phi)					
	constant: a =	1.02				
	vessel speed: v =	0.000	kts			
	turn radius, R, as percentage of Lwl	510.00	%			
	h = KG - mean draft / 2	7.732	m			
	cosine power: n =	0				
	shall not be greater than (<=)	10.0	deg	0.0	Pass	+100.00
	Intermediate values					
	Heel arm amplitude		m	0.000		
3.3 Cargo ships carrying timber deck cargoes	3.3.2.1: Area 0 to 40				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	83.9	deg			
	shall not be less than (>=)	4.5837	m.deg	64.4149	Pass	+1305.30
3.3 Cargo ships carrying timber deck cargoes	3.3.2.2: Maximum GZ				Pass	
	in the range from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	angle of max. GZ	42.7	deg	42.7		
	shall not be less than (>=)	0.250	m	2.666	Pass	+966.40
	Intermediate values					

Table 77. Criteria – WATER BALLAST ARRIVAL 13/20 – (Hydromax), (Maxsurf)



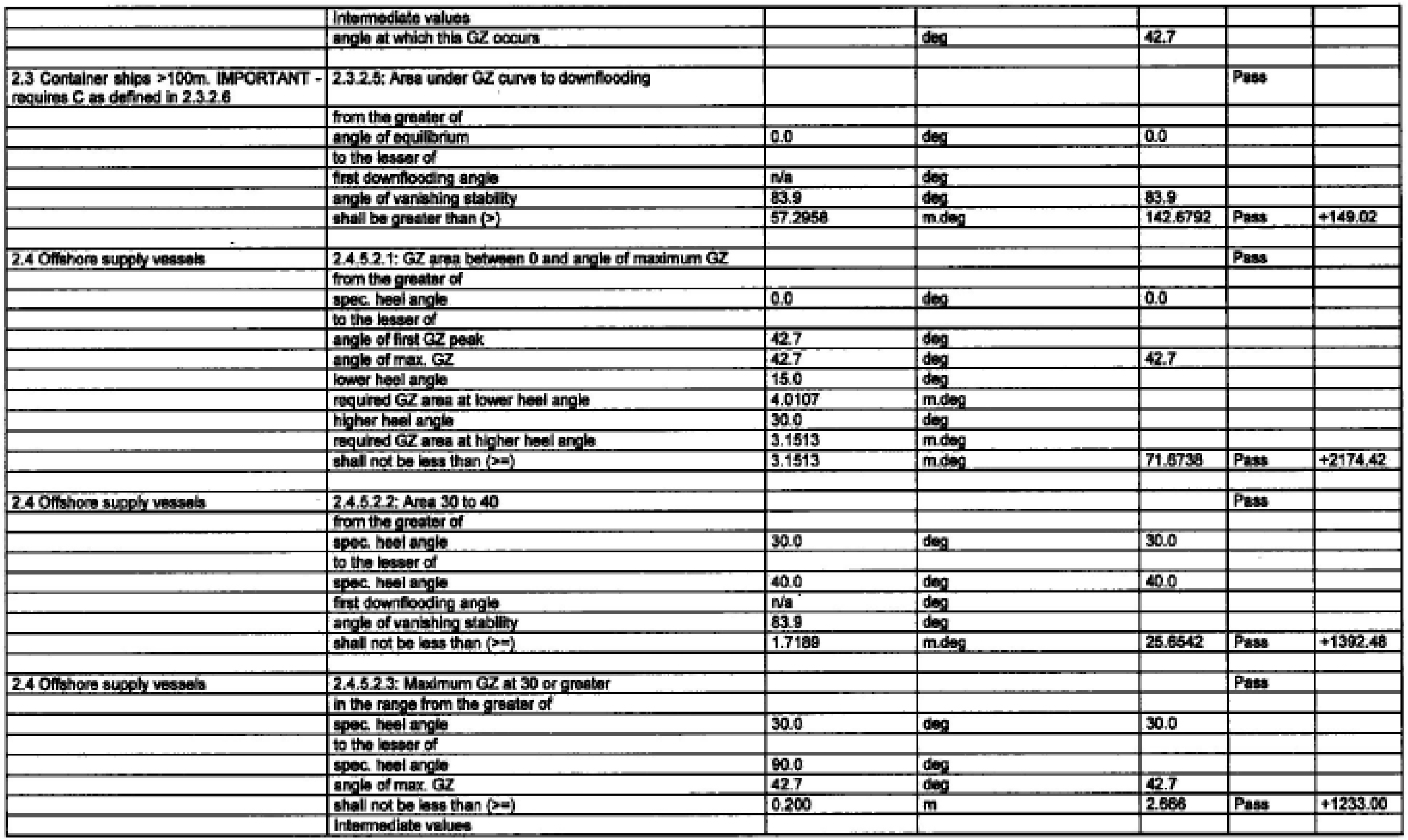
	angle at which this GZ occurs		deg	42.7		
3.3 Cargo ships carrying timber deck cargoes	3.3.2.3: Initial GM				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.100	m	4.613	Pass	+4513.00
3.3 Cargo ships carrying timber deck cargoes	3.3.2.4 Severe wind and rolling				Pass	
	Wind arm: a P A (h - H) / (g disp.) cos^n(phi)					
	constant: a =	0.99966				
	wind pressure: P =	504.0	Pa			
	area centroid height (from zero point): h =	6.000	m			
	additional area: A =	50.000	m^2			
	H = vert. centre of projected lat. u'water area	2.973	m			
	cosine power: n =	0				
	gust ratio	1.5				
	Area2 integrated to the lesser of					
	2.3: IMO roll back angle from equilibrium (with steady heel arm)	25.0 (-24.3)	deg	-24.3		
	Area 1 upper integration range, to the lesser of:					
	spec. heel angle	50.0	deg	50.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with gust heel arm)	83.2	deg			
	Angle for GZ(max) in GZ ratio, the lesser of:					
	angle of max. GZ	42.7	deg	42.7		
	Select required angle for angle of steady heel ratio:	DeckEdgeImmersionAngle				
	Criteria:				Pass	
	Angle of steady heel shall not be greater than (<=)	16.0	deg	0.6	Pass	+96.23
	Area1 / Area2 shall not be less than (>=)	100.00	%	315.85	Pass	+215.85
	Intermediate values					
	Model windage area		m^2	2042.249		
	Model windage area centroid height (from zero point)		m	12.378		
	Total windage area		m^2	2092.249		
	Total windage area centroid height (from zero point)		m	12.225		
	Heel arm amplitude		m	0.048		
	Equilibrium angle with gust heel arm		deg	0.9		
	Area1 (under GZ), from 0.9 to 50.0 deg.		m.deg	90.8529		
	Area1 (under HA), from 0.9 to 50.0 deg.		m.deg	3.5380		
	Area1, from 0.9 to 50.0 deg.		m.deg	87.3149		

Table 78. Criteria – WATER BALLAST ARRIVAL 14/20 – (Hydromax), (Maxsurf)



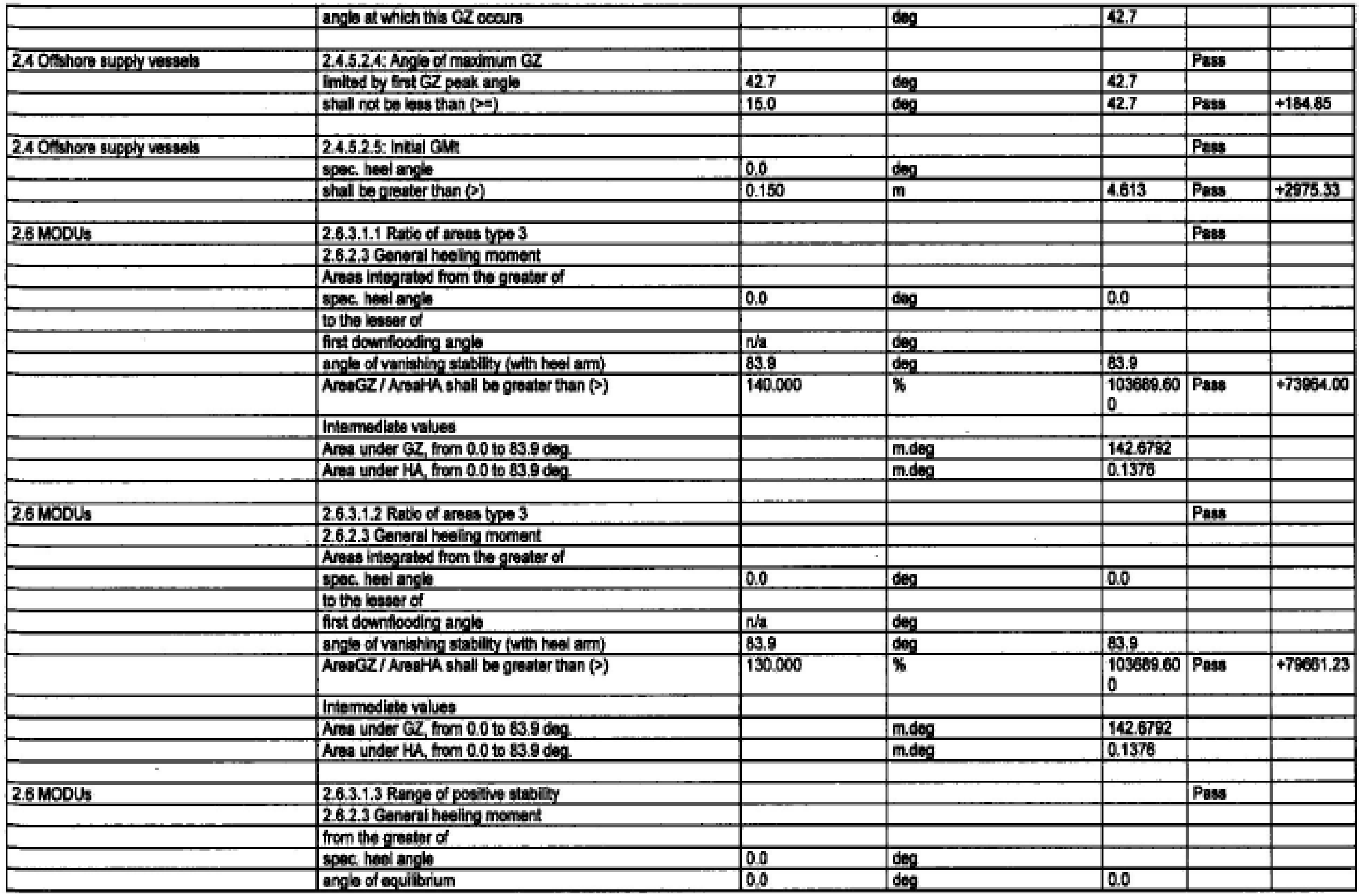
	Area2 (under GZ), from -24.3 to 0.9 deg.		m.deg	-25.8248		
	Area2 (under HA), from -24.3 to 0.9 deg.		m.deg	1.8197		
	Area2, from -24.3 to 0.9 deg.		m.deg	27.6445		
2.1 Fishing vessels	2.1.3.1: Initial GMt for vessels >= 24m in length				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.350	m	4.613	Pass	+1218.00
2.1 Fishing vessels	2.1.3.1: Initial GMt for vessels >= 70m in length				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.150	m	4.613	Pass	+2975.33
2.2 Pontoons	2.2.4.1 GZ area: to Max GZ				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	angle of max. GZ	42.7	deg	42.7		
	shall be greater than (>)	4.5837	m.deg	71.6738	Pass	+1463.67
2.2 Pontoons	2.2.4.2 Angle of equilibrium ratio				Pass	
	2.2.4.2 Wind heeling arm					
	Ratio of equilibrium angle to	DeckEdgeImmersionAngle				
	shall be less than (<)	50.00	%	0.00	Pass	+100.00
	Intermediate values					
	Equilibrium angle		deg	0.0		
	Deck edge immersion angle		deg	40.6		
2.2 Pontoons	2.2.4.3 Angle of vanishing stability <=100m in length				Pass	
	shall be greater than (>)	20.0	deg	83.9	Pass	+319.47
2.2 Pontoons	2.2.4.3 Angle of vanishing stability >=150m in length				Pass	
	shall be greater than (>)	15.0	deg	83.9	Pass	+459.29
2.3 Container ships >100m. IMPORTANT - requires C as defined in 2.3.2.6	2.3.2.1: Area to 30				Fail	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	30.0	deg	30.0		
	angle of vanishing stability	83.9	deg			

Table 79. Criteria – WATER BALLAST ARRIVAL 15/20 – (Hydromax), (Maxsurf)



	Intermediate values					
	angle at which this GZ occurs		deg	42.7		
2.3 Container ships >100m. IMPORTANT - requires C as defined in 2.3.2.6	2.3.2.5: Area under GZ curve to downflooding				Pass	
	from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	n/a	deg			
	angle of vanishing stability	83.9	deg	83.9		
	shall be greater than (>)	57.2958	m.deg	142.6792	Pass	+149.02
2.4 Offshore supply vessels	2.4.5.2.1: GZ area between 0 and angle of maximum GZ				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	angle of first GZ peak	42.7	deg			
	angle of max. GZ	42.7	deg	42.7		
	lower heel angle	15.0	deg			
	required GZ area at lower heel angle	4.0107	m.deg			
	higher heel angle	30.0	deg			
	required GZ area at higher heel angle	3.1513	m.deg			
	shall not be less than (>=)	3.1513	m.deg	71.6738	Pass	+2174.42
2.4 Offshore supply vessels	2.4.5.2.2: Area 30 to 40				Pass	
	from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	83.9	deg			
	shall not be less than (>=)	1.7189	m.deg	25.6542	Pass	+1392.48
2.4 Offshore supply vessels	2.4.5.2.3: Maximum GZ at 30 or greater				Pass	
	in the range from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	42.7	deg	42.7		
	shall not be less than (>=)	0.200	m	2.666	Pass	+1233.00
	Intermediate values					

Table 80. **Criteria – WATER BALLAST ARRIVAL 16/20 – (Hydromax), (Maxsurf)**

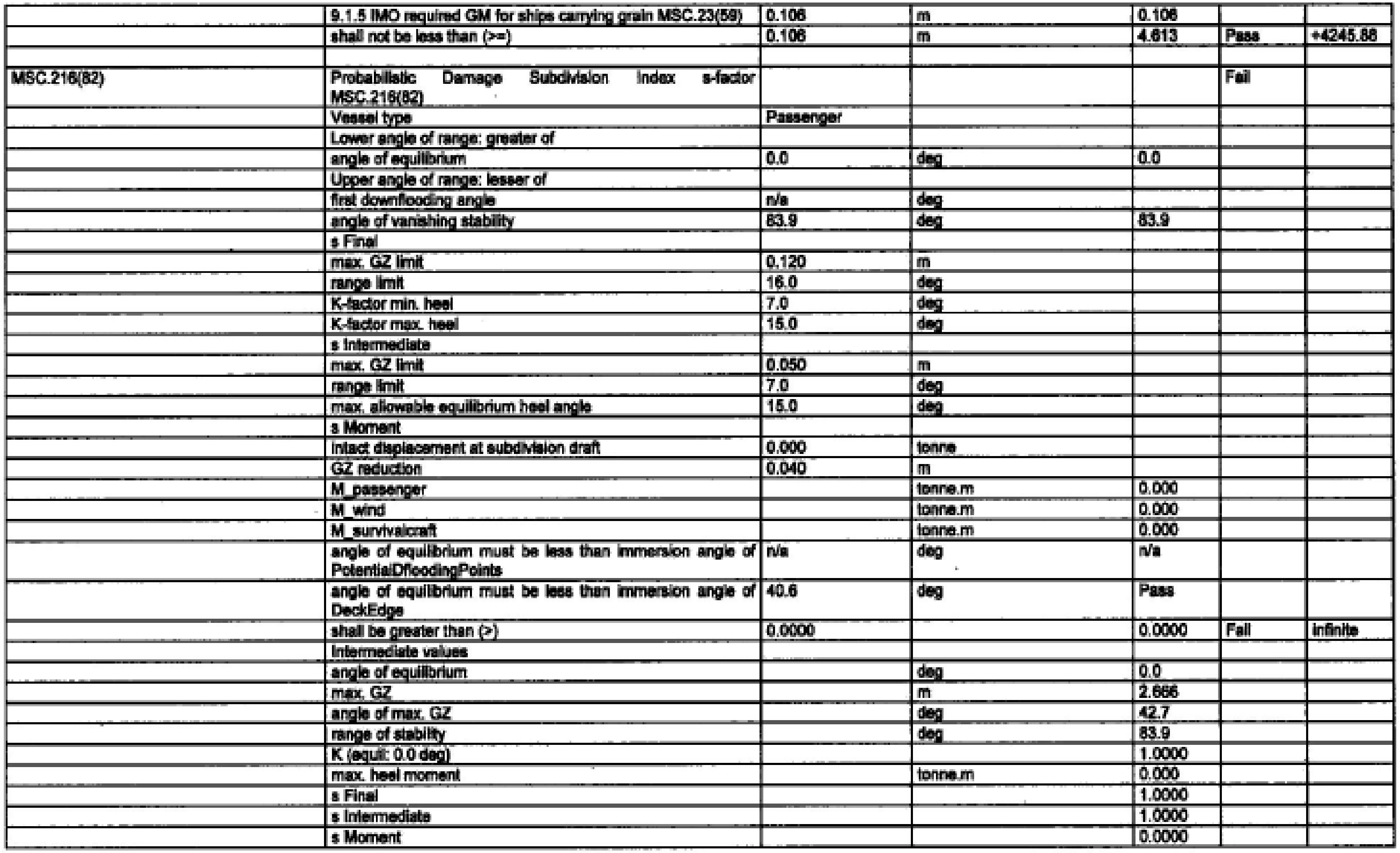


	angle at which this GZ occurs		deg	42.7		
2.4 Offshore supply vessels	2.4.5.2.4: Angle of maximum GZ				Pass	
	limited by first GZ peak angle	42.7	deg	42.7		
	shall not be less than (>=)	15.0	deg	42.7	Pass	+184.85
2.4 Offshore supply vessels	2.4.5.2.5: Initial GMt				Pass	
	spec. heel angle	0.0	deg			
	shall be greater than (>)	0.150	m	4.613	Pass	+2975.33
2.6 MODUs	2.6.3.1.1 Ratio of areas type 3				Pass	
	2.6.2.3 General heeling moment					
	Areas integrated from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with heel arm)	83.9	deg	83.9		
	AreaGZ / AreaHA shall be greater than (>)	140.000	%	103689.600	Pass	+73964.00
	Intermediate values					
	Area under GZ, from 0.0 to 83.9 deg.		m.deg	142.6792		
	Area under HA, from 0.0 to 83.9 deg.		m.deg	0.1376		
2.6 MODUs	2.6.3.1.2 Ratio of areas type 3				Pass	
	2.6.2.3 General heeling moment					
	Areas integrated from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with heel arm)	83.9	deg	83.9		
	AreaGZ / AreaHA shall be greater than (>)	130.000	%	103689.600	Pass	+79661.23
	Intermediate values					
	Area under GZ, from 0.0 to 83.9 deg.		m.deg	142.6792		
	Area under HA, from 0.0 to 83.9 deg.		m.deg	0.1376		
2.6 MODUs	2.6.3.1.3 Range of positive stability				Pass	
	2.6.2.3 General heeling moment					
	from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium	0.0	deg	0.0		

Table 81. Criteria – WATER BALLAST ARRIVAL 17/20 – (Hydromax), (Maxsurf)

	to the lesser of					
	first downflooding angle	n/a	deg			
	angle of vanishing stability	83.9	deg	83.9		
	shall be greater than (>)	0.0	deg	83.9	Pass	infinite
Ch 7. Stability Requirments	7.1.1.a Angle of equilibrium				Pass	
	7.1 Grain heeling arm					
	shall not be greater than (<=)	12.0	deg	0.0	Pass	+99.94
Ch 7. Stability Requirments	7.1.1.b Angle of equilibrium ratio				Pass	
	7.1 Grain heeling arm					
	Ratio of equilibrium angle to	DeckEdgeImmersionAngle				
	shall not be greater than (<=)	100.00	%	0.02	Pass	+99.98
	Intermediate values					
	Equilibrium angle		deg	0.0		
	Deck edge immersion angle		deg	40.6		
Ch 7. Stability Requirments	7.1.2 GZ area between limits type 1				Pass	
	7.1 Grain heeling arm					
	Area integrated from the greater of					
	spec. heel angle	0.0	deg			
	angle of equilibrium (with heel arm)	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	angle of max. GZ above heel arm	42.7	deg			
	first downflooding angle	n/a	deg			
	angle of vanishing stability (with heel arm)	83.9	deg			
	shall not be less than (>=)	4.2972	m.deg	64.3946	Pass	+1398.52
	Intermediate values					
	Area under GZ curve.		m.deg	64.4149		
	Area under heeling arm curve.		m.deg	0.0203		
Ch 7. Stability Requirments	7.1.3.a Value of GMt at				Pass	
	spec. heel angle	0.0	deg			
	shall not be less than (>=)	0.300	m	4.613	Pass	+1437.67
Ch 9. Optional Stability Requirements for Ships without Documents of Authorisation Carrying Partial Cargos of Grain	9.1.5 Value of GMt at				Pass	
	spec. heel angle	0.0	deg			

Table 82. Criteria – WATER BALLAST ARRIVAL 18/20 – (Hydromax), (Maxsurf)



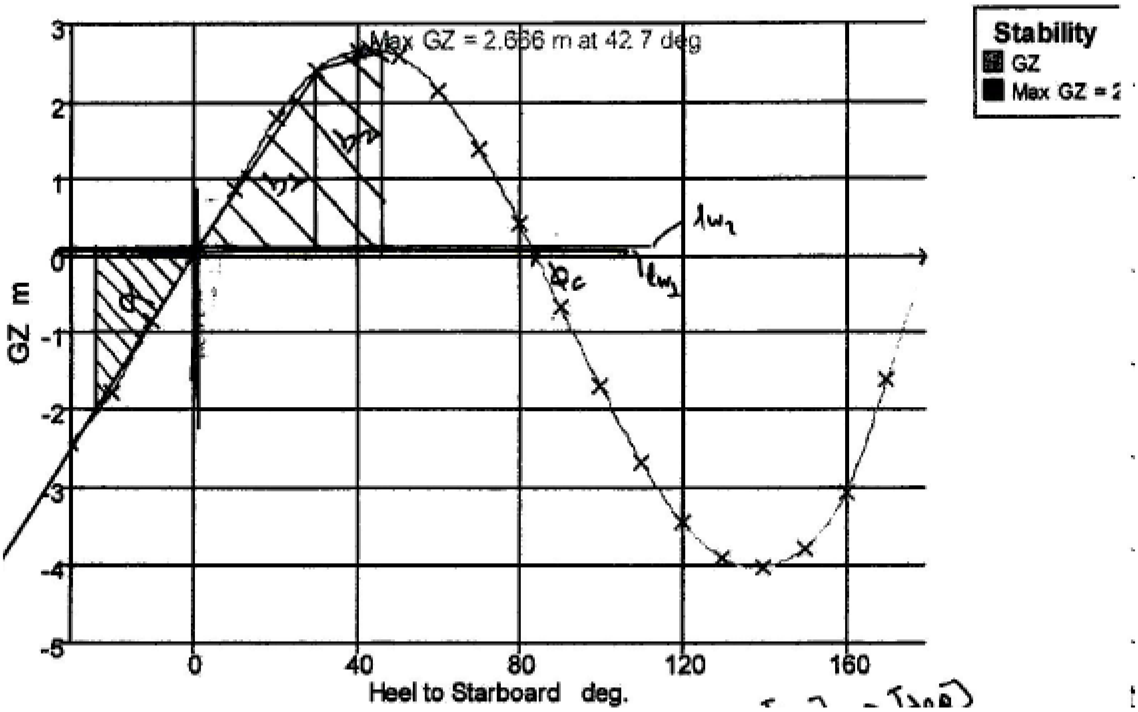
	9.1.5 IMO required GM for ships carrying grain MSC.23(59)	0.106	m	0.106		
	shall not be less than (>=)	0.106	m	4.613	Pass	+4245.88
MSC.216(82)	Probabilistic Damage Subdivision Index s-factor MSC.216(82)				Fail	
	Vessel type	Passenger				
	Lower angle of range: greater of					
	angle of equilibrium	0.0	deg	0.0		
	Upper angle of range: lesser of					
	first downflooding angle	n/a	deg			
	angle of vanishing stability	83.9	deg	83.9		
	s Final					
	max. GZ limit	0.120	m			
	range limit	16.0	deg			
	K-factor min. heel	7.0	deg			
	K-factor max. heel	15.0	deg			
	s Intermediate					
	max. GZ limit	0.050	m			
	range limit	7.0	deg			
	max. allowable equilibrium heel angle	15.0	deg			
	s Moment					
	intact displacement at subdivision draft	0.000	tonne			
	GZ reduction	0.040	m			
	M_passenger		tonne.m	0.000		
	M_wind		tonne.m	0.000		
	M_survivalcraft		tonne.m	0.000		
	angle of equilibrium must be less than immersion angle of PotentialDfloodingPoints	n/a	deg	n/a		
	angle of equilibrium must be less than immersion angle of DeckEdge	40.6	deg	Pass		
	shall be greater than (>)	0.0000		0.0000	Fail	infinite
	Intermediate values					
	angle of equilibrium		deg	0.0		
	max. GZ		m	2.666		
	angle of max. GZ		deg	42.7		
	range of stability		deg	83.9		
	K (equil: 0.0 deg)			1.0000		
	max. heel moment		tonne.m	0.000		
	s Final			1.0000		
	s Intermediate			1.0000		
	s Moment			0.0000		

Table 83. Criteria – WATER BALLAST ARRIVAL 19/20 (Hydromax), (Maxsurf)

	shall not be less than (>=)	57.2958	m.deg	38.7608	Fail	-32.35
2.3 Container ships >100m. IMPORTANT - requires C as defined in 2.3.2.6	2.3.2.1: Area 0 to 40				Pass	
	from the greater of					
	spec. heel angle	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	83.9	deg			
	shall not be less than (>=)	57.2958	m.deg	64.4149	Pass	+12.43
2.3 Container ships >100m. IMPORTANT - requires C as defined in 2.3.2.6	2.3.2.2: Area 30 to 40				Fail	
	from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	40.0	deg	40.0		
	first downflooding angle	n/a	deg			
	angle of vanishing stability	83.9	deg			
	shall not be less than (>=)	57.2958	m.deg	25.6542	Fail	-55.23
2.3 Container ships >100m. IMPORTANT - requires C as defined in 2.3.2.6	2.3.2.3: Maximum GZ at 30 or greater				Pass	
	in the range from the greater of					
	spec. heel angle	30.0	deg	30.0		
	to the lesser of					
	spec. heel angle	90.0	deg			
	angle of max. GZ	42.7	deg	42.7		
	shall not be less than (>=)	1.000	m	2.666	Pass	+166.60
	Intermediate values					
	angle at which this GZ occurs		deg	42.7		
2.3 Container ships >100m. IMPORTANT - requires C as defined in 2.3.2.6	2.3.2.4: Value of maximum GZ				Pass	
	in the range from the greater of					
	angle of equilibrium	0.0	deg	0.0		
	to the lesser of					
	spec. heel angle	180.0	deg			
	angle of max. GZ	42.7	deg	42.7		
	shall be greater than (>)	1.000	m	2.666	Pass	+166.60

Table 84. Criteria – WATER BALLAST ARRIVAL 20/20 (Hydromax), (Maxsurf)

According to bibliographical source (ANNEX 2 RESOLUTION MSC.267(85) (adopted on 4 December 2008) MSC 85/26/Add.1) the weather criterion will be applied for Water Ballast Arrival.



Picture 40. Weather Criterion – Water Ballast Arrival – (Hydromax), (Maxsurf), Personal Estimation

A=projected lateral area of the portion of the ship and deck cargo above the waterline (m^2)=2487.0

Z=vertical distance from the center of A to the center of the underwater lateral area or approximately to a point at one half the mean draught (m)=11.75

θfd=38deg, θf=46deg, GM=4.615m, Displ.=20699t, P=504Pa

lw1=(P*A*Z)/(1000*g*Displ.)=(504*2487.0*11.75)/(1000*9.81*20699)=0.073m

lw2=1.5*lw1=1.5*0.073=0.109m

Lwl=153.55m

Φc=84deg

Φ0=1.12deg<min(16deg,0.8*38deg)=min(16deg,30.4deg)=16deg (Ok)

Φ1=109*K*X1*X2*sqrt(r*S)[deg]

Φ2=min(θf,50deg, Φc)=min(46,50,84)=46deg

B/d=29.58/5.88=5.031->X1=0.8

Cb=0.754->X2=1.00

Ak=0->K=1.00

OG=KG-d=10.743-5.883=4.86m

r=0.73+0.6*OG/d=0.73+0.6*4.86/5.88=1.225m

C=0.373+0.023*B/d-0.043*(Lwl/100)=0.373+0.023*5.031 -0.043*(153.55/100)=0.43

T=(2*C*B)/sqrt(GM)=(2*0.43*29.58)/sqrt(4.615)=11.84sec->S=0.066

Φc=84.0deg->φ2=min(46deg,50deg,84deg)=46deg

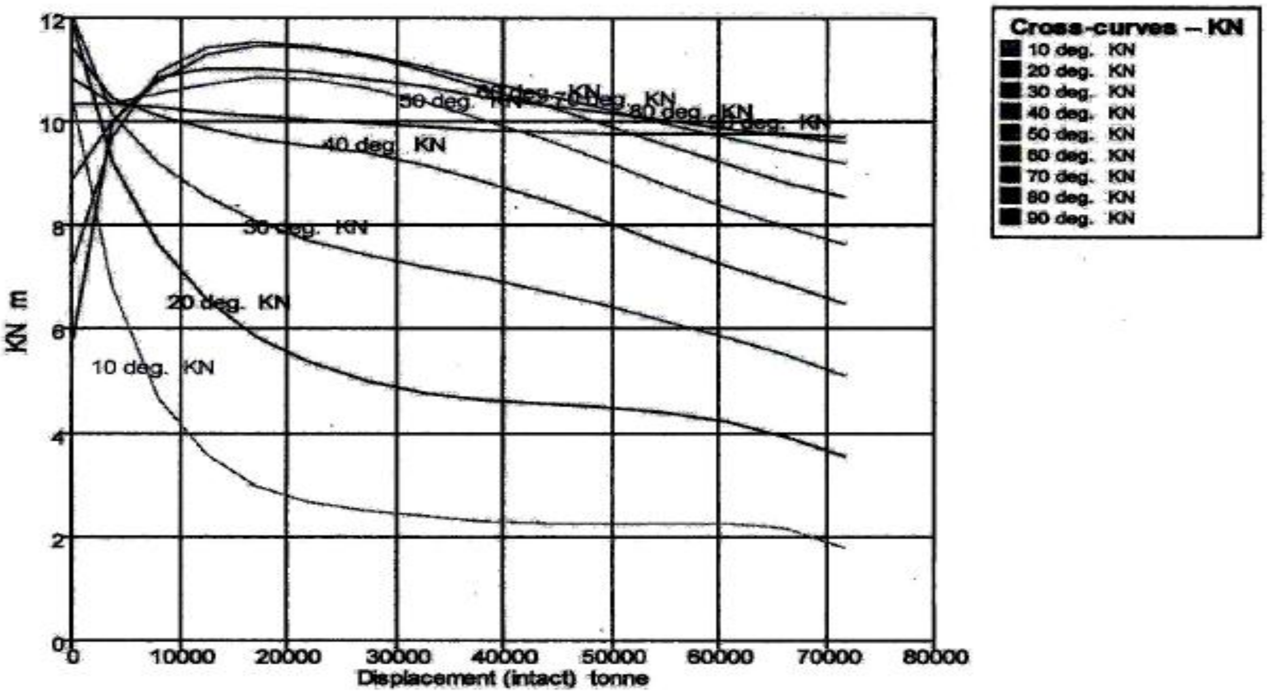
Φ1=109*1.0*0.8*1.0*sqrt(1.225*0.066)=24.80deg

a=26.67deg*m

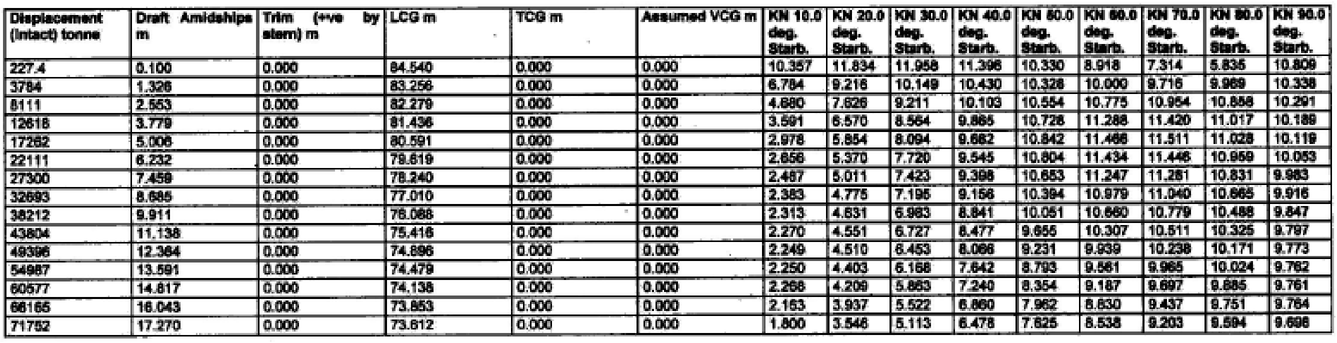
b=b1+b2=0.5*28.8*2.25+0.5*16*(2.25+2.5)=70.4deg

b>a->(OK)

Equation 4. **Weather Criterion Application – Water Ballast Arrival** (ANNEX 2 RESOLUTION MSC.267(85) (adopted on 4 December 2008) MSC 85/26/Add.1)

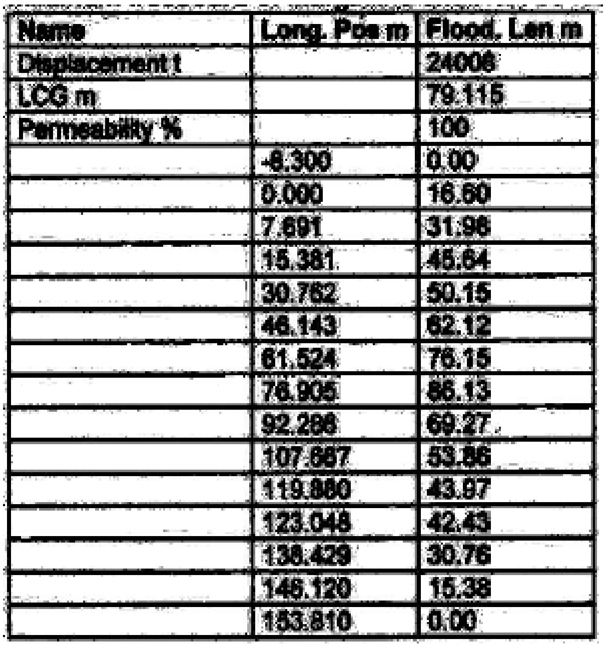


Picture 41. **Cross Curves ½ – (Hydromax), (Maxsurf)**



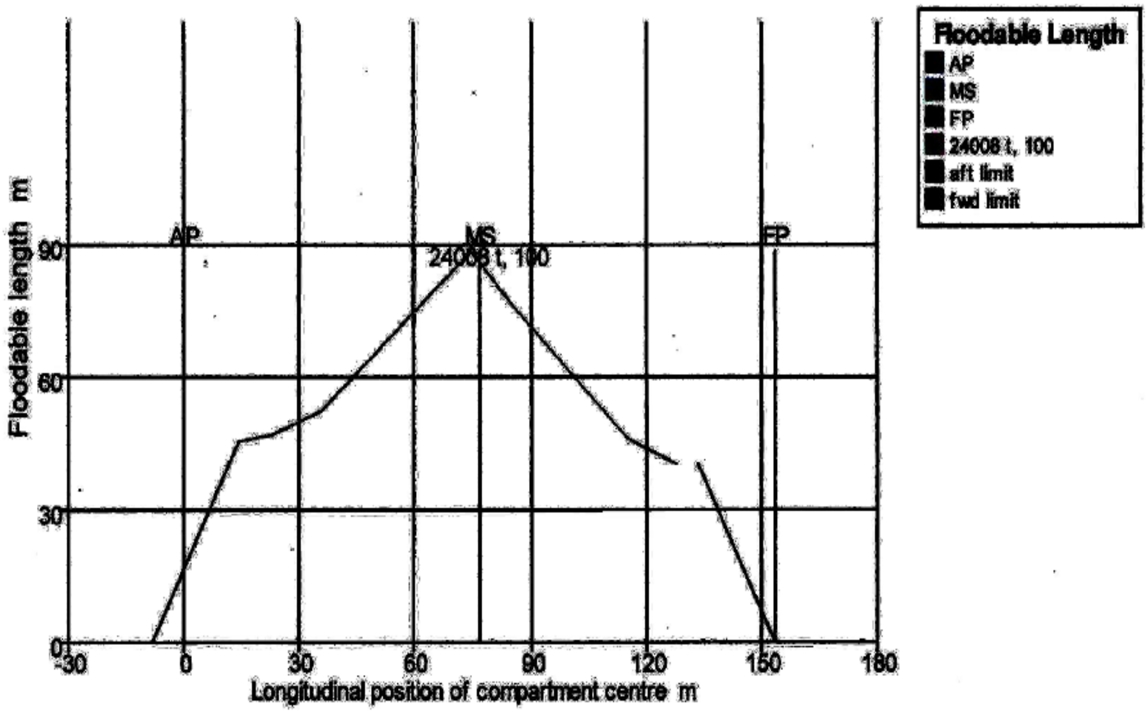
Displacement (Intact) tonne	Draft Amidships m	Trim (+ve by stem) m	LCG m	TCG m	Assumed VCG m	KN 10.0 deg. Starb.	KN 20.0 deg. Starb.	KN 30.0 deg. Starb.	KN 40.0 deg. Starb.	KN 50.0 deg. Starb.	KN 60.0 deg. Starb.	KN 70.0 deg. Starb.	KN 80.0 deg. Starb.	KN 90.0 deg. Starb.
227.4	0.100	0.000	84.540	0.000	0.000	10.357	11.834	11.958	11.396	10.330	8.918	7.314	5.835	10.809
3784	1.326	0.000	83.256	0.000	0.000	6.784	9.216	10.149	10.430	10.328	10.000	9.716	9.969	10.338
8111	2.553	0.000	82.279	0.000	0.000	4.680	7.626	9.211	10.103	10.554	10.775	10.954	10.858	10.291
12618	3.779	0.000	81.436	0.000	0.000	3.591	6.570	8.564	9.865	10.728	11.288	11.420	11.017	10.189
17262	5.006	0.000	80.591	0.000	0.000	2.978	5.854	8.094	9.682	10.842	11.466	11.511	11.028	10.119
22111	6.232	0.000	79.619	0.000	0.000	2.656	5.370	7.720	9.545	10.804	11.434	11.446	10.959	10.053
27300	7.459	0.000	78.240	0.000	0.000	2.487	5.011	7.423	9.398	10.653	11.247	11.281	10.831	9.983
32693	8.685	0.000	77.010	0.000	0.000	2.383	4.775	7.196	9.156	10.394	10.979	11.040	10.665	9.916
38212	9.911	0.000	76.088	0.000	0.000	2.313	4.631	6.983	8.841	10.051	10.660	10.779	10.488	9.847
43804	11.138	0.000	75.416	0.000	0.000	2.270	4.551	6.727	8.477	9.655	10.307	10.511	10.325	9.797
49396	12.364	0.000	74.896	0.000	0.000	2.249	4.510	6.453	8.066	9.231	9.939	10.238	10.171	9.773
54987	13.591	0.000	74.479	0.000	0.000	2.250	4.403	6.168	7.642	8.793	9.561	9.965	10.024	9.762
60577	14.817	0.000	74.138	0.000	0.000	2.268	4.209	5.863	7.240	8.354	9.187	9.697	9.885	9.761
66165	16.043	0.000	73.853	0.000	0.000	2.163	3.937	5.522	6.860	7.962	8.830	9.437	9.751	9.764
71752	17.270	0.000	73.612	0.000	0.000	1.800	3.546	5.113	6.478	7.625	8.538	9.203	9.594	9.696

Table 85. **Cross Curves 2/2 – (Hydromax), (Maxsurf)**

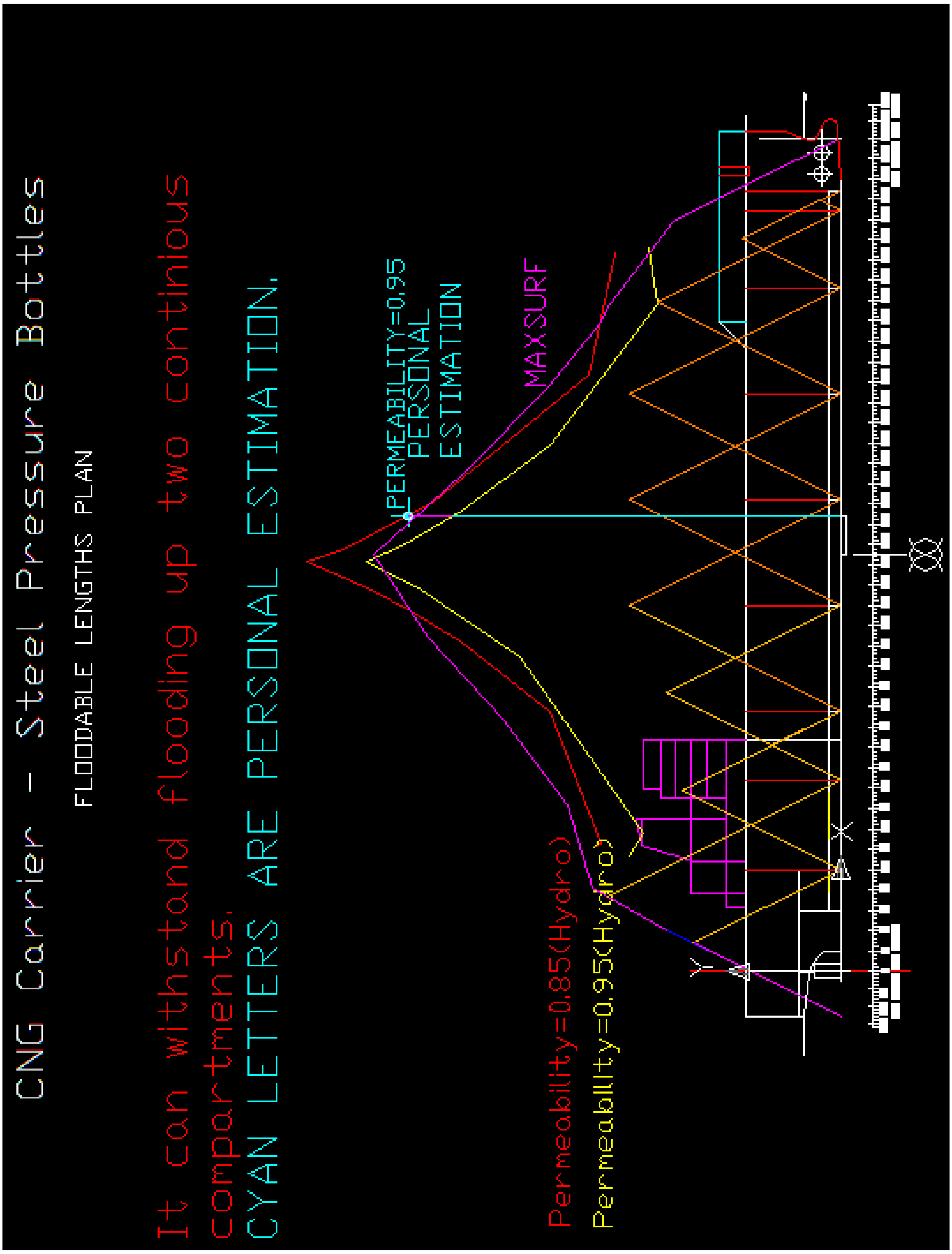


Name	Long. Pos m	Flood. Len m
Displacement t		24008
LCG m		79.115
Permeability %		100
	-8.300	0.00
	0.000	16.60
	7.691	31.98
	15.381	45.64
	30.762	50.15
	46.143	62.12
	61.524	76.15
	76.905	86.13
	92.286	69.27
	107.667	53.86
	119.860	43.97
	123.048	42.43
	138.429	30.76
	146.120	15.38
	153.810	0.00

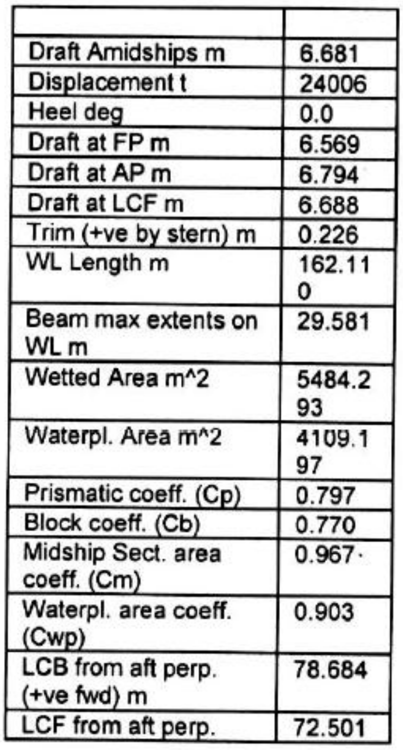
Table 86. Floodable Lengths 1/3 – (Hydromax), (Maxsurf)



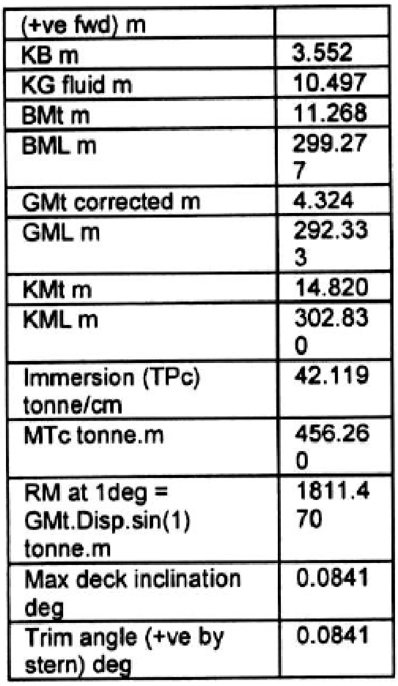
Picture 42. Floodable Lengths 2/3 – (Hydromax), (Maxsurf)



Picture 43. **Floodable Lengths 3/3** – (HYDROSTATICAL PROPERTIES CALCULATION PROGRAM), (Hydromax), (Maxsurf), (AUTOCAD, 2017), (ΘΟΔΩΡΟΥ ΛΟΥΚΑΚΗ et al., 2000)



Draft Amidships m	6.681
Displacement t	24006
Heel deg	0.0
Draft at FP m	6.569
Draft at AP m	6.794
Draft at LCF m	6.688
Trim (+ve by stern) m	0.226
WL Length m	162.110
Beam max extents on WL m	29.581
Wetted Area m^2	5484.293
Waterpl. Area m^2	4109.197
Prismatic coeff. (Cp)	0.797
Block coeff. (Cb)	0.770
Midship Sect. area coeff. (Cm)	0.967
Waterpl. area coeff. (Cwp)	0.903
LCB from aft perp. (+ve fwd) m	78.684
LCF from aft perp.	72.501



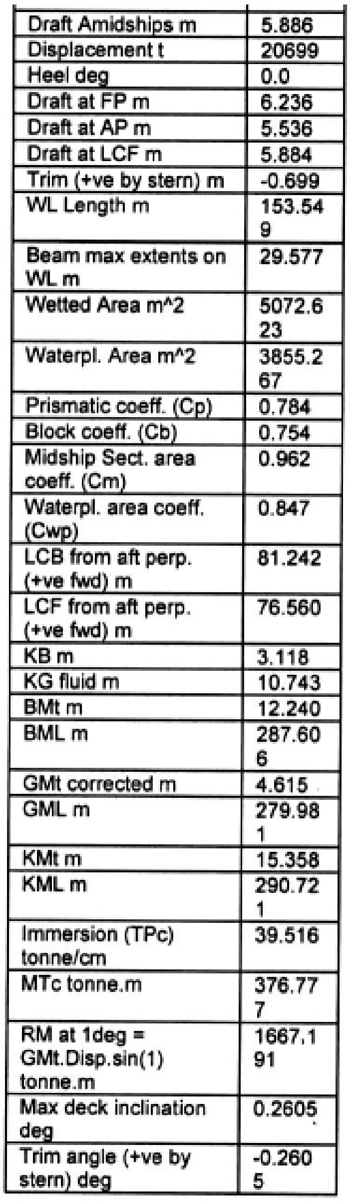
(+ve fwd) m	
KB m	3.552
KG fluid m	10.497
BMt m	11.268
BML m	299.277
GMt corrected m	4.324
GML m	292.333
KMt m	14.820
KML m	302.830
Immersion (TPc) tonne/cm	42.119
MTc tonne.m	456.260
RM at 1deg = GMt.Disp.sin(1) tonne.m	1811.470
Max deck inclination deg	0.0841
Trim angle (+ve by stern) deg	0.0841

Table 87. Full Load Departure – **Equilibrium (Hydromax), (Maxsurf)**

Trim by Stern (Full Load Departure)=0.226m<0.3m (Ok)

Equation 5. **Full Load Departure Requirements**

(Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)



Draft Amidships m	5.886
Displacement t	20699
Heel deg	0.0
Draft at FP m	6.236
Draft at AP m	5.536
Draft at LCF m	5.884
Trim (+ve by stern) m	-0.699
WL Length m	153.549
Beam max extents on WL m	29.577
Wetted Area m^2	5072.623
Waterpl. Area m^2	3855.267
Prismatic coeff. (Cp)	0.784
Block coeff. (Cb)	0.754
Midship Sect. area coeff. (Cm)	0.962
Waterpl. area coeff. (Cwp)	0.847
LCB from aft perp. (+ve fwd) m	81.242
LCF from aft perp. (+ve fwd) m	76.560
KB m	3.118
KG fluid m	10.743
BMt m	12.240
BML m	287.606
GMt corrected m	4.615
GML m	279.981
KMt m	15.358
KML m	290.721
Immersion (TPc) tonne/cm	39.516
MTc tonne.m	376.777
RM at 1deg = GMt.Disp.sin(1) tonne.m	1667.191
Max deck inclination deg	0.2605
Trim angle (+ve by stern) deg	-0.2605

Table 88. Water Ballast Arrival – Equilibrium (Hydromax), (Maxsurf)

Ta=5.536m>Dprop+0.6=3.82m+0.6m=4.42m (Ok)

Tf=6.236m>2.7%*Lbp=0.027*153.81=4.15m (Ok)

Trim by Bow – (Water Ballast Arrival)=700mm<900mm (Ok)

Equation 6. Water Ballast Arrival Requirements

(Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)

Tables 89 and 90 will present the intact stability properties of the righting levers in Full Load Departure and in Water Ballast Arrival respectively.

INTACT STABILITY CRITERIA – FULL LOAD DEPARTURE

Area up to 30 degrees [rad*m]		0.625	>= 0,055	ok		
φ f [Degrees]	**44**					
Area up to 40 degrees [rad*m]		1.071	>=0,09	ok		
Area between 30 and 40 degrees [rad*m]			0.447	>=0,03	ok	
The GZ must not be less than 0,2m at an angle >=30 degrees			ok			
The maximum lever shall occur at an angle not less than 25 degrees			43.6	ok		
Intial GM shall not be less than 0,15m			4.383	ok		

Table 89. **Intact Stability Criteria of Righting Lever in FULL LOAD DEPARTURE.** Source: (ANNEX 2 RESOLUTION MSC.267(85) (adopted on 4 December 2008) MSC 85/26/Add.1)

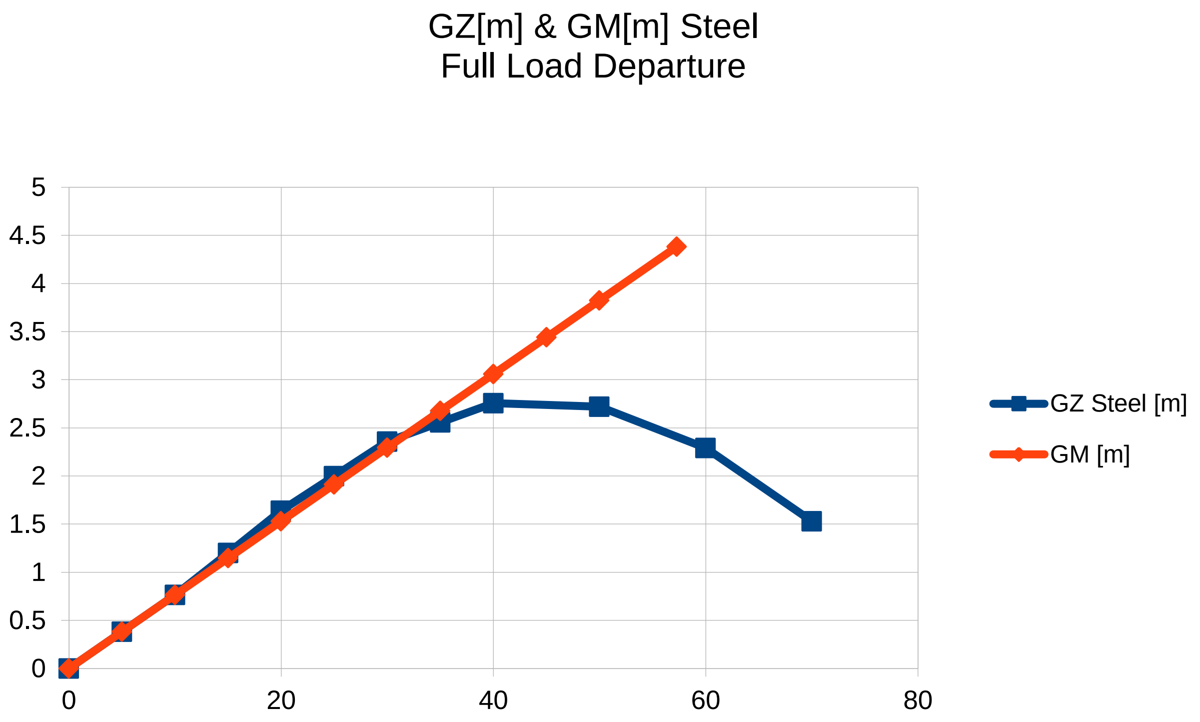


Figure 7. **GZ[m] & GM[m] – Full Load Departure** (Hydromax), (Maxsurf), (ΘΟΔΩΡΟΥ ΛΟΥΚΑΚΗ et al., 2000)

INTACT STABILITY CRITERIA – WATER BALLAST ARRIVAL

Area up to 30 degrees [rad*m]		0.671	>= 0,055	ok		
φ f [Degrees]	**46**					
Area up to 40 degrees [rad*m]		1.114	>=0,09	ok		
Area between 30 and 40 degrees [rad*m]			0.443	>=0,03	ok	
The GZ must not be less than 0,2m at an angle >=30 degrees			ok			
The maximum lever shall occur at an angle not less than 25 degrees			42.7	ok		
Intial GM shall not be less than 0,15m			4.830	ok		

Table 90. **Intact Stability Criteria of Righting Lever in WATER BALLAST ARRIVAL.** Source: (ANNEX 2 RESOLUTION MSC.267(85) (adopted on 4 December 2008) MSC 85/26/Add.1)

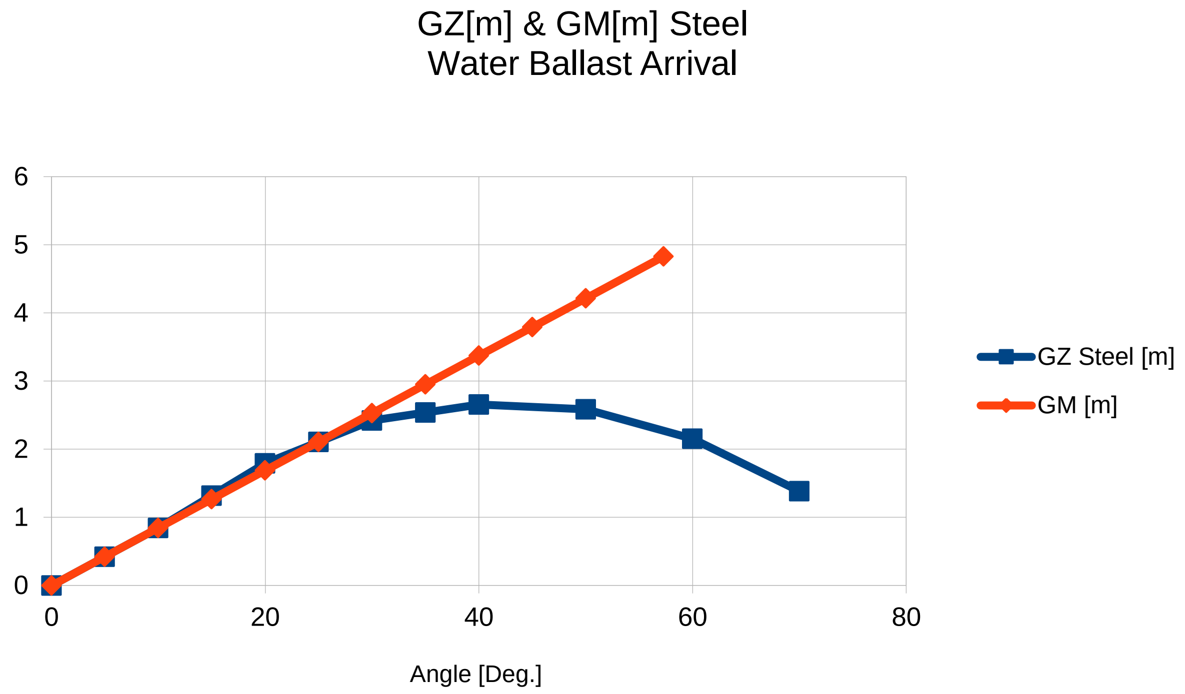


Figure 8. **GZ[m] & GM[m] – Water Ballast Arrival** (Hydromax), (Maxsurf), (ΘΟΔΩΡΟΥ ΛΟΥΚΑΚΗ et al., 2000)

15. Tonnage & Crew Synthesis

In accordance with bibliographical source: **(Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)**, tables 91, 92, 93 and 94 present the tonnage (gross and net) of the examined vessel.

(TONNAGE) STEEL

1. Hull Volume up to Main Deck

V hull [m3]	**69865.62**

2. Aft Superstructure Volume

Exhaust Gas Tunnel Area [m2]	**38.5**

Deck	**hi [m]**	**Area [m2] for tonnage**	**Area without Exhaust Gas Tunnel (engine casing) [m2]**	**Volume without Exhaust Gas Tunnel (engine casing) [m2]**
I	**3.85**	**735.42**	696.92	2683.142
II	**3.5**	**404.5**	404.5	1415.750
III	**2.8**	**404.5**	404.5	1132.600
IV	**2.98**	**258**	258	768.840
V	**2.63**	**258**	258	678.540
VI	**3.325**	**139.01**	139.01	462.208
			Total	7141.08

Table 91. **Hull & Aft Superstructure Volume.**

According to the previous bibliographical reference, volumes of the superstructures (mid or fore or aft) which contain any type of machine or any part of the propulsion engines can be exempted. Source: **(Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)**

3. Forecastle Volume
It is NOT taken into consideration as it holds Natural Gas Compressors

Vforecastle [m3]	0

Total Closed Volumes [m3]	77006.70

Table 92. **Forecastle Volume.**

4. Gross Tonnage	
K1	0.298
Gross Tonnage	22927.25

Table 93. **Gross Tonnage** (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)

Picture 44 is presented in Appandix A.

Picture 44. **Gross and Net Tonnage Mathematical Model.** Source: (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)

5. Net Tonnage

	Area [m2]	Height [m]	Volume [m3]
HOLD 5	**346.71**	**15.29**	5301.20
HOLD 4	**346.71**	**15.29**	5301.20
HOLD 3	**346.71**	**15.29**	5301.20
HOLD 2	**337.04**	**15.29**	5153.34
HOLD 1	**158.71**	**15.29**	2426.68
		Sum	23483.61

N1: Number of Passengers in rooms not more than 8 beds.
N2: Number of Rest Passengers
Εάν (N1+N2)<13 then N1=N2=0
T: Summer Load Line Draft

T summer load line [m]	**6.68**
Depth [m]	**17.27**

N1	**0**
N2	**0**
Vc [m3]	23483.61

K2	0.287
K3	4.116

					STATE
((4T)/(3D))^2	0.266	<=1			ok
k2*Vc*(((4T)/(3D))^2)	1795.231	>=	0,25GT	5731.812	X
Net Tonnage		>=	0,3GT	6878.175	X
	1795.231	5731.812			

ΤΕΛΙΚΟ ΑΠΟΤΕΛΕΣΜΑ

k2*Vc*(((4T)/(3D))^2)	5731.81
Gross Tonnage	22927.25
Net Tonnage	6878.17

5731.81	6878.17

The Factor ((4T/(3D))^2 not to be taken into consideration greater than 1.
The value k2*Vc*((4T/(3D))^2 not to be taken into consideration smaller than 0.25GT.
The Net Tonnage must not be less than 0,3GT.

Table 94. **Net Tonnage** (A. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)

Bibliographical **Source: (A. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)** provides us the requested data for Equipment Number, Anchors, Chain Cable, Tow Line, Mooring Line and Chain Locker Calculation.

Picture 45 is presented in Appendix A.

Picture 45. **Equipment Number 1/5.** Source: (A. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)

Picture 46 is presented in Appendix A.

Picture 46. **Equipment Number 2/5.** Source: (A. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)

Picture 47 is presented in Appendix A.

Picture 47. **Equipment Number 3/5.** Source: (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)

Picture 48 is presented in Appendix A.

Picture 48. **Equipment Number 4/5.** Source: (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)

Picture 49 is presented in Appendix A.

Picture 49. **Equipment Number 5/5.** Source: (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)

6. EQUIPMENT NUMBER

Displacement [t] Summer Load Line	**24008**
Ship Breadth [m]	**29.58**
h: Sum of summer load line freeboard and height of the superstructure [m]	**29.68**
A: summer load line freeboard area [m2]	**2361**

Equipment Number	*2824.19*
Equipment Index	***U38***

7. Anchors, Chain Cable, Tow Line and Mooring Line

Stockless Anchors	
Bower Anchors Number	**3**
Weight per Anchor [kg]	**8300**
Chain Cable	
Stud Link Bower Chain Length [m]	**632.5**
Diameter (Grade 1) [mm]	**92**
Diameter (Grade 2) [mm]	**81**

Tow Line	
Minimum Length [m]]	**260**
Breaking Strength [kg]	**150000**
Mooring Lines	
Number	**6**
Min Length of Each [m]	**200**
Min Breaking Strength [kg]	**50000**

8. Chain Locker

Minimum Volume of Chain Locker	*15.34*

Chain Locker Breadth=Chain Locker Length [m]	*1.64*
Chain Locker Height [m]	*5.73*

It is assumed that the chain locker height to its length is equal to 3,5
It is assumed that the chain locker length is equal to its breadth.

Table 95. **For Equipment Number, Anchors, Chain Cable, Tow Line, Mooring Line and Chain Locker Calculation.** Source: (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)

Table 96 presents the crew synthesis according to bibliographical source: (Α. Παπανικολάου, 2004).

9. Crew Selection	
Gross Tonnage	22927.25
Horse Power [HP]	**16085.79**

A. Deck Crew

Number of Positions	**Position**
1	**ΠΛΟΙΑΡΧΟΣ Α’**
1	**ΠΛΟΙΑΡΧΟΣ Β’**
2	**ΠΛΟΙΑΡΧΟΣ Γ’**
1	**ΝΑΥΚΛΗΡΟΣ**
5	**ΝΑΥΤΕΣ**

10

B. Engine Room Crew

Number of Positions	Position
1	ΜΗΧΑΝΙΚΟΣ Α’
1	ΜΗΧΑΝΙΚΟΣ Β’
2	ΜΗΧΑΝΙΚΟΣ Γ’
1	ΔΟΚΙΜΟΣ ΜΗΧΑΝΙΚΟΣ
1	ΜΗΧΑΝΟΔΗΓΟΣ Α’
1	ΜΗΧΑΝΟΔΗΓΟΣ Β’
1	ΜΑΘΗΤΕΥΟΜΕΝΟΣ ΜΗΧΑΝΙΚΟΣ
1	ΗΛΕΚΤΡΟΛΟΓΟΣ
9	

C. General Duty Crew

Number of Positions	Position
1	ΜΑΓΕΙΡΑΣ
1	ΘΑΛΑΜΗΠΟΛΟΣ
1	ΒΟΗΘΟΣ ΘΑΛΑΜΗΠΟΛΟΥ
1	ΡΑΔΙΟΤΗΛΕΓΡΑΦΗΤΗΣ Α’
1	ΘΕΡΜΑΣΤΗΣ
1	ΔΟΚΙΜΟΣ ΑΞΙΩΜΑΤΙΚΟΣ
6	

Total Number of Positions	*25*

Table 96. **Crew Synthesis.** (Α. Παπανικολάου, 2004)

16. Resistance, Propulsion & Powering

In this chapter, the resistance & propulsion analysis of the examined CNG-carrier will take place. Moreover, according to them at the end of this chapter, main propulsion engines will be selected.

According to (J. Holtrop, G. Mennen), (J. Holtrop), (Γερασίμου Κ. Πολίτη, 2005), (Γ.Κ. ΠΟΛΙΤΗ et al., 23/11/2005), (MATLAB, 2017), (ΜΕΛΕΤΗ & ΣΧΕΔΙΑΣΗ ΠΛΟΙΩΝ ΕΙΔΙΚΟΥ ΤΥΠΟΥ Σημειώσεις Μαθήματος, 2016-2017) the resistance of the vessel for still water, heavy weather (+20%) and for heavy weather (+40%) is illustrated in figures 9, 10 and 11.

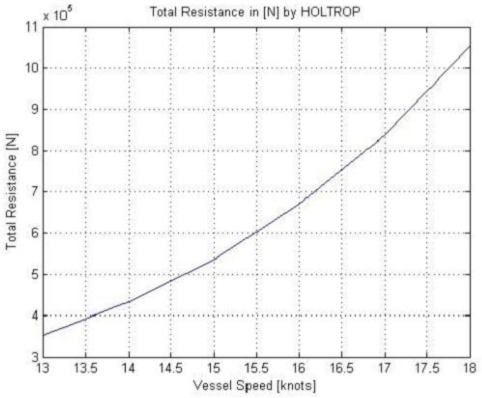


Figure 9. Resistance in [N] – Still Water. (J. Holtrop, G. Mennen), (J. Holtrop), (Γερασίμου Κ. Πολίτη, 2005), (Γ.Κ. ΠΟΛΙΤΗ et al., 23/11/2005), (MATLAB, 2017), (ΜΕΛΕΤΗ & ΣΧΕΔΙΑΣΗ ΠΛΟΙΩΝ ΕΙΔΙΚΟΥ ΤΥΠΟΥ Σημειώσεις Μαθήματος, 2016-2017)

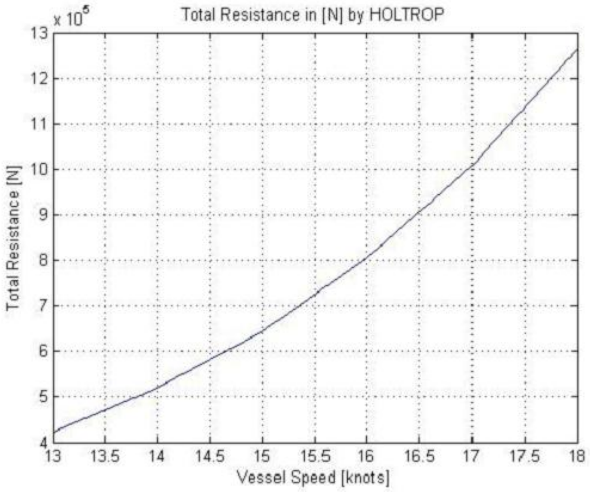


Figure 10. Resistance in [N] – Heavy Weather (+20%).

(J. Holtrop, G. Mennen), (J. Holtrop), (MATLAB, 2017), (Γερασίμου Κ. Πολίτη, 2005), (Γ.Κ. ΠΟΛΙΤΗ et al., 23/11/2005), (ΜΕΛΕΤΗ & ΣΧΕΔΙΑΣΗ ΠΛΟΙΩΝ ΕΙΔΙΚΟΥ ΤΥΠΟΥ Σημειώσεις Μαθήματος, 2016-2017)

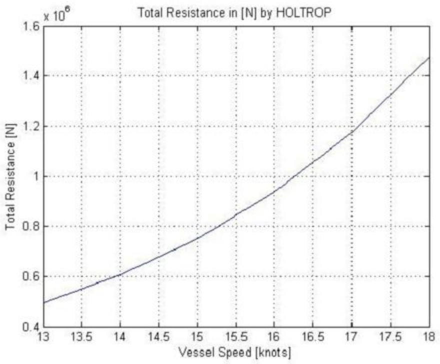


Figure 11. Resistance in [N] – Heavy Weather (+40%).(J. Holtrop, G. Mennen), (J. Holtrop), (MATLAB, 2017), (Γερασίμου Κ. Πολίτη, 2005), (Γ.Κ. ΠΟΛΙΤΗ et al., 23/11/2005), (ΜΕΛΕΤΗ & ΣΧΕΔΙΑΣΗ ΠΛΟΙΩΝ ΕΙΔΙΚΟΥ ΤΥΠΟΥ Σημειώσεις Μαθήματος, 2016-2017)

In accordance with bibliographical sources: (ΥΔΡΟΔΥΝΑΜΙΚΗ ΠΛΟΙΟΥ (Αντίσταση - Πρόωση) ΣΤΟΙΧΕΙΑ ΓΙΑ ΥΠΟΛΟΓΙΣΜΟΥΣ, 1982), (Γερασίμου Κ. Πολίτη, Μάιος 2005), (Γ.Κ. ΠΟΛΙΤΗ et al., 23/11/2005), (ΜΕΛΕΤΗ & ΣΧΕΔΙΑΣΗ ΠΛΟΙΩΝ ΕΙΔΙΚΟΥ ΤΥΠΟΥ Σημειώσεις Μαθήματος, 2016-2017) the thrust deduction factor (t), wake fraction factor (w), relative revolution factor (N_R), Expanded Area to Disk Area Ratio (Ae/Ao) and Propellers Trust (T) will be calculated. It is noted that for that purposes, **Two (2X) Wagenigen B Series** propellers will be used.

$$w=0.81*Cb-0.34=0.81*0.77-0.34=0.2837$$

$$w=0.7*Cp-0.3=0.7*0.797-0.3=0.2579$$

$$\mathbf{w=0.2708}$$

Equation 7. Wake Fraction Factor. Source: (ΥΔΡΟΔΥΝΑΜΙΚΗ ΠΛΟΙΟΥ (Αντίσταση - Πρόωση) ΣΤΟΙΧΕΙΑ ΓΙΑ ΥΠΟΛΟΓΙΣΜΟΥΣ, 1982) (Γερασίμου Κ. Πολίτη, 2005), (Γ.Κ. ΠΟΛΙΤΗ et al., 23/11/2005), (ΜΕΛΕΤΗ & ΣΧΕΔΙΑΣΗ ΠΛΟΙΩΝ ΕΙΔΙΚΟΥ ΤΥΠΟΥ Σημειώσεις Μαθήματος, 2016-2017)

$$t=0.5*Cp-0.18=0.5*0.797-0.18=0.2185$$

$$t=0.52*Cb-0.18=0.52*0.77-0.18=0.2204$$

$$t=w*(1.67-2.3*(Cb/Cwl)+1.5*Cb)=0.2708*(1.67-2.3*0.77/0.903+1.5*0.77)=0.234$$

$$t=0.325*Cb-0.1885*D/sqrt(BT)=0.325*0.77-0.1885*3.82/sqrt(29.58*6.68)=0.199$$

$$\mathbf{t=0.218}$$

Equation 8. Thrust Deduction Factor. Source: (ΥΔΡΟΔΥΝΑΜΙΚΗ ΠΛΟΙΟΥ (Αντίσταση - Πρόωση) ΣΤΟΙΧΕΙΑ ΓΙΑ ΥΠΟΛΟΓΙΣΜΟΥΣ, 1982), (Γερασίμου Κ. Πολίτη, 2005), (Γ.Κ. ΠΟΛΙΤΗ et al., 23/11/2005), (ΜΕΛΕΤΗ & ΣΧΕΔΙΑΣΗ ΠΛΟΙΩΝ ΕΙΔΙΚΟΥ ΤΥΠΟΥ Σημειώσεις Μαθήματος, 2016-2017)

From Equations 7 & 8, the hull efficiency is calculated as follows:

n_H=(1-t)/(1-w)=(1-0.218)/(1-0.2708)=1.0724

n_H=1.0724

Equation 9. **Hull Efficiency. Source:** (ΥΔΡΟΔΥΝΑΜΙΚΗ ΠΛΟΙΟΥ (Αντίσταση - Πρόωση) ΣΤΟΙΧΕΙΑ ΓΙΑ ΥΠΟΛΟΓΙΣΜΟΥΣ, 1982), (Γερασίμου Κ. Πολίτη, 2005), (Γ.Κ. ΠΟΛΙΤΗ et al., 23/11/2005), (ΜΕΛΕΤΗ & ΣΧΕΔΙΑΣΗ ΠΛΟΙΩΝ ΕΙΔΙΚΟΥ ΤΥΠΟΥ Σημειώσεις Μαθήματος, 2016-2017)

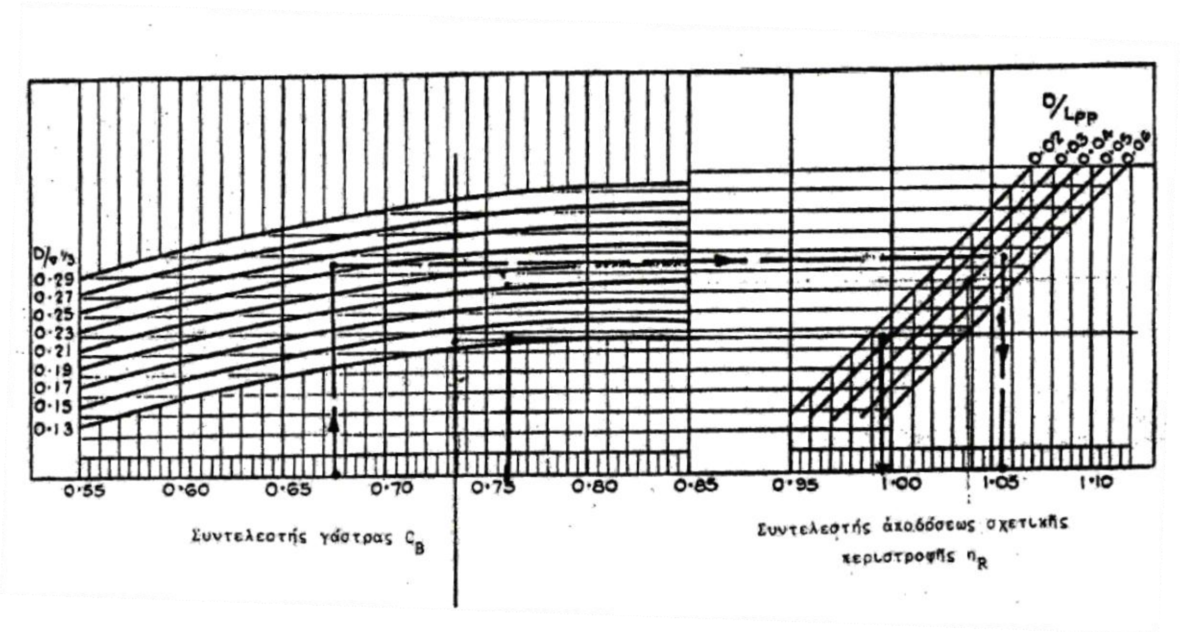
According to bibliographical source: (ΥΔΡΟΔΥΝΑΜΙΚΗ ΠΛΟΙΟΥ (Αντίσταση - Πρόωση) ΣΤΟΙΧΕΙΑ ΓΙΑ ΥΠΟΛΟΓΙΣΜΟΥΣ, 1982), the relative rotating efficiency can be calculated as follows:

Cb=0.77

D/(Vol^0.3333)=3.82/((24008/1.027)^0.3333)=0.1336

D/Lbp=3.82/153.81=0.0248

From Picture 50: **n_R=0.99**



Picture 50. **N_R Calculation.** Source: (ΥΔΡΟΔΥΝΑΜΙΚΗ ΠΛΟΙΟΥ (Αντίσταση - Πρόωση) ΣΤΟΙΧΕΙΑ ΓΙΑ ΥΠΟΛΟΓΙΣΜΟΥΣ, 1982)

In accordance with bibliographical source: (Γερασίμου Κ. Πολίτη, 2005), the thrust of each propeller can be calculated as follows (T_{each}):

T=R0/(z(1-t))=0.5367*10^6/(2*(1-0.218))=**343159N**

p_V=173.25kp/m^2=1700N/m^2=**1700Pa**

Bibliographical source: (Γερασίμου Κ. Πολίτη, 2005), the ratio of propeller expanded area to the circle area can be calculated as follows:

$$p_0=p_{atm}+\rho gh=100000Pa+1025kg/m^3*9.81m/s^2*4m=140221Pa=$$

$$=140221N/m^2=1.4bar$$

$$\mathbf{p_0=1.4bar}$$

$$A_E/A_0= (1.3+0.3*Z)T/((p0-pv)D^2)=(1.3+0.3*4)*343159/((140221-1700)(3.82^2))=$$

$$=0.424$$

Let’s assume **$A_E/A_0=0.5$**

Let’s also assume shaft efficiency (n_S) **$n_S=0.98$**

Equation 10. **Pressure, Ae/A0 & Shaft Efficiency Group of Equations** (Γερασίμου Κ. Πολίτη, 2005)

From bibliographical reference: (Γερασίμου Κ. Πολίτη, 2005), the fluid velocity at the inlet side of each propeller can be calculated as follows:

$$V_A=V_S(1-w)=15knots*0.5144(m/sec)/knots*(1-0.2708)=5.63m/sec$$

$$\mathbf{V_A=5.63m/sec}$$

Equation 11. **Propeller Open Flow Speed Calculation** (Γερασίμου Κ. Πολίτη, 2005)

It is underlined once again that there are **two propellers** accompanied by **two rudders**.

In accordance with bibliographical source: (Γερασίμου Κ. Πολίτη, 2005), we use professor’s Gerasimos Politis code named as Grid in order to calculate each propeller (Wagenigen B Series) behavior (Thrust, Torque, Efficiency) for various vessels speeds, angular velocity and pitch.

Picture 51 is presented in Appendix B.

Picture 51. **Wagenigen B Series , z=4, A_E/A_0=0.4.** Source: (Γερασίμου Κ. Πολίτη, 2005)

Picture 52 is presented in Appendix B.

Picture 52. **Wagenigen B Series , z=4, A_E/A_0=0.55.** Source: (Γερασίμου Κ. Πολίτη, 2005)

By using linear interpolation for A_E/A_0=0.5, the data for the referred propellers are taken.

The referred Grid program of professor Gerasimos Politis calculates the propellers behavior as follows (picture 53, picture 54).

Picture 53 is presented in Appendix B.

Picture 53. **Propeller Behavior Calculation Method 1/2.** Source: (Γερασίμου Κ. Πολίτη, 2005)

Picture 54 is presented in Appendix B.

Picture 54. **Propeller Behavior Calculation Method 2/2.** Source: (Γερασίμου Κ. Πολίτη, 2005)

According to program Grid (Professor Gerasimos Politis), the behavior of each propeller is presented **in tables 97, 98 and 99**. (**table 97 – still water, table 98 – heavy weather +20%, table 99 – heavy weather +40%**).

```
3.81999993 0.500000000 4

0.980000019

2

104.610001

10 6

Diam (m)=  3.820  AE/A0=  0.500  No of blades=  4

Shaft efficiency=  0.980

no of propellers=  2

fluid density (kp*s^2/m^4)= 104.61

Wagenigen B-series
```

```
      V (m/s)    R (kp)      w       t       nr       F (kp)

    6.687      35953.0    0.271    0.218    0.990         0.0

    7.201      44159.0    0.271    0.218    0.990         0.0

    7.716      54709.0    0.271    0.218    0.990         0.0

    8.230      68348.0    0.271    0.218    0.990         0.0

    8.745      85505.0    0.271    0.218    0.990         0.0

    9.259     107360.0    0.271    0.218    0.990         0.0
```

```
                 ********   iso – P/D  ********

           P/D=     0.500  number of propellers=  2

 rpm    V (knots) T (kp)   Q (kp*m)  DHP (PS)  SHP (PS)   P.C.

 208.2    13.000   22987.8  10486.4   3048.3    3110.5     0.515

 227.8    13.999   28234.6  12737.3   4051.5    4134.2     0.513

 249.5    15.000   34980.2  15559.2   5419.3    5529.9     0.509

 273.5    15.999   43700.8  19121.2   7301.3    7450.3     0.503

 299.7    17.000   54670.7  23520.4   9843.9   10044.8     0.496

 328.8    18.000   68644.5  29022.7  13324.5   13596.5     0.487

           P/D=     0.600  number of propellers=  2

 rpm    V (knots) T (kp)   Q (kp*m)  DHP (PS)  SHP (PS)   P.C.

 182.8    13.000   22987.8  10836.7   2765.9    2822.4     0.568

 200.2    13.999   28234.6  13194.2   3687.5    3762.8     0.563
```

219.4	15.000	34980.2	16166.1	4951.9	5052.9	0.557
240.8	15.999	43700.8	19936.9	6702.3	6839.1	0.548
264.2	17.000	54670.7	24612.0	9079.5	9264.8	0.538
290.2	18.000	68644.5	30481.8	12351.0	12603.0	0.526

P/D= 0.700 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
163.9	13.000	22987.8	11508.8	2633.6	2687.3	0.596
179.6	13.999	28234.6	14035.1	3518.9	3590.7	0.590
197.0	15.000	34980.2	17231.3	4738.7	4835.4	0.582
216.4	15.999	43700.7	21300.5	6435.0	6566.3	0.571
237.7	17.000	54670.7	26358.1	8747.1	8925.6	0.559
261.3	18.000	68644.5	32723.7	11940.7	12184.4	0.544

P/D= 0.800 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
149.3	13.000	22987.8	12365.7	2578.2	2630.8	0.609
163.7	13.999	28234.6	15097.0	3450.6	3521.0	0.602
179.7	15.000	34980.2	18561.1	4656.5	4751.5	0.592
197.5	15.999	43700.7	22981.4	6339.0	6468.3	0.580
217.2	17.000	54670.7	28484.8	8638.6	8814.9	0.566
239.1	18.000	68644.5	35423.1	11823.8	12065.1	0.549

P/D= 0.900 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
137.8	13.000	22987.8	13340.4	2566.8	2619.2	0.612
151.1	13.999	28234.6	16299.9	3439.8	3510.0	0.604
166.0	15.000	34980.2	20060.1	4649.7	4744.6	0.593

182.7	15.999	43700.8	24866.0	6342.0	6471.4	0.579
201.0	17.000	54670.7	30857.1	8660.1	8836.8	0.564
221.4	18.000	68644.5	38419.5	11878.2	12120.6	0.547

P/D= 1.000 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
128.5	13.000	22987.8	14392.7	2582.3	2635.0	0.608
141.0	13.999	28234.6	17596.0	3464.2	3534.9	0.600
155.0	15.000	34980.2	21671.2	4689.0	4784.7	0.588
170.6	15.999	43700.8	26886.3	6405.9	6536.7	0.574
187.9	17.000	54670.7	33393.7	8762.1	8940.9	0.558
207.2	18.000	68644.5	41615.8	12039.2	12284.9	0.539

P/D= 1.100 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
120.8	13.000	22987.8	15491.0	2613.8	2667.1	0.601
132.7	13.999	28234.6	18947.2	3509.7	3581.3	0.592
145.9	15.000	34980.2	23348.8	4756.1	4853.2	0.580
160.8	15.999	43700.7	28987.3	6506.7	6639.4	0.565
177.2	17.000	54670.7	36028.9	8913.0	9094.8	0.548
195.5	18.000	68644.5	44933.2	12265.6	12516.0	0.529

P/D= 1.200 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
114.4	13.000	22987.8	16602.0	2653.0	2707.1	0.592
125.7	13.999	28234.6	20313.7	3565.2	3638.0	0.583
138.3	15.000	34980.2	25045.0	4836.6	4935.3	0.570

```
 152.5   15.999  43700.7  31111.4   6625.2   6760.4    0.555
 168.2   17.000  54670.7  38692.8   9087.7   9273.1    0.538
185.8   18.000  68644.5  48287.7  12524.3  12779.9    0.519
              P/D=    1.300  number of propellers=  2
 rpm    V (knots) T (kp)   Q (kp*m)  DHP (PS)  SHP (PS)  P.C.
 109.0   13.000  22987.8  17685.6   2692.1   2747.0    0.583
 119.8   13.999  28234.6  21647.3   3620.7   3694.5    0.574
 131.9   15.000  34980.2  26701.4   4916.8   5017.1    0.561
 145.5   15.999  43700.8  33187.4   6743.4   6881.0    0.545
 160.6   17.000  54670.7  41299.5   9262.0   9451.0    0.527
177.5   18.000  68644.5  51574.1  12782.7  13043.5    0.508



              P/D=    1.400  number of propellers=  2
 rpm    V (knots) T (kp)   Q (kp*m)  DHP (PS)  SHP (PS)  P.C.
 104.3   13.000  22987.8  18690.8   2723.0   2778.5    0.577
 114.7   13.999  28234.6  22885.9   3665.0   3739.8    0.567
 126.3   15.000  34980.2  28242.8   4982.1   5083.8    0.554
 139.5   15.999  43700.7  35123.7   6841.5   6981.1    0.537
 154.1   17.000  54670.7  43736.9   9409.3   9601.3    0.519
170.4   18.000  68644.5  54655.6  13004.6  13270.0    0.499
              ********   iso – V (or iso – pull)  ********
           V (knots)=    13.000  number of propellers=  2
  rpm      P/D     T (kp)    Q (kp*m)  DHP (PS)  SHP (PS)  P.C.
  208.2     0.50  22987.8  10486.4   3048.3   3110.5    0.515
  182.8     0.60  22987.8  10836.7   2765.9   2822.4    0.568
```

163.9	0.70	22987.8	11508.8	2633.6	2687.3	0.596
149.3	0.80	22987.8	12365.7	2578.2	2630.8	0.609
137.8	0.90	22987.8	13340.4	2566.8	2619.2	0.612
128.5	1.00	22987.8	14392.7	2582.3	2635.0	0.608
120.8	1.10	22987.8	15491.0	2613.8	2667.1	0.601
114.4	1.20	22987.8	16602.0	2653.0	2707.1	0.592
109.0	1.30	22987.8	17685.6	2692.1	2747.0	0.583
104.3	1.40	22987.8	18690.8	2723.0	2778.5	0.577

V (knots)= 13.999 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
227.8	0.50	28234.6	12737.3	4051.5	4134.2	0.513
200.2	0.60	28234.6	13194.2	3687.5	3762.8	0.563
179.6	0.70	28234.6	14035.1	3518.9	3590.7	0.590
163.7	0.80	28234.6	15097.0	3450.6	3521.0	0.602
151.1	0.90	28234.6	16299.9	3439.8	3510.0	0.604
141.0	1.00	28234.6	17596.0	3464.2	3534.9	0.600
132.7	1.10	28234.6	18947.2	3509.7	3581.3	0.592
125.7	1.20	28234.6	20313.7	3565.2	3638.0	0.583
119.8	1.30	28234.6	21647.3	3620.7	3694.5	0.574
114.7	1.40	28234.6	22885.9	3665.0	3739.8	0.567

V (knots)= 15.000 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
249.5	0.50	34980.2	15559.2	5419.3	5529.9	0.509
219.4	0.60	34980.2	16166.1	4951.9	5052.9	0.557
197.0	0.70	34980.2	17231.3	4738.7	4835.4	0.582
179.7	0.80	34980.2	18561.1	4656.5	4751.5	0.592
166.0	0.90	34980.2	20060.1	4649.7	4744.6	0.593

155.0	1.00	34980.2	21671.2	4689.0	4784.7	0.588
145.9	1.10	34980.2	23348.8	4756.1	4853.2	0.580
138.3	1.20	34980.2	25045.0	4836.6	4935.3	0.570
131.9	1.30	34980.2	26701.4	4916.8	5017.1	0.561
126.3	1.40	34980.2	28242.8	4982.1	5083.8	0.554

V (knots)= 15.999 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
273.5	0.50	43700.8	19121.2	7301.3	7450.3	0.503
240.8	0.60	43700.8	19936.9	6702.3	6839.1	0.548
216.4	0.70	43700.7	21300.5	6435.0	6566.3	0.571
197.5	0.80	43700.7	22981.4	6339.0	6468.3	0.580
182.7	0.90	43700.8	24866.0	6342.0	6471.4	0.579
170.6	1.00	43700.8	26886.3	6405.9	6536.7	0.574
160.8	1.10	43700.7	28987.3	6506.7	6639.4	0.565
152.5	1.20	43700.7	31111.4	6625.2	6760.4	0.555
145.5	1.30	43700.8	33187.4	6743.4	6881.0	0.545
139.5	1.40	43700.7	35123.7	6841.5	6981.1	0.537

V (knots)= 17.000 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
299.7	0.50	54670.7	23520.4	9843.9	10044.8	0.496
264.2	0.60	54670.7	24612.0	9079.5	9264.8	0.538
237.7	0.70	54670.7	26358.1	8747.1	8925.6	0.559
217.2	0.80	54670.7	28484.8	8638.6	8814.9	0.566
201.0	0.90	54670.7	30857.1	8660.1	8836.8	0.564
187.9	1.00	54670.7	33393.7	8762.1	8940.9	0.558
177.2	1.10	54670.7	36028.9	8913.0	9094.8	0.548

168.2	1.20	54670.7	38692.8	9087.7	9273.1	0.538
160.6	1.30	54670.7	41299.5	9262.0	9451.0	0.527
154.1	1.40	54670.7	43736.9	9409.3	9601.3	0.519

V (knots)= 18.000 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
328.8	0.50	68644.5	29022.7	13324.5	13596.5	0.487
290.2	0.60	68644.5	30481.8	12351.0	12603.0	0.526
261.3	0.70	68644.5	32723.7	11940.7	12184.4	0.544
239.1	0.80	68644.5	35423.1	11823.8	12065.1	0.549
221.4	0.90	68644.5	38419.5	11878.2	12120.6	0.547
207.2	1.00	68644.5	41615.8	12039.2	12284.9	0.539
195.5	1.10	68644.5	44933.2	12265.6	12516.0	0.529
185.8	1.20	68644.5	48287.7	12524.3	12779.9	0.519
177.5	1.30	68644.5	51574.1	12782.7	13043.5	0.508
170.4	1.40	68644.5	54655.6	13004.6	13270.0	0.499

Table 97. Still Water **Propeller Behavior.** (Γερασίμου Κ. Πολίτη, 2005)

3.81999993 0.500000000 4

0.980000019

2

104.610001

10 6

Diam (m)= 3.820 AE/A0= 0.500 No of blades= 4

Shaft efficiency= 0.980

no of propellers= 2

fluid density (kp*s^2/m^4)= 104.61

Wagenigen B-series

V (m/s)	R (kp)	w	t	nr	F (kp)
6.687	43139.0	0.271	0.218	0.990	0.0
7.201	52987.0	0.271	0.218	0.990	0.0
7.716	65647.0	0.271	0.218	0.990	0.0
8.230	82018.0	0.271	0.218	0.990	0.0
8.745	102600.0	0.271	0.218	0.990	0.0
9.259	128838.0	0.271	0.218	0.990	0.0

******** iso – P/D ********

P/D= 0.500 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
219.3	13.000	27582.5	12162.8	3723.8	3799.7	0.506
240.2	13.999	33879.1	14792.2	4960.7	5061.9	0.503
263.3	15.000	41973.8	18098.2	6654.8	6790.6	0.497
289.2	15.999	52441.2	22283.7	8997.5	9181.1	0.490
317.5	17.000	65601.0	27461.2	12173.7	12422.2	0.482
348.9	18.000	82377.2	33955.2	16543.0	16880.6	0.471

P/D= 0.600 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
192.9	13.000	27582.5	12660.6	3410.8	3480.4	0.553
211.5	13.999	33879.1	15430.3	4556.4	4649.4	0.547

232.1	15.000	41973.8	18929.2	6134.2	6259.4	0.539
255.1	15.999	52441.1	23379.1	8328.1	8498.1	0.530
280.4	17.000	65601.0	28902.3	11316.5	11547.4	0.518
308.6	18.000	82377.2	35853.1	15446.7	15762.0	0.505

P/D= 0.700 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
173.3	13.000	27582.5	13511.6	3269.7	3336.4	0.576
190.1	13.999	33879.1	16490.6	4376.6	4465.9	0.570
208.8	15.000	41973.8	20265.8	5906.9	6027.5	0.560
229.7	15.999	52441.1	25081.1	8043.2	8207.4	0.548
252.7	17.000	65601.0	31070.8	10962.7	11186.4	0.535
278.3	18.000	82377.3	38624.9	15011.1	15317.5	0.519

P/D= 0.800 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
158.2	13.000	27582.5	14566.8	3217.1	3282.8	0.586
173.6	13.999	33879.2	17795.6	4312.6	4400.7	0.578
190.7	15.000	41973.8	21896.2	5831.7	5950.7	0.567
210.0	15.999	52441.2	27137.1	7958.4	8120.8	0.554
231.3	17.000	65601.0	33665.8	10871.9	11093.8	0.539
255.0	18.000	82377.2	41911.7	14922.2	15226.8	0.522

P/D= 0.900 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
146.2	13.000	27582.5	15752.8	3215.7	3281.3	0.586
160.5	13.999	33879.1	19257.9	4315.8	4403.9	0.578
176.5	15.000	41973.8	23716.1	5844.7	5964.0	0.566

```
 194.5    15.999   52441.2   29422.4    7990.1    8153.2     0.552
214.3    17.000   65601.0   36538.5   10935.2   11158.3     0.536
236.5    18.000   82377.2   45536.2   15037.6   15344.5     0.518
                    P/D=     1.000  number of propellers=  2
  rpm     V (knots) T (kp)     Q (kp*m)   DHP (PS)  SHP (PS)   P.C.
 136.5    13.000   27582.5   17025.7    3245.6    3311.9     0.581
 150.0    13.999   33879.1   20824.8    4360.2    4449.2     0.572
 165.0    15.000   41973.8   25662.7    5912.2    6032.8     0.560
 181.9    15.999   52441.2   31861.7    8094.3    8259.5     0.545
200.7    17.000   65601.0   39599.1   11094.8   11321.2     0.528
221.6    18.000   82377.2   49390.9   15281.8   15593.7     0.510




                    P/D=     1.100  number of propellers=  2
  rpm     V (knots) T (kp)     Q (kp*m)   DHP (PS)  SHP (PS)   P.C.
 128.6    13.000   27582.5   18350.3    3294.5    3361.7     0.572
 141.3    13.999   33879.1   22454.2    4429.6    4520.0     0.563
 155.5    15.000   41973.8   27685.2    6012.8    6135.5     0.550
 171.6    15.999   52441.2   34394.1    8242.8    8411.0     0.535
189.4    17.000   65601.0   42774.4   11313.8   11544.7     0.518
209.4    18.000   82377.3   53388.1   15606.2   15924.7     0.499
                    P/D=     1.200  number of propellers=  2
  rpm     V (knots) T (kp)     Q (kp*m)   DHP (PS)  SHP (PS)   P.C.
 121.9    13.000   27582.5   19689.4    3352.5    3420.9     0.562
 134.1    13.999   33879.1   24101.3    4511.0    4603.1     0.553
 147.7    15.000   41973.8   29729.8    6129.6    6254.7     0.540
```

```
 163.0   15.999   52441.2   36954.6    8413.0    8584.7     0.524
180.1    17.000   65601.0   45985.7   11562.3   11798.3     0.507
199.2    18.000   82377.2   57432.3   15970.9   16296.8     0.488
                P/D=     1.300  number of propellers=  2
 rpm     V (knots) T (kp)     Q (kp*m)   DHP (PS)  SHP (PS)   P.C.
 116.3   13.000   27582.5   20997.6    3410.3    3479.8     0.553
 127.9   13.999   33879.1   25711.5    4592.3    4686.0     0.543
 141.0   15.000   41973.8   31730.0    6246.0    6373.5     0.530
 155.8   15.999   52441.2   39462.2    8583.0    8758.2     0.514
172.2    17.000   65601.0   49134.5   11810.8   12051.8     0.496
190.5    18.000   82377.2   61403.5   16336.3   16669.7     0.477



                P/D=     1.400  number of propellers=  2
 rpm     V (knots) T (kp)     Q (kp*m)   DHP (PS)  SHP (PS)   P.C.
 111.5   13.000   27582.5   22216.6    3457.8    3528.4     0.545
 122.6   13.999   33879.1   27213.8    4659.8    4754.9     0.535
 135.2   15.000   41973.8   33599.8    6344.2    6473.7     0.522
 149.5   15.999   52441.1   41811.5    8728.4    8906.5     0.505
165.3    17.000   65601.0   52091.7   12026.2   12271.6     0.487
183.1    18.000   82377.2   65142.7   16657.2   16997.1     0.468

                ********   iso – V (or iso – pull)   ********
             V (knots)=    13.000  number of propellers=  2
  rpm      P/D     T (kp)     Q (kp*m)   DHP (PS)  SHP (PS)  P.C.
  219.3     0.50   27582.5   12162.8    3723.8    3799.7     0.506
```

192.9	0.60	27582.5	12660.6	3410.8	3480.4	0.553
173.3	0.70	27582.5	13511.6	3269.7	3336.4	0.576
158.2	0.80	27582.5	14566.8	3217.1	3282.8	0.586
146.2	0.90	27582.5	15752.8	3215.7	3281.3	0.586
136.5	1.00	27582.5	17025.7	3245.6	3311.9	0.581
128.6	1.10	27582.5	18350.3	3294.5	3361.7	0.572
121.9	1.20	27582.5	19689.4	3352.5	3420.9	0.562
116.3	1.30	27582.5	20997.6	3410.3	3479.8	0.553
111.5	1.40	27582.5	22216.6	3457.8	3528.4	0.545

V (knots)= 13.999 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
240.2	0.50	33879.1	14792.2	4960.7	5061.9	0.503
211.5	0.60	33879.1	15430.3	4556.4	4649.4	0.547
190.1	0.70	33879.1	16490.6	4376.6	4465.9	0.570
173.6	0.80	33879.2	17795.6	4312.6	4400.7	0.578
160.5	0.90	33879.1	19257.9	4315.8	4403.9	0.578
150.0	1.00	33879.1	20824.8	4360.2	4449.2	0.572
141.3	1.10	33879.1	22454.2	4429.6	4520.0	0.563
134.1	1.20	33879.1	24101.3	4511.0	4603.1	0.553
127.9	1.30	33879.1	25711.5	4592.3	4686.0	0.543
122.6	1.40	33879.1	27213.8	4659.8	4754.9	0.535

V (knots)= 15.000 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
263.3	0.50	41973.8	18098.2	6654.8	6790.6	0.497
232.1	0.60	41973.8	18929.2	6134.2	6259.4	0.539

208.8	0.70	41973.8	20265.8	5906.9	6027.5	0.560
190.7	0.80	41973.8	21896.2	5831.7	5950.7	0.567
176.5	0.90	41973.8	23716.1	5844.7	5964.0	0.566
165.0	1.00	41973.8	25662.7	5912.2	6032.8	0.560
155.5	1.10	41973.8	27685.2	6012.8	6135.5	0.550
147.7	1.20	41973.8	29729.8	6129.6	6254.7	0.540
141.0	1.30	41973.8	31730.0	6246.0	6373.5	0.530
135.2	1.40	41973.8	33599.8	6344.2	6473.7	0.522

V (knots)= 15.999 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
289.2	0.50	52441.2	22283.7	8997.5	9181.1	0.490
255.1	0.60	52441.1	23379.1	8328.1	8498.1	0.530
229.7	0.70	52441.1	25081.1	8043.2	8207.4	0.548
210.0	0.80	52441.2	27137.1	7958.4	8120.8	0.554
194.5	0.90	52441.2	29422.4	7990.1	8153.2	0.552
181.9	1.00	52441.2	31861.7	8094.3	8259.5	0.545
171.6	1.10	52441.2	34394.1	8242.8	8411.0	0.535
163.0	1.20	52441.2	36954.6	8413.0	8584.7	0.524
155.8	1.30	52441.2	39462.2	8583.0	8758.2	0.514
149.5	1.40	52441.1	41811.5	8728.4	8906.5	0.505

V (knots)= 17.000 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
317.5	0.50	65601.0	27461.2	12173.7	12422.2	0.482
280.4	0.60	65601.0	28902.3	11316.5	11547.4	0.518
252.7	0.70	65601.0	31070.8	10962.7	11186.4	0.535
231.3	0.80	65601.0	33665.8	10871.9	11093.8	0.539

214.3	0.90	65601.0	36538.5	10935.2	11158.3	0.536
200.7	1.00	65601.0	39599.1	11094.8	11321.2	0.528
189.4	1.10	65601.0	42774.4	11313.8	11544.7	0.518
180.1	1.20	65601.0	45985.7	11562.3	11798.3	0.507
172.2	1.30	65601.0	49134.5	11810.8	12051.8	0.496
165.3	1.40	65601.0	52091.7	12026.2	12271.6	0.487

V (knots)= 18.000 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
348.9	0.50	82377.2	33955.2	16543.0	16880.6	0.471
308.6	0.60	82377.2	35853.1	15446.7	15762.0	0.505
278.3	0.70	82377.3	38624.9	15011.1	15317.5	0.519
255.0	0.80	82377.2	41911.7	14922.2	15226.8	0.522
236.5	0.90	82377.2	45536.2	15037.6	15344.5	0.518
221.6	1.00	82377.2	49390.9	15281.8	15593.7	0.510
209.4	1.10	82377.3	53388.1	15606.2	15924.7	0.499
199.2	1.20	82377.2	57432.3	15970.9	16296.8	0.488
190.5	1.30	82377.2	61403.5	16336.3	16669.7	0.477
183.1	1.40	82377.2	65142.7	16657.2	16997.1	0.468

Table 98. Heavy Weather +20% Propeller Behavior. (Γερασίμου Κ. Πολίτη, 2005)

3.81999993 0.500000000 4

0.980000019

2

104.610001

10 6

Diam (m)= 3.820 AE/A0= 0.500 No of blades= 4

Shaft efficiency= 0.980

no of propellers= 2

```
               fluid density (kp*s^2/m^4)= 104.61

                      Wagenigen B-series


        V (m/s)    R (kp)     w      t      nr      F (kp)

      6.687     50326.0    0.271   0.218   0.990      0.0

      7.201     61825.0    0.271   0.218   0.990      0.0

      7.716     76585.0    0.271   0.218   0.990      0.0

      8.230     95688.0    0.271   0.218   0.990      0.0

      8.745    119704.0    0.271   0.218   0.990      0.0

      9.259    150305.0    0.271   0.218   0.990      0.0




                  ********   iso – P/D   ********

               P/D=     0.500  number of propellers=  2

   rpm    V (knots) T (kp)    Q (kp*m)   DHP (PS)  SHP (PS)   P.C.

   229.7    13.000   32177.7   13829.0    4434.7    4525.2    0.496

   251.8    13.999   39530.0   16837.0    5919.4    6040.2    0.491

   276.4    15.000   48967.4   20622.1    7957.7    8120.1    0.485

  303.9    15.999   61181.6   25428.1   10788.7   11008.9    0.477

  334.1    17.000   76537.1   31382.3   14639.1   14937.8    0.467

  367.7    18.000   96102.9   38859.2   19950.4   20357.6    0.456

               P/D=     0.600  number of propellers=  2

   rpm    V (knots) T (kp)    Q (kp*m)   DHP (PS)  SHP (PS)   P.C.

   202.5    13.000   32177.7   14474.1    4091.6    4175.1    0.537

   222.1    13.999   39530.0   17655.9    5475.4    5587.1    0.531

   244.0    15.000   48967.4   21676.8    7384.6    7535.3    0.523
```

268.5	15.999	61181.6	26802.9	10049.7	10254.8	0.512
295.6	17.000	76537.1	33172.9	13689.8	13969.2	0.500
325.7	18.000	96102.9	41195.8	18732.7	19115.0	0.485

P/D= 0.700 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
182.1	13.000	32177.7	15503.2	3942.6	4023.0	0.558
199.9	13.999	39530.0	18935.0	5285.6	5393.4	0.550
219.8	15.000	48967.4	23283.8	7145.0	7290.8	0.540
242.1	15.999	61181.6	28842.3	9749.8	9948.8	0.528
266.7	17.000	76537.1	35763.1	13318.1	13589.9	0.514
294.2	18.000	96102.9	44496.3	18276.5	18649.5	0.497

P/D= 0.800 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
166.5	13.000	32177.7	16755.8	3894.3	3973.8	0.565
182.8	13.999	39530.0	20482.5	5227.9	5334.6	0.556
201.1	15.000	48967.4	25213.9	7079.3	7223.7	0.545
221.7	15.999	61181.6	31272.3	9679.7	9877.3	0.532
244.4	17.000	76537.1	38825.5	13250.1	13520.5	0.516
269.8	18.000	96102.9	48369.2	18222.6	18594.5	0.499

P/D= 0.900 number of propellers= 2

rpm	V (knots)	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
154.0	13.000	32177.7	18152.6	3904.5	3984.2	0.563
169.3	13.999	39530.0	22203.8	5247.3	5354.4	0.554
186.3	15.000	48967.4	27354.1	7115.2	7260.4	0.543
205.5	15.999	61181.6	33957.5	9744.6	9943.5	0.528

```
 226.8   17.000  76537.1  42198.3  13361.3  13634.0    0.512
 250.5   18.000  96102.9  52621.0  18407.8  18783.4    0.494
          P/D=     1.000  number of propellers=  2
  rpm    V (knots) T (kp)    Q (kp*m)  DHP (PS)  SHP (PS)   P.C.
  144.0   13.000  32177.7  19645.8   3950.9   4031.5    0.557
  158.3   13.999  39530.1  24041.7   5314.4   5422.9    0.547
  174.4   15.000  48967.4  29636.0   7214.6   7361.8    0.535
  192.5   15.999  61181.6  36815.9   9894.3  10096.2    0.520
 212.5   17.000  76537.1  45783.3  13585.9  13863.1    0.503
 235.0   18.000  96102.9  57134.3  18745.3  19127.9    0.485



          P/D=     1.100  number of propellers=  2
  rpm    V (knots) T (kp)    Q (kp*m)  DHP (PS)  SHP (PS)   P.C.
  135.8   13.000  32177.7  21197.1   4019.3   4101.3    0.547
  149.3   13.999  39530.0  25950.0   5410.8   5521.2    0.538
  164.5   15.000  48967.4  32003.9   7352.9   7503.0    0.525
 181.8   15.999  61181.6  39780.6  10096.3  10302.4    0.510
 200.8   17.000  76537.1  49500.2  13881.2  14164.5    0.493
 222.2   18.000  96102.9  61812.4  19179.0  19570.4    0.474
          P/D=     1.200  number of propellers=  2
  rpm    V (knots) T (kp)    Q (kp*m)  DHP (PS)  SHP (PS)   P.C.
  128.9   13.000  32177.8  22765.3   4098.4   4182.1    0.536
  141.8   13.999  39530.0  27879.3   5521.4   5634.1    0.527
  156.4   15.000  48967.4  34398.4   7510.5   7663.8    0.514
 172.8   15.999  61181.6  42779.5  10324.6  10535.3    0.498
```

```
191.1   17.000   76537.1   53261.7   14212.4   14502.5    0.481

211.6   18.000   96103.0   66549.3   19662.4   20063.6    0.462

              P/D=     1.300  number of propellers=  2

 rpm    V (knots) T (kp)   Q (kp*m)  DHP (PS)  SHP (PS)   P.C.

 123.1   13.000   32177.7   24299.8    4177.4    4262.6    0.526

 135.5   13.999   39530.0   29768.4    5631.9    5746.8    0.516

 149.5   15.000   48967.4   36745.2    7668.0    7824.5    0.503

165.3   15.999   61181.6   45722.0   10553.1   10768.4    0.488

182.9   17.000   76537.1   56957.1   14544.6   14841.4    0.470

202.6   18.000   96102.9   71209.8   20148.0   20559.2    0.451




              P/D=     1.400  number of propellers=  2

 rpm    V (knots) T (kp)   Q (kp*m)  DHP (PS)  SHP (PS)   P.C.

 118.1   13.000   32177.7   25735.0    4244.2    4330.8    0.518

 130.0   13.999   39530.0   31537.7    5726.1    5843.0    0.508

 143.5   15.000   48967.4   38946.9    7803.7    7963.0    0.495

158.8   15.999   61181.6   48488.6   10752.3   10971.7    0.479

175.8   17.000   76537.1   60439.8   14837.4   15140.2    0.461

194.9   18.000   96102.9   75613.1   20581.0   21001.0    0.442


               ********   iso – V (or iso – pull)  ********

            V (knots)=    13.000  number of propellers=  2

  rpm     P/D     T (kp)    Q (kp*m)  DHP (PS)  SHP (PS)  P.C.

  229.7    0.50   32177.7   13829.0    4434.7    4525.2    0.496

  202.5    0.60   32177.7   14474.1    4091.6    4175.1    0.537
```

182.1	0.70	32177.7	15503.2	3942.6	4023.0	0.558
166.5	0.80	32177.7	16755.8	3894.3	3973.8	0.565
154.0	0.90	32177.7	18152.6	3904.5	3984.2	0.563
144.0	1.00	32177.7	19645.8	3950.9	4031.5	0.557
135.8	1.10	32177.7	21197.1	4019.3	4101.3	0.547
128.9	1.20	32177.8	22765.3	4098.4	4182.1	0.536
123.1	1.30	32177.7	24299.8	4177.4	4262.6	0.526
118.1	1.40	32177.7	25735.0	4244.2	4330.8	0.518

V (knots)= 13.999 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
251.8	0.50	39530.0	16837.0	5919.4	6040.2	0.491
222.1	0.60	39530.0	17655.9	5475.4	5587.1	0.531
199.9	0.70	39530.0	18935.0	5285.6	5393.4	0.550
182.8	0.80	39530.0	20482.5	5227.9	5334.6	0.556
169.3	0.90	39530.0	22203.8	5247.3	5354.4	0.554
158.3	1.00	39530.1	24041.7	5314.4	5422.9	0.547
149.3	1.10	39530.0	25950.0	5410.8	5521.2	0.538
141.8	1.20	39530.0	27879.3	5521.4	5634.1	0.527
135.5	1.30	39530.0	29768.4	5631.9	5746.8	0.516
130.0	1.40	39530.0	31537.7	5726.1	5843.0	0.508

V (knots)= 15.000 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
276.4	0.50	48967.4	20622.1	7957.7	8120.1	0.485
244.0	0.60	48967.4	21676.8	7384.6	7535.3	0.523
219.8	0.70	48967.4	23283.8	7145.0	7290.8	0.540
201.1	0.80	48967.4	25213.9	7079.3	7223.7	0.545
186.3	0.90	48967.4	27354.1	7115.2	7260.4	0.543

174.4	1.00	48967.4	29636.0	7214.6	7361.8	0.535
164.5	1.10	48967.4	32003.9	7352.9	7503.0	0.525
156.4	1.20	48967.4	34398.4	7510.5	7663.8	0.514
149.5	1.30	48967.4	36745.2	7668.0	7824.5	0.503
143.5	1.40	48967.4	38946.9	7803.7	7963.0	0.495

V (knots)= 15.999 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
303.9	0.50	61181.6	25428.1	10788.7	11008.9	0.477
268.5	0.60	61181.6	26802.9	10049.7	10254.8	0.512
242.1	0.70	61181.6	28842.3	9749.8	9948.8	0.528
221.7	0.80	61181.6	31272.3	9679.7	9877.3	0.532
205.5	0.90	61181.6	33957.5	9744.6	9943.5	0.528
192.5	1.00	61181.6	36815.9	9894.3	10096.2	0.520
181.8	1.10	61181.6	39780.6	10096.3	10302.4	0.510
172.8	1.20	61181.6	42779.5	10324.6	10535.3	0.498
165.3	1.30	61181.6	45722.0	10553.1	10768.4	0.488
158.8	1.40	61181.6	48488.6	10752.3	10971.7	0.479

V (knots)= 17.000 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
334.1	0.50	76537.1	31382.3	14639.1	14937.8	0.467
295.6	0.60	76537.1	33172.9	13689.8	13969.2	0.500
266.7	0.70	76537.1	35763.1	13318.1	13589.9	0.514
244.4	0.80	76537.1	38825.5	13250.1	13520.5	0.516
226.8	0.90	76537.1	42198.3	13361.3	13634.0	0.512
212.5	1.00	76537.1	45783.3	13585.9	13863.1	0.503
200.8	1.10	76537.1	49500.2	13881.2	14164.5	0.493
191.1	1.20	76537.1	53261.7	14212.4	14502.5	0.481

182.9	1.30	76537.1	56957.1	14544.6	14841.4	0.470
175.8	1.40	76537.1	60439.8	14837.4	15140.2	0.461

V (knots)= 18.000 number of propellers= 2

rpm	P/D	T (kp)	Q (kp*m)	DHP (PS)	SHP (PS)	P.C.
367.7	0.50	96102.9	38859.2	19950.4	20357.6	0.456
325.7	0.60	96102.9	41195.8	18732.7	19115.0	0.485
294.2	0.70	96102.9	44496.3	18276.5	18649.5	0.497
269.8	0.80	96102.9	48369.2	18222.6	18594.5	0.499
250.5	0.90	96102.9	52621.0	18407.8	18783.4	0.494
235.0	1.00	96102.9	57134.3	18745.3	19127.9	0.485
222.2	1.10	96102.9	61812.4	19179.0	19570.4	0.474
211.6	1.20	96103.0	66549.3	19662.4	20063.6	0.462
202.6	1.30	96102.9	71209.8	20148.0	20559.2	0.451
194.9	1.40	96102.9	75613.1	20581.0	21001.0	0.442

Table 99. Heavy Weather +40% Propeller Behavior. (Γερασίμου Κ. Πολίτη, 2005)

From Tables 97, 98 & 99, Table 100 summarizes the propellers operating conditions (each propeller):

EACH PROPELLER	
Still Water	
Nprop[RPM]	**166**
SHPprop[PS]	**4744.6**
P/D	**0.9**
Ae/Ao	**0.5**
20%	
Nprop[RPM]	**176.5**
SHPprop[PS]	**5964**
P/D	**0.9**
Ae/Ao	**0.5**
40%	
Nprop[RPM]	**186.3**
SHPprop[PS]	**7260.4**
P/D	**0.9**
Ae/Ao	**0.5**

Table 100. Propellers Operating Condition & Behavior. (Γερασίμου Κ. Πολίτη, 2005)

Regardless the previous results, the cavitation of the propellers in the two operating conditions (still water, heavy weather +20%) described in Table 100 must be calculated.

$$\mathrm{A_E/A_0} = 0.5 \Rightarrow \mathrm{A_E} = 0.5\mathrm{A_0} = 0.5\frac{\pi D^2}{4} = 0.5\frac{3.1415(3.82^2)}{4} = 5.73m^2$$

Equation 12. **A_E/A_0 Ratio.** (Γερασίμου Κ. Πολίτη, 2005)

$$A_D / A_0 \cong \mathrm{A_E/A_0} = 0.5 \Rightarrow A_D = 5.73m^2$$

Equation 13. **A_D/A_0 Ratio.** (Γερασίμου Κ. Πολίτη, 2005)

From Bibliographical Source: (Γερασίμου Κ. Πολίτη, Μάιος 2005) the projected area is calculated as follows:

$$A_P = A_D(1.067 - 0.229\frac{P}{D}) = 5.73(1.067 - 0.229 * 0.9) = 4.93m^2$$

Equation 14. **A_P Area.** (Γερασίμου Κ. Πολίτη, 2005)

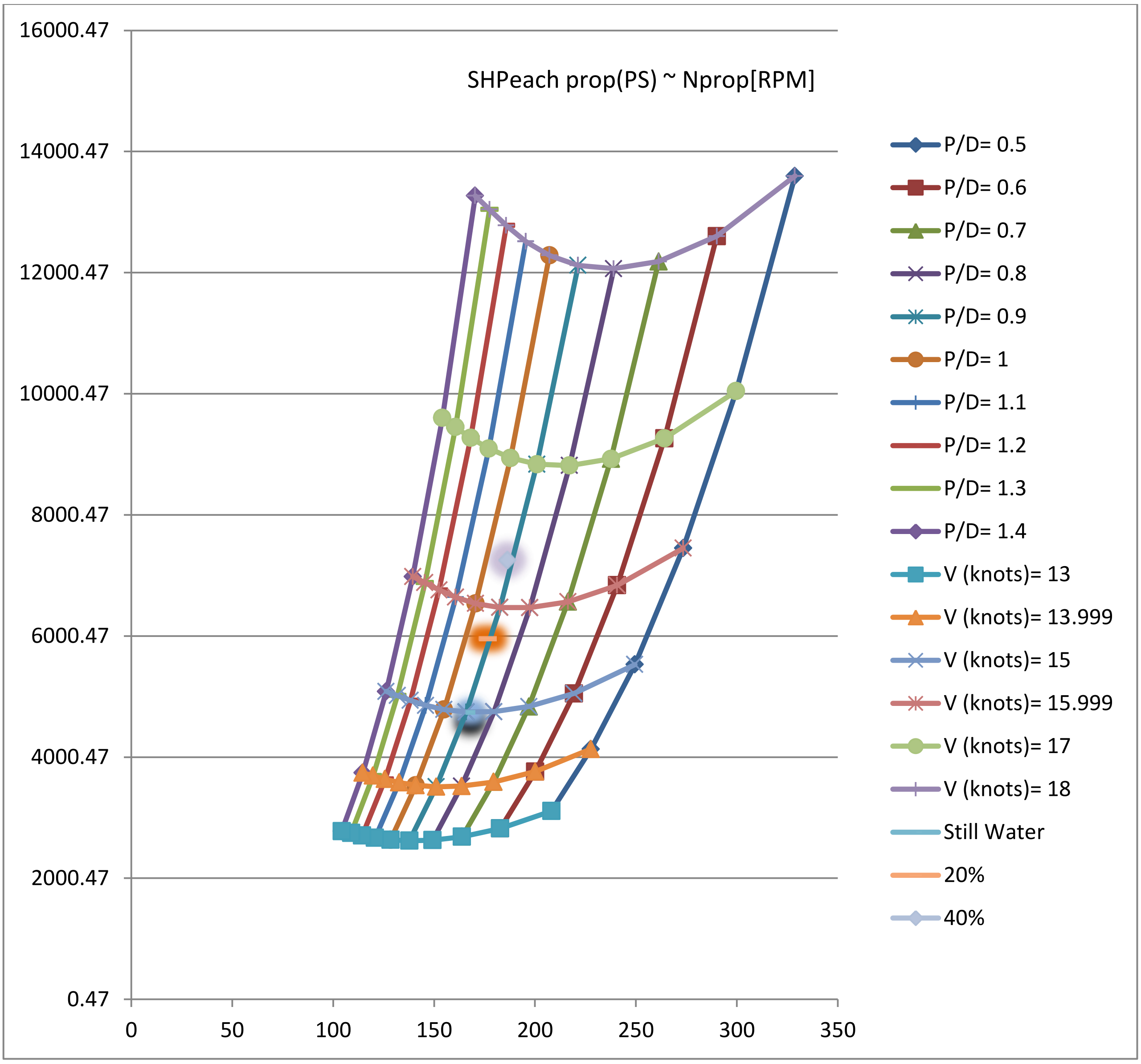


Figure 12. **Grid Figure.** (Γερασίμου Κ. Πολίτη, 2005)

Cavitation in Still Water

$$V_R^{\,2} = V_A^{\,2} + \left(0.7\pi nD\right)^2 = (5.63)^2 + \left(0.7\pi\, 2.77 * 3.82\right)^2 = 573.14\,\frac{m^2}{\sec^2}$$

Equation 15. **Velocity of the Propeller Blade Still Water.** (Γερασίμου Κ. Πολίτη, 2005)

$$q_{0.7R} = \frac{1}{2}\rho V_R^{\,2} = 0.5 * 1025 * 573.14 = 293734.25\,\frac{kg}{m * \sec^2}$$

Equation 16. **$q_{0.7R}$ of the Propeller Blade** Still Water. (Γερασίμου Κ. Πολίτη, 2005)

$$\tau_C = \frac{T_{each} / A_{Peach}}{q_{0.7R}} = \frac{343155.76N / 4.93m^2}{293734.25 \frac{kg}{m\sec^2}} = 0.237$$

$$\sigma_{0.7R} = \frac{p_0 - p_V}{q_{0.7R}} = \frac{(140221 - 1700)N / m^2}{293734.25 \frac{kg}{m\sec^2}} = 0.472$$

Equation 17. **Burrill Diagram Coordinates Still Water.** (Γερασίμου Κ. Πολίτη, 2005)

Cavitation in Heavy Weather +20%

$$V_R^2 = V_A^2 + (0.7\pi nD)^2 = (5.63)^2 + (0.7\pi 2.936 * 3.82)^2 = 639.98 \frac{m^2}{\sec^2}$$

Equation 18. **Velocity of the Propeller Blade Heavy Weather +20%.** (Γερασίμου Κ. Πολίτη, 2005)

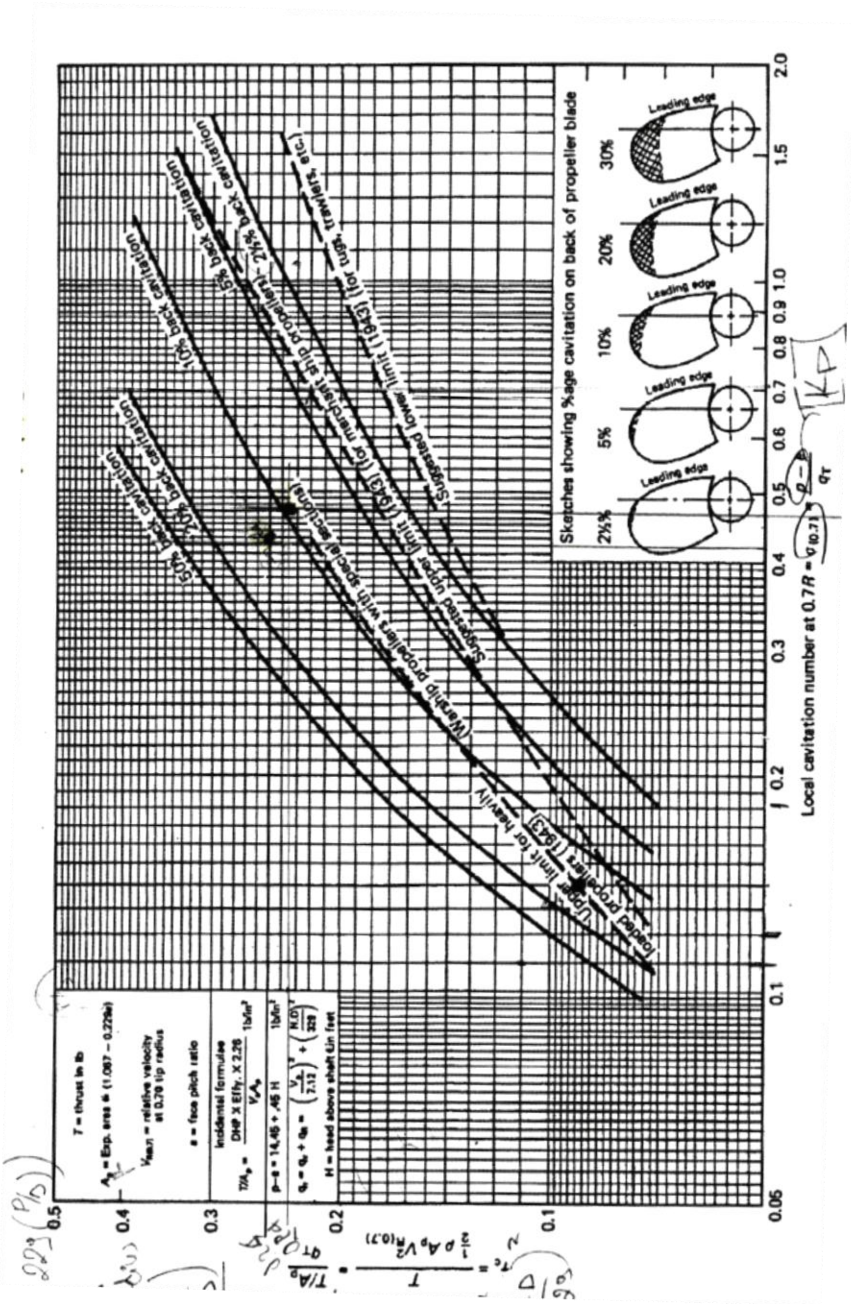
$$q_{0.7R} = \frac{1}{2}\rho V_R^2 = 0.5 * 1025 * 639.98 = 327989.75 \frac{kg}{m * \sec^2}$$

Equation 19. **$q_{0.7R}$ of the Propeller Blade Heavy Weather +20%..** (Γερασίμου Κ. Πολίτη, 2005)

$$\tau_C = \frac{T_{each} / A_{Peach}}{q_{0.7R}} = \frac{411762.98N / 4.93m^2}{327989.75 \frac{kg}{m\sec^2}} = 0.25$$

$$\sigma_{0.7R} = \frac{p_0 - p_V}{q_{0.7R}} = \frac{(140221 - 1700)N / m^2}{327989.75 \frac{kg}{m\sec^2}} = 0.42$$

Equation 20. **Burrill Diagram Coordinates Heavy Weather +20%..** (Γερασίμου Κ. Πολίτη, 2005)



Picture 55. Burrill Diagram. Plotted Points of Still Water and Heavy Weather +20% Operation. (Γερασίμου Κ. Πολίτη, 2005)

It is underlined that despite the fact that the **cavitation is ~10%**, it is generally accepted as the **propellers** are **heavily loaded** due to their **small size**. This happens because of the fact that for **a given displacement** and because of the **need for high waterline area** in order to **accommodate the pressure bottles**, the **draught is decreased** so the **propeller size** is **also decreased**.

For the propulsion needs of the examined vessel **two four stroke (4X) medium speed duel fuel engines** will be chosen. **Each** of these **engines** will power **one of the two referred propellers** via **gearboxes (reduction gears)**.

The **Maximum Continuous Rating (MCR)** of each of these engines must be as closest as possible to the point of table 101.

Service Point (+20%)	
SHP each [kW]	N each [RPM]
4386.52	467.73

Table 101.**Service Point – Heavy Weather +20%.**

The **maximum installed power (12MW)** in **still water** according to **figure 12** corresponds to **~16.7knots sailing speed**.

Blade Thickness – Propeller Design Point (Still Water)

The minimum propeller blade thickness will be calculated for the purposes of the present post graduate thesis. The calculations will concern two different positions. That of the 25% and 60% of the propeller diameter. The material which will be used is Grade Cu 3 (Ni-Aluminium bronze), with density G = 7.6 g/cm^3 and maximum acceptable stress U = 56 N/mm^2. The calculations will be made in accordance with bibliographical source: (ΓΕΩΡΓΙΟΣ ΔΗΜΟΠΟΥΛΟΣ, 1998). According to the just referred bibliographical source the minimum blade thickness T is given from the following mathematical type:

$$T = \frac{K \cdot C \cdot A}{E \cdot F \cdot U \cdot L \cdot N} + 100 \cdot \sqrt{\frac{3150 \cdot M \cdot P}{E \cdot F \cdot R \cdot U \cdot L \cdot N}} \quad (mm)$$

Equation 21. **Blade Minimum Required Thickness ½.** Source: (ΓΕΩΡΓΙΟΣ ΔΗΜΟΠΟΥΛΟΣ, 1998)

Where:

1. $K = \frac{G \cdot B \cdot D^3 \cdot R^2}{675}$
2. B = 0.5
3. D = 3.82 m
4. R = 166 RPM **(Propeller Design Point)**
5. C = 1.0 (25%), 1.6(60%)
6. A(rake) = tan15 ·D/2= 0.268*3.82/2=0.512m
7. E = 1.25
8. $F_{0,25} = \frac{P_{0,25}}{D} + 0.8$ =0.855*0.9+0.8=1.57 (Picture 56)
9. $F_{0,60} = \frac{P_{0,60}}{D} + 4.5$ =1.0*0.9+4.5=5.4 (Picture 56)

10. N = 4
11. $L_{0,25}=\frac{1.772\cdot D\cdot B}{N}=\frac{1.772*3.82*0.5}{4}=0.846m$
12. $L_{0,60}=\frac{2.187\cdot D\cdot B}{N}=\frac{2.187*3.82*0.5}{4}=1.044m$
13. P = 1.2·4744.6PS =5693.52 PS = 4187.64 kW , 1.2***(Propeller Design Point)**
14. $M_{0,25}=1.0+\frac{3.75\cdot D}{P_{0,7}}+2.8\cdot\frac{P_{0,25}}{D}$ = 1.0+3.75/0.9+2.8*0.855*0.9=7.32
15. $M_{0,6}=1.35+\frac{5\cdot D}{P_{0,7}}+1.35\cdot\frac{P_{0,6}}{D}$ = 1.35+5/0.9+1.35*0.9=8.121
16. $P_{1,0}=0.9\cdot D=0.9*3.82=3.44$ (Picture 56)
17. $P_{0,25}=0.855*0.9\cdot D=0.855*0.9*3.82=2.94$ (Picture 56)
18. $P_{0,6}=1.0\cdot P_{1,0}=1.0*0.9*3.82=3.44$ (Picture 56)
19. $P_{0,7}=1.0\cdot P_{1,0}=1.0*0.9*3.82=3.44$ (Picture 56)

Equation 22**. Blade Minimum Required Thickness 2/2 Group of Equations.** (ΓΕΩΡΓΙΟΣ ΔΗΜΟΠΟΥΛΟΣ, 1998)

The **Minimum Required Blade Thickness** is:

$$T_{0.25R}=116.72\ mm,\ T_{0.6R}=62.29mm$$

From picture 57 it is calculated that $T_{0.25R\_Actual}=132\ mm,\ T_{0.6R\_Actual}=77\ mm$. This means that we are on the safe side of the problem. (Equation 23)

Picture 56 is presented in Appandix B.

Picture 56. **Wagenigen B Series – Pitch Distribution.** Source: (Γερασίμου Κ. Πολίτη, 2005)

Picture 57 is presented in Appandix B.

Picture 57. **Wagenigen B Series - Blade Thickness Distribution.** Source: (Γερασίμου Κ. Πολίτη, 2005)

Z=4

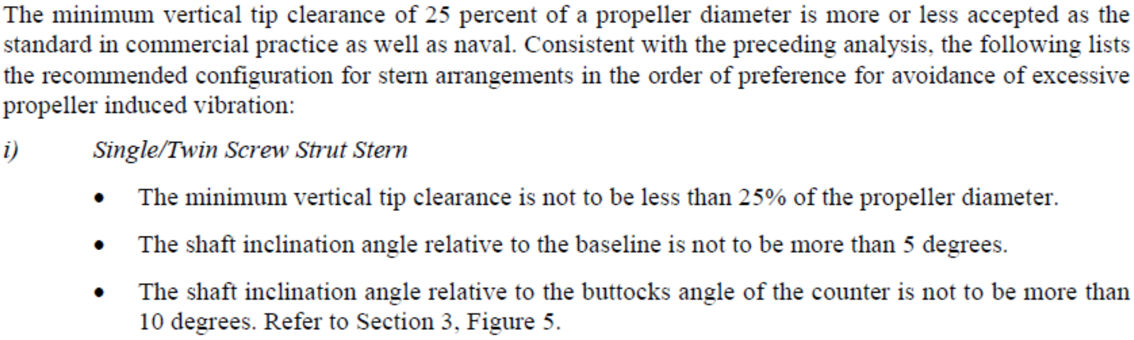
$$\frac{r}{R}=0.25\Rightarrow\ Ar=0.0495,Br=0.00375\Rightarrow\ t/D=0.0345\Rightarrow\ t=132mm$$

$$\frac{r}{R}=0.60\Rightarrow\ Ar=0.0278,Br=0.00200\Rightarrow\ t/D=0.0198\Rightarrow\ t=77mm$$

Equation 23. **Actual Blade Thickness.** Source: (Γερασίμου Κ. Πολίτη, 2005)

Propeller – Hull Tolerances

From bibliographical source: (GUIDANCE NOTES ON SHIP VIBRATION ABS, 2006), the propeller – hull tolerances will be calculated.



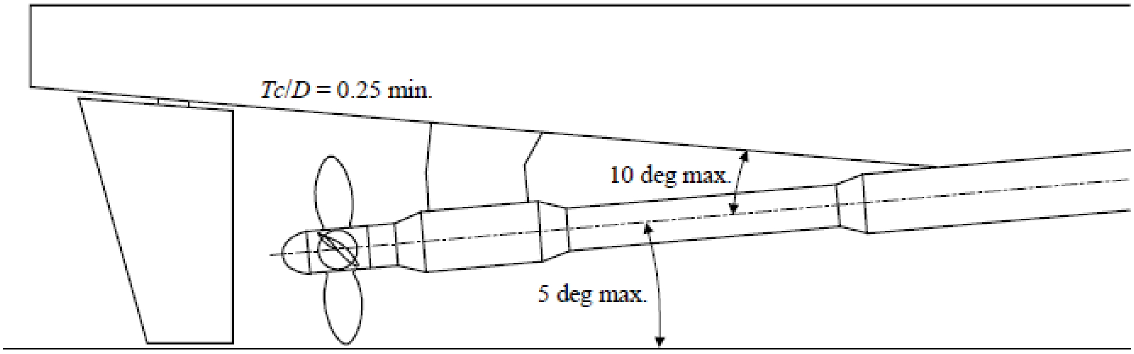
The minimum vertical tip clearance of 25 percent of a propeller diameter is more or less accepted as the standard in commercial practice as well as naval. Consistent with the preceding analysis, the following lists the recommended configuration for stern arrangements in the order of preference for avoidance of excessive propeller induced vibration:

i) *Single/Twin Screw Strut Stern*

- The minimum vertical tip clearance is not to be less than 25% of the propeller diameter.
- The shaft inclination angle relative to the baseline is not to be more than 5 degrees.
- The shaft inclination angle relative to the buttocks angle of the counter is not to be more than 10 degrees. Refer to Section 3, Figure 5.

Picture 58. **Propeller – Hull Clearances 1/4.** Source: (GUIDANCE NOTES ON SHIP VIBRATION ABS, 2006)

FIGURE 5
Open Strut Stern Arrangement

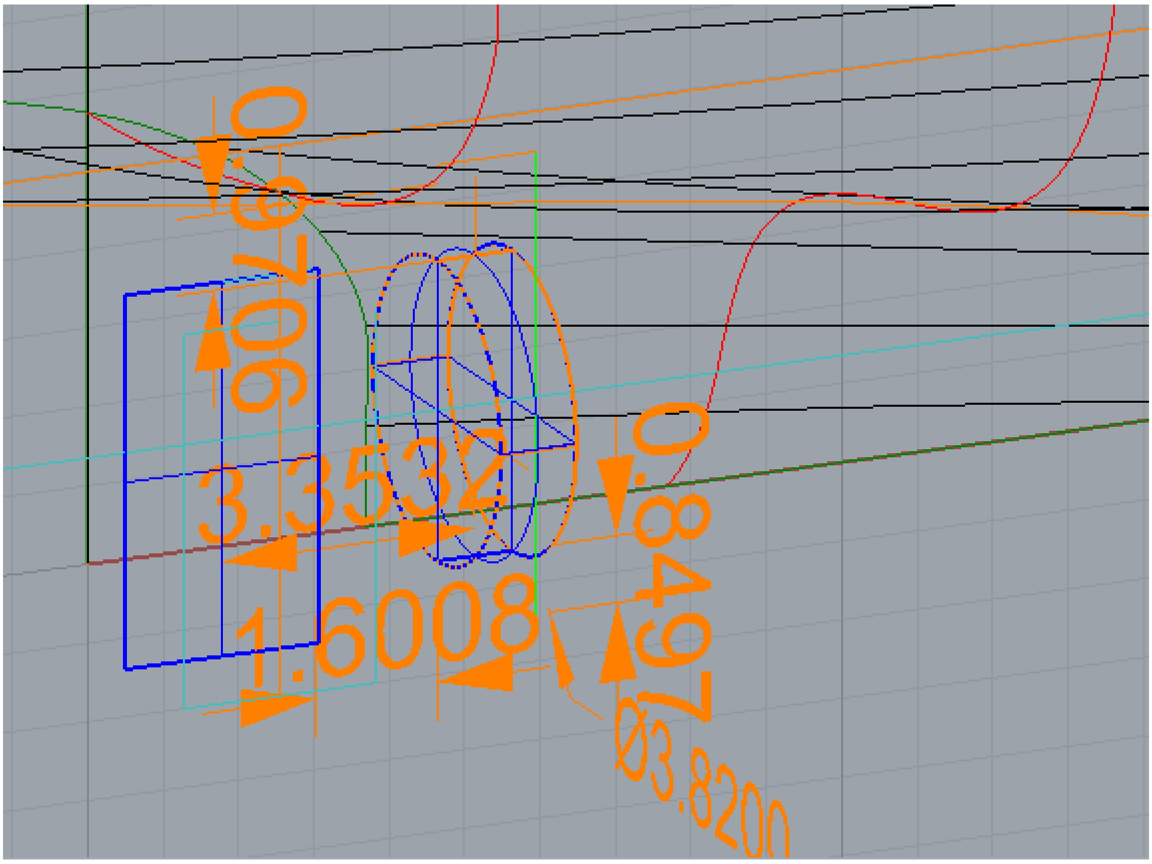


Picture 59. **Propeller – Hull Clearances 2/4.** Source: (GUIDANCE NOTES ON SHIP VIBRATION ABS, 2006)

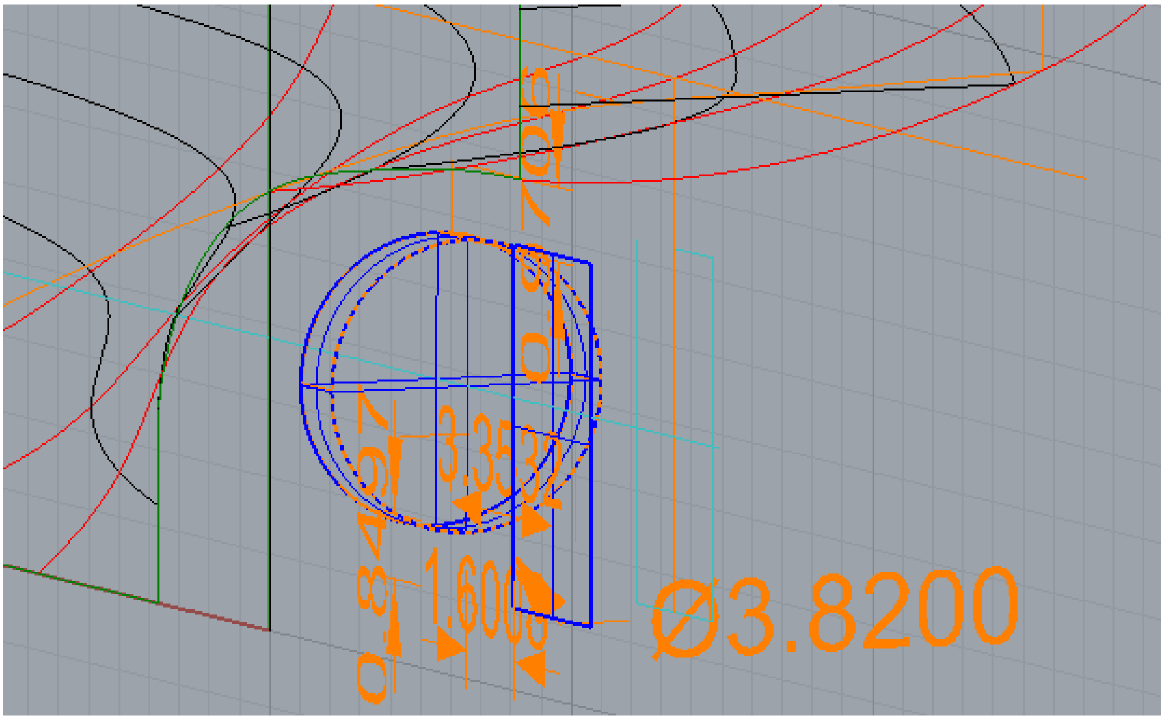
In accordance with picture 60 & 61, the **actual vertical tip clearance** is equal to **0.9706m > 0.25*3.82=0.955m.** **(Pass)** (see picture 60 & 61)

The **shaft inclination angle relative to the baseline** is **0 degrees < 5 degrees**. **(Pass)**

The **shaft inclination angle relative to the buttocks angle** of the encounter is **7degrees < 10 degrees**. **(Pass)**



Picture 60. **Propeller – Hull Tolerances 3/4.** (Rhinoceros, 2017)



Picture 61. **Propeller – Hull Tolerances 4/4.** (Rhinoceros, 2017)

Main Engine(s) Selection

Reduction Gear Ratio	**2.65**
Number of Engines	**2**
Number of Propellers	**2**

Table 102. Gearboxes Reduction Ratio.

Propeller Power Curves						
Still Water						
V[knots]	N[RPM] Propeller	N[RPM] Engine	SHP[PS] each	SHP[PS] total	SHP[kW] each	SHP[kW] total
13.00	**137.80**	365.17	**2619.20**	5238.40	1926.42	3852.84
14.00	**151.10**	400.42	**3510.00**	7020.00	2581.61	5163.21
15.00	**166.00**	439.90	**4744.60**	9489.20	3489.65	6979.31
16.00	**182.70**	484.16	**6471.40**	12942.80	4759.71	9519.43
17.00	**201.00**	532.65	**8836.80**	17673.60	6499.47	12998.93
18.00	**221.40**	586.71	**12120.60**	24241.20	8914.70	17829.40

+ 20 %						
V[knots]	N[RPM] Propeller	N[RPM] Engine	SHP[PS] each	SHP[PS] total	SHP[kW] each	SHP[kW] total
13.00	**146.20**	387.43	**3281.30**	6562.60	2413.40	4826.79
14.00	**160.50**	425.33	**4403.90**	8807.80	3239.07	6478.14
15.00	**176.50**	467.73	**5964.00**	11928.00	4386.52	8773.04
16.00	**194.50**	515.43	**8153.20**	16306.40	5996.68	11993.36
17.00	**214.30**	567.90	**11158.30**	22316.60	8206.93	16413.86
18.00	**236.50**	626.73	**15344.50**	30689.00	11285.88	22571.76

+ 40 %						
V[knots]	N[RPM] Propeller	N[RPM] Engine	SHP[PS] each	SHP[PS] total	SHP[kW] each	SHP[kW] total
13.00	**154.00**	408.10	**3984.20**	7968.40	2930.38	5860.76
14.00	**169.30**	448.65	**5354.40**	10708.80	3938.16	7876.32
15.00	**186.30**	493.70	**7260.40**	14520.80	5340.02	10680.05
16.00	**205.50**	544.58	**9943.50**	19887.00	7313.44	14626.89
17.00	**226.80**	601.02	**13634.00**	27268.00	10027.81	20055.61
18.00	**250.50**	663.83	**18783.40**	37566.80	13815.19	27630.38

Table 103. Propeller(s) Requirements from the Main Engines. (Γερασίμου Κ. Πολίτη, 2005)

MAN 2 X 6L51/60 DF
2 X 6000kW @ 514 RPM

Table 104. Main Engine MCR. Source: (Marine Engine IMO Tier II Programme 2014 MAN Diesel & Turbo)

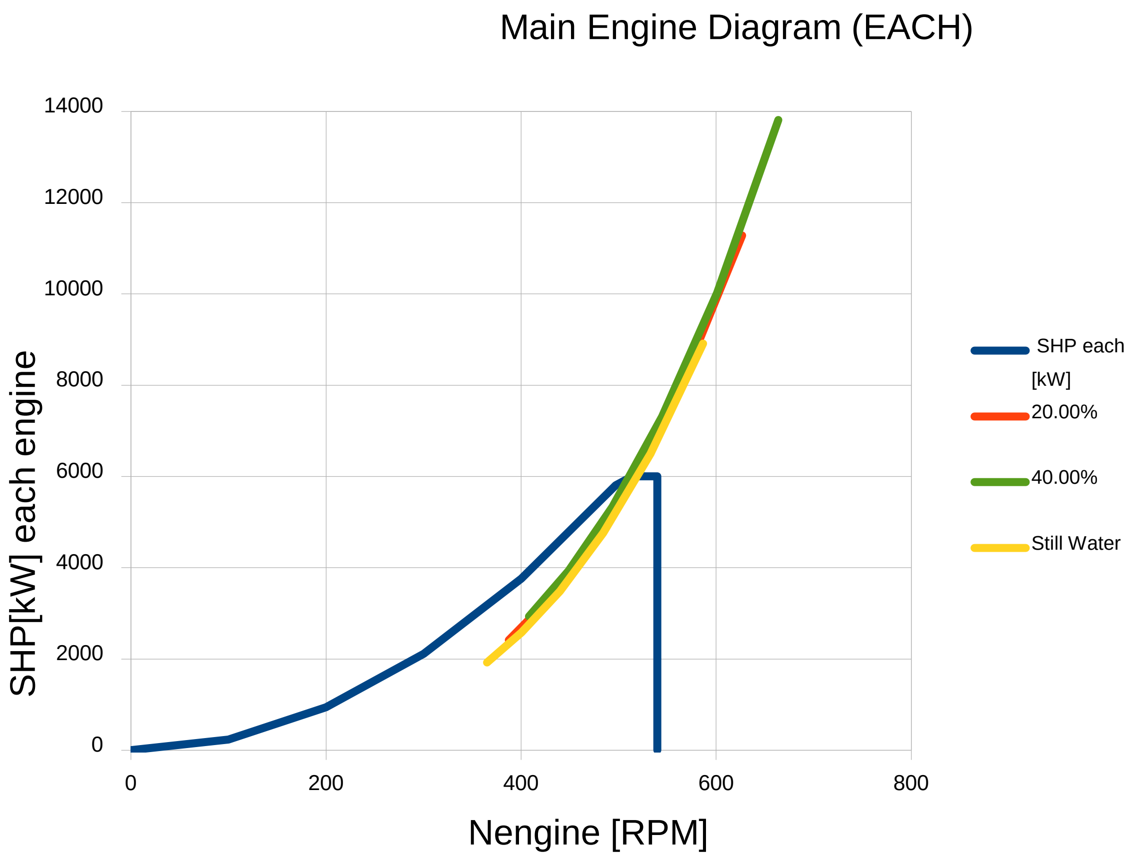


Figure 13. **Main Engines (Each) & Propellers Diagram (Each).** (Γερασίμου Κ. Πολίτη, 2005), (Βασικές Αρχές Πρόωσης Πλοίων, 2004)

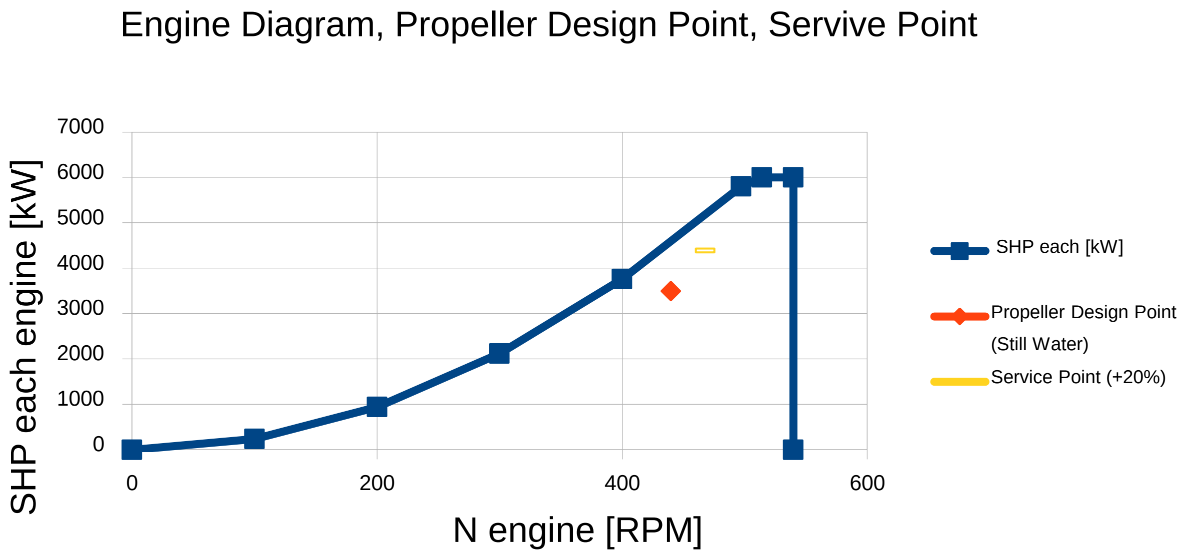


Figure 14. **Main Engines (Each) & Operation Points Diagram.** (Γερασίμου Κ. Πολίτη, 2005), (Βασικές Αρχές Πρόωσης Πλοίων, 2004)

As far as the Power Margin is concerned, it is calculated between the total MCR of each the engines and the point corresponding to heavy weather +20%.

Power Margin = (6000kW-4386.52kW)/6000kW=0.27=27%

Power Margin = 27%

N engine [RPM]	SHP each [kW]
0	**0**
100	**235**
200	**940**
300	**2115**
400	**3760**
497	**5804.7115**
514	**6002.7615**
539.7	**6002.7615**
539.7	**0**

Table 105. **Main Engine Diagrams Coordinates.** (Βασικές Αρχές Πρόωσης Πλοίων, 2004)

For the **Reduction Gear** being concerned, there is need for **two same reduction gears** with **power (transfer) requirement** of **6000kW (each)**.

From the bibliographical source: (WARTSILA SOLUTIONS FOR MARINE AND OIL & GAS MARKETS 2013) it is chosen:

2 X SCV 68

Length (each): 0.37+1.25=1.62m

Width (each): 1.72m

Height (each): 2.37m

Weight (each): 8.5t

Last but not least, as far as NOx Reducer (the engines are IMO Tier II) to meet IMO Tier III Requirements, the following parts are chosen by using bibliographical reference: (WARTSILA SOLUTIONS FOR MARINE AND OIL & GAS MARKETS 2013)

Wartsila NOx Reducer:
Engine Power Output [kW]:
2X6000kW+3X3580kW=22740kW
Reactor Size: 2X28
Reactor Length Each: 2920 mm,
Reactor Breadth Each: 3080 mm,
Reactor Height Each: 4688 mm
Reactor Weight: 2X9600kg=19200kg

Energy Efficiency Design Index (EEDI) Calculation

In this chapter, the energy efficiency design index (EEDI) will be calculated by taking input data from the following bibliographical references: (Module 2: Ship Energy Efficiency Regulations and Related Guidelines), (IMO Train the Trainer (TTT) Course on Energy Efficient Ship Operation, 2016), (MAN L35/44DF), (MAN 51/60DF).

MAN 2 X 6L51/60 DF [EACH] (MAIN ENGINE)		
SPECIFIC FUEL CONSUMPTION [gr/kWh]		
	75% MCR	100% MCR
LSHFO	182	184.5
N.G	154.64	152.5

Table 106. **Main Engines Specific Fuel Consumption [gr/kWh].** (MAN 51/60DF), (Section: Appendix A Lower and Higher Heating Values of Gas, Liquid and Solid Fuels)

MAN 3 X 7L35/44 DF [EACH] (AUXILIARY ENGINE)			
SPECIFIC FUEL CONSUMPTION [gr/kWh]			
	50% MCR	75% MCR	100% MCR
LSHFO	186	186	177
N.G	177.98	165.67	158.5

Table 107. **Gen-Sets Specific Fuel Consumption [gr/kWh].** (MAN L35/44DF), (Section: Appendix A Lower and Higher Heating Values of Gas, Liquid and Solid Fuels)

The **vessels EEDI** will be calculated in **two operating conditions** **(normal shipping (main engines at 75% MCR & normal loading of D/G))** and in **(main engines 0% MCR & 100% of D/G (no vessels motion & cargo compressing and storage)).** Moreover, **two different fuels** will be examined (**Low Sulphur Fuel Oil** and **Natural Gas (CNG)**).

In accordance with Bibliographical Source: (Module 2: Ship Energy Efficiency Regulations and Related Guidelines), as the Main Propulsion installed power is more than 10000kW, the requirement for propulsion and auxiliary power should be calculated from the following types:

$$P_{ME} = 0.75 \cdot 12000kW = 9000kW$$ (Normal Shipping)

$$P_{AE} = (0.025 \cdot \sum MCR_{ME}) + 250 = 0.025 \cdot 12000 + 250 = 550kW$$ (Normal Shipping)

$$P_{ME} = 0kW$$ (Cargo Compression and Storage)

$$P_{AE} = (0.025 \cdot \sum MCR_{ME}) + 250 + 104 * 93.25kW = 0.025 \cdot 12000 + 250 + 9698kW = 10248kW$$

(Cargo Compression and Storage)

Equation 24. **Propulsion and Auxiliary Power Needs for EEDI.** Source: (Module 2: Ship Energy Efficiency Regulations and Related Guidelines)

For the **CO_2 emission factors** being, they can be taken from **table 4**.

From bibliographical source: (Module 2: Ship Energy Efficiency Regulations and Related Guidelines), all requested factors for EEDI calculations can be taken.

Power Correction Factor:

Fj=1.0 , (Module 2: Ship Energy Efficiency Regulations and Related Guidelines)

Capacity Factor:

$$F_i = 1 + \left(0.08 \cdot \frac{LWT}{DWT}\right) = 1 + 0.08 \frac{20316}{3691} = 1.44$$, **Fi=1.44**

(Module 2: Ship Energy Efficiency Regulations and Related Guidelines)

(It is assumed that for this instance, the examined vessel is considered as typical bulk carrier because it is not ice-classed and because it is not considered as vessel with Voluntary Structural Enhancement)

Cubic Capacity Correction Factor:

(In this case the examined vessel is considered as chemical tanker because it must exists to an existing category)

R=DWT/Cargo Tanks Volume=3691/7885=0.468

$$F_c = R^{-0.7} - 0.014 = (0.468)^{-0.7} - 0.014 = 1.687$$

Fc=1.687

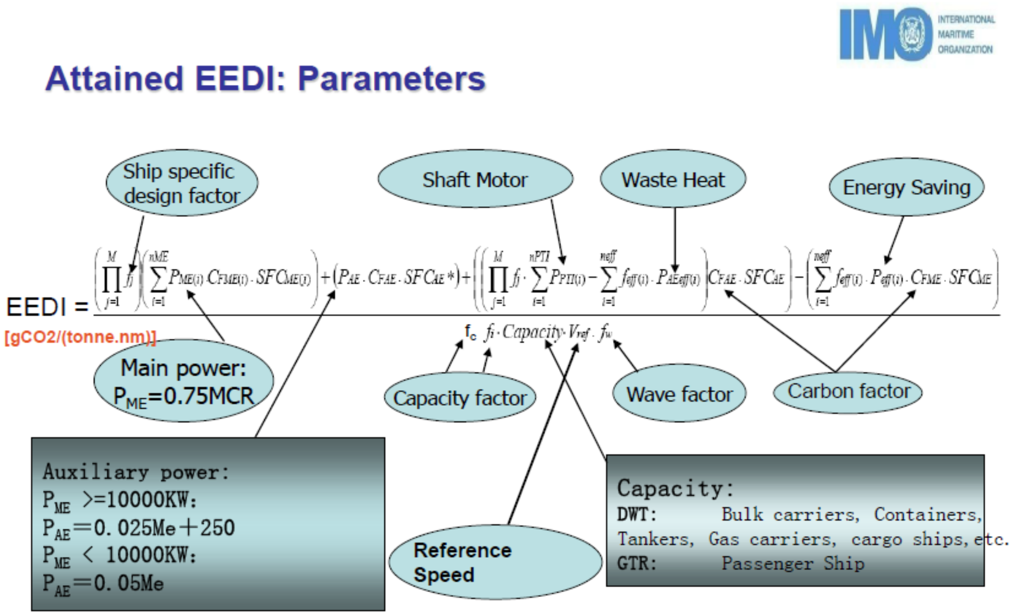
(Module 2: Ship Energy Efficiency Regulations and Related Guidelines)

Equation 25. **Required EEDI Factors.** (Module 2: Ship Energy Efficiency Regulations and Related Guidelines)

As far as the vessels speed corresponding to the 75%MCR is concerned, it will be assumed in order to be on the safe side of the problem, that there is linear correlation between the power and the speed for a given 100% MCR. *(With linear correlation, the curve will be above to the curve with cubic correlation for a given 100%MCR (nominal point)).*

Speed[knots]	Shaft Power [kW] (Still Water) (2XEng).
15	**6989.16**
15.77	**9000**
16	**9604.01**

Table 108. Shaft Horse Power [kW] for Various Speeds. (Linear Interpolation & Still Water)



Attained EEDI: Parameters

$$\text{EEDI} = \frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}{*}\right) + \left(\left(\prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}\right)}{f_c \cdot f_i \cdot Capacity \cdot V_{ref} \cdot f_w}$$

[gCO2/(tonne.nm)]

Ship specific design factor

Shaft Motor

Waste Heat

Energy Saving

Main power: $P_{ME}=0.75MCR$

Capacity factor

Wave factor

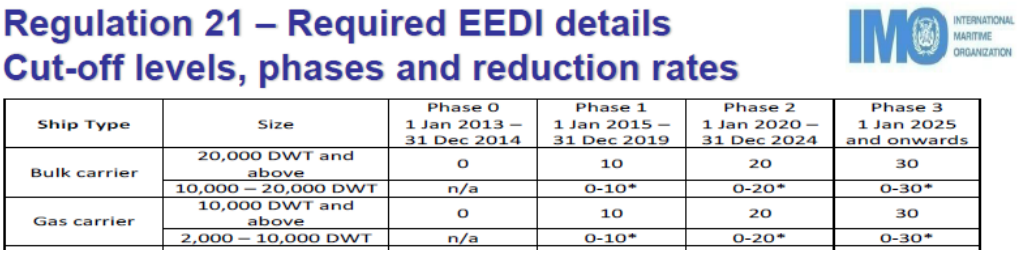
Carbon factor

Auxiliary power:
P_{ME} >=10000KW:
P_{AE}=0.025Me+250
P_{ME} < 10000KW:
P_{AE}=0.05Me

Reference Speed

Capacity:
DWT: Bulk carriers, Containers, Tankers, Gas carriers, cargo ships, etc.
GTR: Passenger Ship

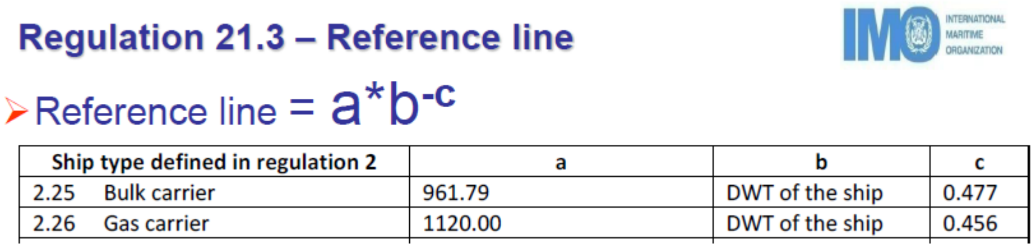
Picture 62. EEDI Formula. Source: (Module 2: Ship Energy Efficiency Regulations and Related Guidelines)



Regulation 21 – Required EEDI details
Cut-off levels, phases and reduction rates

Ship Type	Size	Phase 0 1 Jan 2013 – 31 Dec 2014	Phase 1 1 Jan 2015 – 31 Dec 2019	Phase 2 1 Jan 2020 – 31 Dec 2024	Phase 3 1 Jan 2025 and onwards
Bulk carrier	20,000 DWT and above	0	10	20	30
	10,000 – 20,000 DWT	n/a	0-10*	0-20*	0-30*
Gas carrier	10,000 DWT and above	0	10	20	30
	2,000 – 10,000 DWT	n/a	0-10*	0-20*	0-30*

Table 109. EEDI Cut-off Levels. Source: (Module 2: Ship Energy Efficiency Regulations and Related Guidelines)



Regulation 21.3 – Reference line

- Reference line = $a*b^{-c}$

Ship type defined in regulation 2	a	b	c
2.25 Bulk carrier	961.79	DWT of the ship	0.477
2.26 Gas carrier	1120.00	DWT of the ship	0.456

Table 110. EEDI Reference Line. Source: (Module 2: Ship Energy Efficiency Regulations and Related Guidelines)

It is underlined that as far as the auxiliary engines are concerned, its specific fuel consumption for the active at its time percentage of MCR must not correspond to a loading less than 50%MCR. This means that even in normal shipping the loading of the engines is 550kW/11MW=5%MCR (auxiliary), in this loading, only for EEDI, it is considered that the specific fuel consumption is that of 50%MCR.

Equations 26, 27, 28 and 29 will calculate the **Energy Efficiency Design Index (EEDI)**.

- **Low Sulphur Heavy Fuel Oil & Normal Shipping**

$$EEDI = \frac{1.0 \cdot 2 \cdot 0.75 \cdot 6000kW \cdot 3.206\frac{grCO_2}{grFuel} \cdot 182.0\frac{grFuel}{kWh} + 550kW \cdot 3.206\frac{grCO_2}{grFuel} \cdot 186\frac{grFuel}{kWh}}{1.44 \cdot 1.687 \cdot 1.0 \cdot 15.77knots \cdot 0.5144\frac{m/\sec}{knots} \cdot 3691t} =$$

$$= 76.7\frac{grCO_2 \cdot \sec}{t \cdot m \cdot h} = 21.31\frac{grCO_2}{t \cdot km}$$

Equation 26. EEDI for Low Sulphur Heavy Fuel Oil & Normal Shipping. (Module 2: Ship Energy Efficiency Regulations and Related Guidelines)

- **Natural Gas & Normal Shipping**

$$EEDI = \frac{1.0 \cdot 2 \cdot 0.75 \cdot 6000kW \cdot 2.75\frac{grCO_2}{grFuel} \cdot 154.64\frac{grFuel}{kWh} + 550kW \cdot 2.75\frac{grCO_2}{grFuel} \cdot 177.98\frac{grFuel}{kWh}}{1.44 \cdot 1.687 \cdot 1.0 \cdot 15.77knots \cdot 0.5144\frac{m/\sec}{knots} \cdot 3691t} =$$

$$= 56.32\frac{grCO_2 \cdot \sec}{t \cdot m \cdot h} = 15.64\frac{grCO_2}{t \cdot km}$$

Equation 27. EEDI for Natural Gas & Normal Shipping. (Module 2: Ship Energy Efficiency Regulations and Related Guidelines)

In Cargo Compressing & Storage despite the fact that the vessel is not be moving, in order to calculate just a representative EEDI, it is supposed that in its denominator, the vessels speed remains constant equal to 15.77knots.

- **Low Sulphur Heavy Fuel Oil & Cargo Compression and Storage**

$$EEDI = \frac{0 + 10248kW \cdot 3.206\frac{grCO_2}{grFuel} \cdot 177\frac{grFuel}{kWh}}{1.44 \cdot 1.687 \cdot 1.0 \cdot 15.77knots \cdot 0.5144\frac{m/\sec}{knots} \cdot 3691t} =$$

$$= 80.0\frac{grCO_2 \cdot \sec}{t \cdot m \cdot h} = 22.21\frac{grCO_2}{t \cdot km}$$

Equation 28. EEDI for Low Sulphur Heavy Fuel Oil & Cargo Compression and Storage. (Module 2: Ship Energy Efficiency Regulations and Related Guidelines)

- **Natural Gas & Cargo Compression and Storage**

$$EEDI = \frac{0 + 10248kW \cdot 2.75\frac{grCO_2}{grFuel} \cdot 158.5\frac{grFuel}{kWh}}{1.44 \cdot 1.687 \cdot 1.0 \cdot 15.77knots \cdot 0.5144\frac{m/\sec}{knots} \cdot 3691t} =$$

$$= 61.41\frac{grCO_2 \cdot \sec}{t \cdot m \cdot h} = 17.06\frac{grCO_2}{t \cdot km}$$

Equation 29. EEDI for Natural Gas & Cargo Compression and Storage. (Module 2: Ship Energy Efficiency Regulations and Related Guidelines)

In equations 26, 27, 28 and 29, the achieved energy efficiency design indexes are calculated. In accordance with tables 109 and 110, the maximum required EEDI is calculated as follows:

Vessel DWT=3691t and it is estimated that the keel will be laid before 2019. With linear interpolation, the **reduction** is **2.11** (The vessel here is considered as gas carrier).

As far as the **Reference EEDI** is concerned**, a=1120** and **c=0.456** (The vessel here is considered as gas carrier).

From the above data, the Reference EEDI plotted with the achieved EEDI for the two types of fuels and with the two different shipping conditions, they are presented in figure 15.

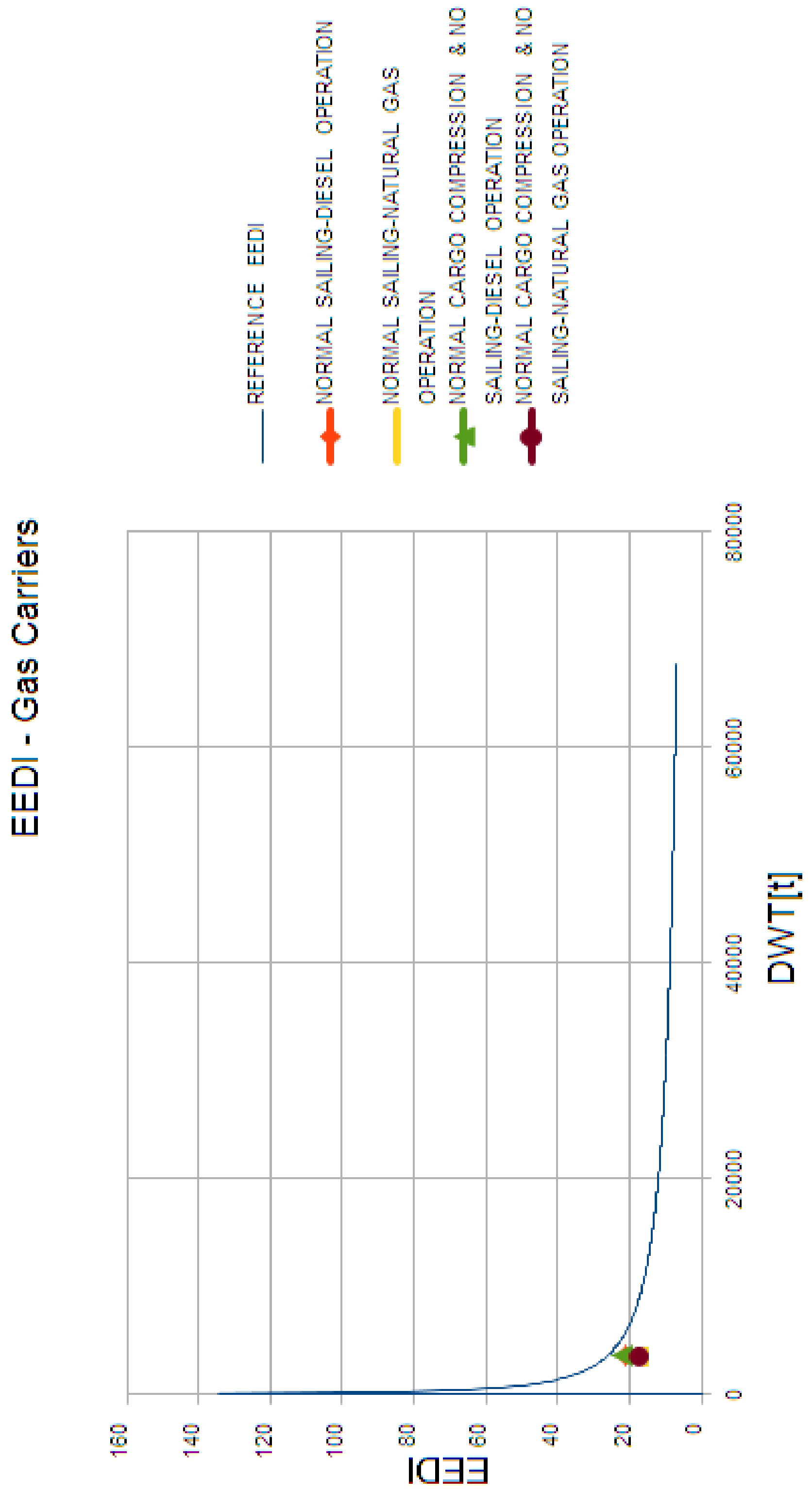
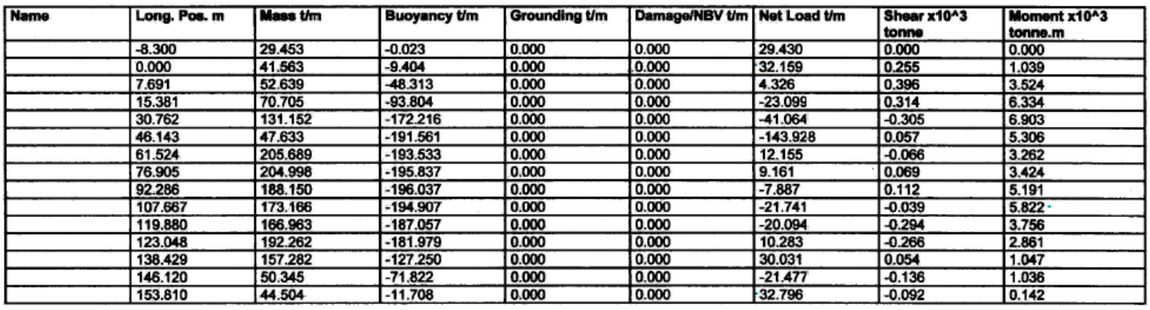


Figure 15. **EEDI (Reference and Operation Points).** (Module 2: Ship Energy Efficiency Regulations and Related Guidelines)

17. Ship Strength

In this chapter, the vessels stress loading will be examined. In detail, two loading conditions will be examined: **Full Load Departure** & **Water Ballast Arrival**.



Name	Long. Pos. m	Mass t/m	Buoyancy t/m	Grounding t/m	Damage/NBV t/m	Net Load t/m	Shear x10^3 tonne	Moment x10^3 tonne.m
	-8.300	29.453	-0.023	0.000	0.000	29.430	0.000	0.000
	0.000	41.563	-9.404	0.000	0.000	32.159	0.255	1.039
	7.691	52.639	-48.313	0.000	0.000	4.326	0.396	3.524
	15.381	70.705	-93.804	0.000	0.000	-23.099	0.314	6.334
	30.762	131.152	-172.216	0.000	0.000	-41.064	-0.305	6.903
	46.143	47.633	-191.561	0.000	0.000	-143.928	0.057	5.306
	61.524	205.689	-193.533	0.000	0.000	12.155	-0.066	3.262
	76.905	204.998	-195.837	0.000	0.000	9.161	0.069	3.424
	92.286	188.150	-196.037	0.000	0.000	-7.887	0.112	5.191
	107.667	173.166	-194.907	0.000	0.000	-21.741	-0.039	5.822
	119.880	166.963	-187.057	0.000	0.000	-20.094	-0.294	3.756
	123.048	192.262	-181.979	0.000	0.000	10.283	-0.266	2.861
	138.429	157.282	-127.250	0.000	0.000	30.031	0.054	1.047
	146.120	50.345	-71.822	0.000	0.000	-21.477	-0.136	1.036
	153.810	44.504	-11.708	0.000	0.000	32.796	-0.092	0.142

Table 111. **Vessels Strength & Stresses – Full Load Departure. (Maxsurf), (Hydromax)**

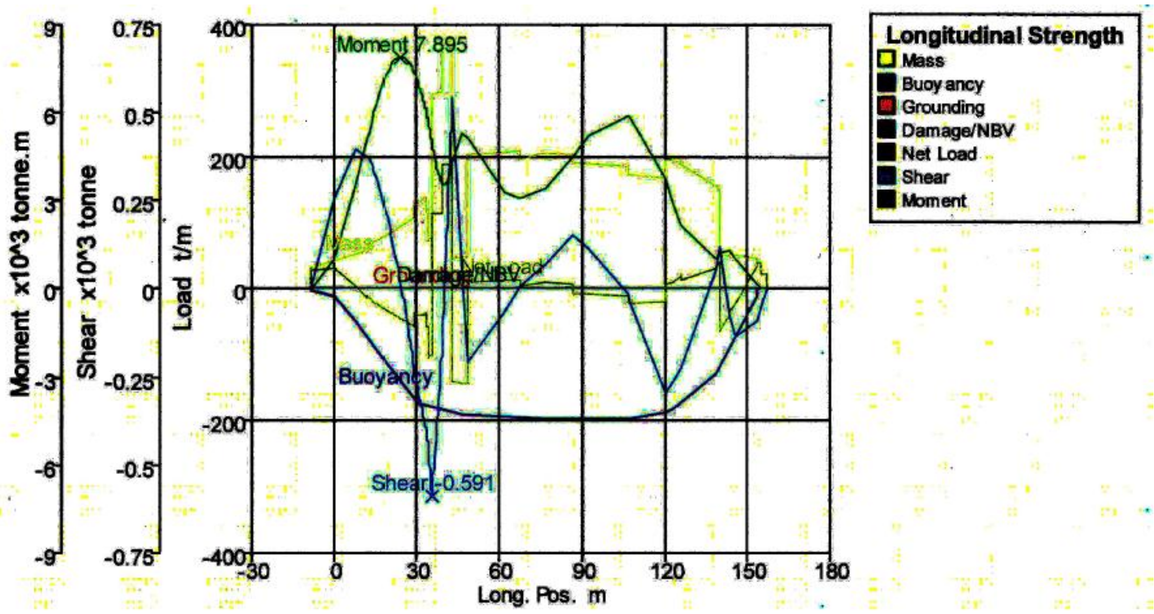
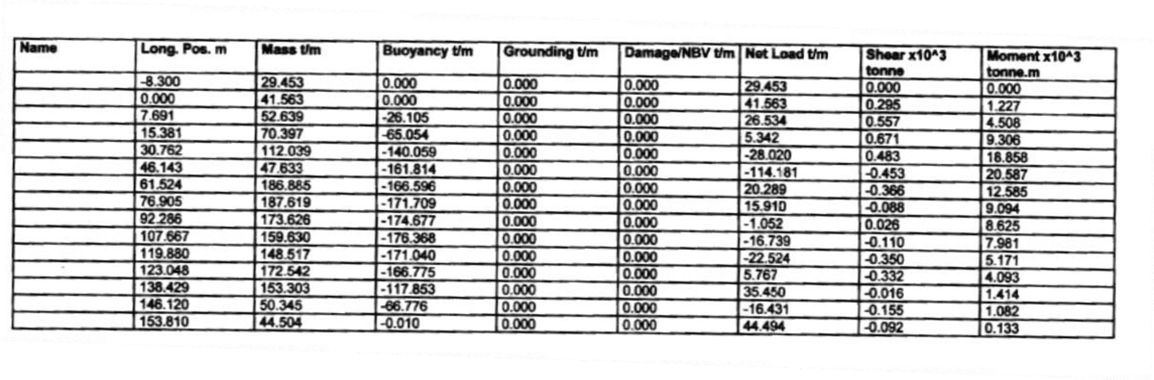


Figure 16. **Vessels Strength & Stresses – Full Load Departure. (Maxsurf), (Hydromax)**



Name	Long. Pos. m	Mass t/m	Buoyancy t/m	Grounding t/m	Damage/NBV t/m	Net Load t/m	Shear x10^3 tonne	Moment x10^3 tonne.m
	-8.300	29.453	0.000	0.000	0.000	29.453	0.000	0.000
	0.000	41.563	0.000	0.000	0.000	41.563	0.295	1.227
	7.691	52.639	-26.105	0.000	0.000	26.534	0.557	4.508
	15.381	70.397	-65.054	0.000	0.000	5.342	0.671	9.306
	30.762	112.039	-140.059	0.000	0.000	-28.020	0.483	18.858
	46.143	47.633	-161.814	0.000	0.000	-114.181	-0.453	20.587
	61.524	186.885	-166.596	0.000	0.000	20.289	-0.366	12.585
	76.905	187.619	-171.709	0.000	0.000	15.910	-0.088	9.094
	92.286	173.626	-174.677	0.000	0.000	-1.052	0.026	8.625
	107.667	159.630	-176.368	0.000	0.000	-16.739	-0.110	7.981
	119.880	148.517	-171.040	0.000	0.000	-22.524	-0.350	5.171
	123.048	172.542	-166.775	0.000	0.000	5.767	-0.332	4.093
	138.429	153.303	-117.853	0.000	0.000	35.450	-0.016	1.414
	146.120	50.345	-66.776	0.000	0.000	-16.431	-0.155	1.082
	153.810	44.504	-0.010	0.000	0.000	44.494	-0.092	0.133

Table 112. Vessels Strength & Stresses – Water Ballast Arrival. (Maxsurf), (Hydromax)

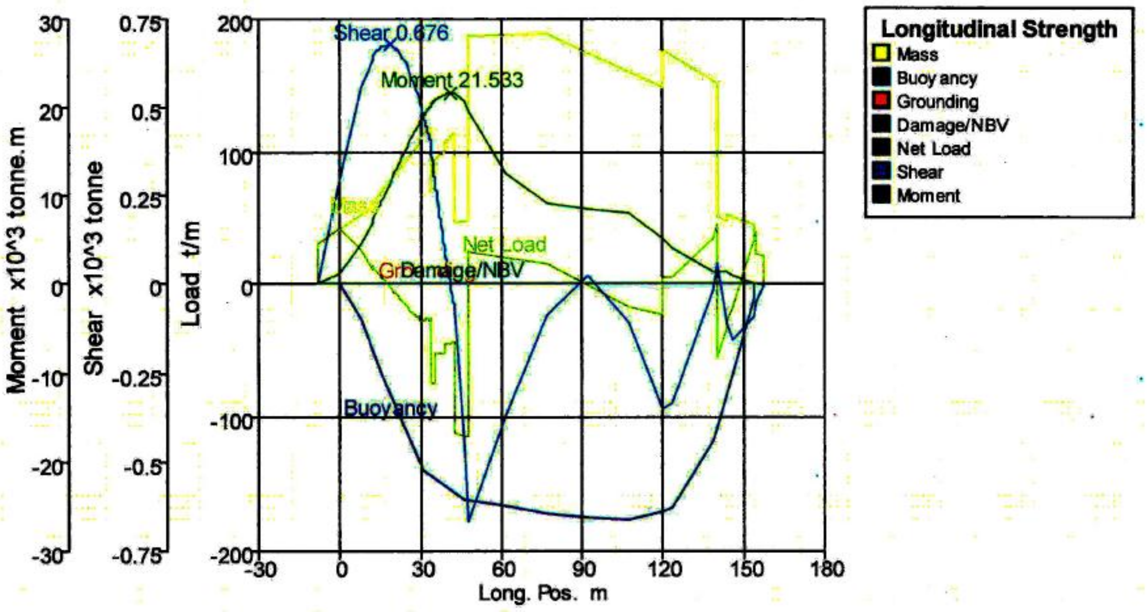
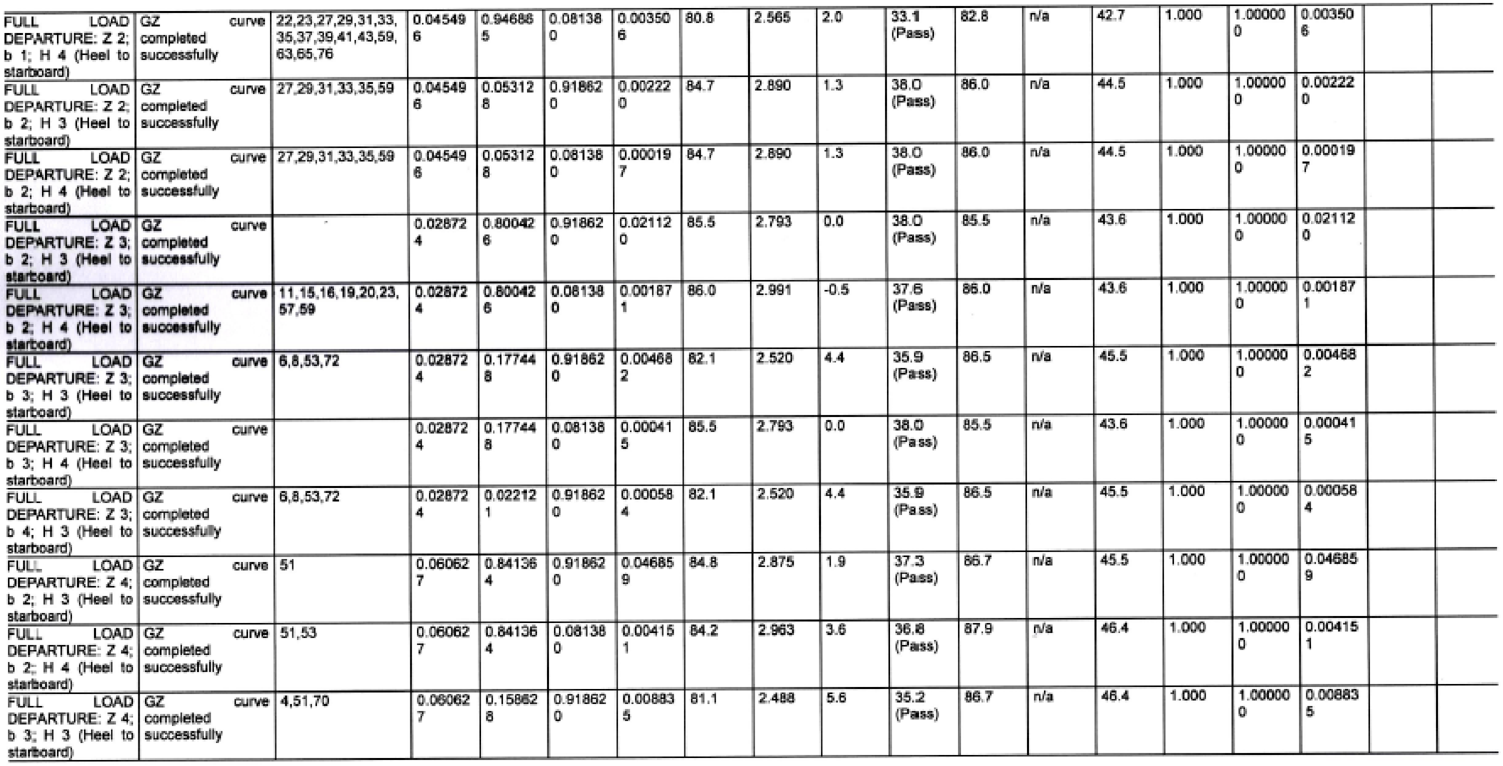


Figure 17. Vessels Strength & Stresses – Water Ballast Arrival. (Maxsurf), (Hydromax)

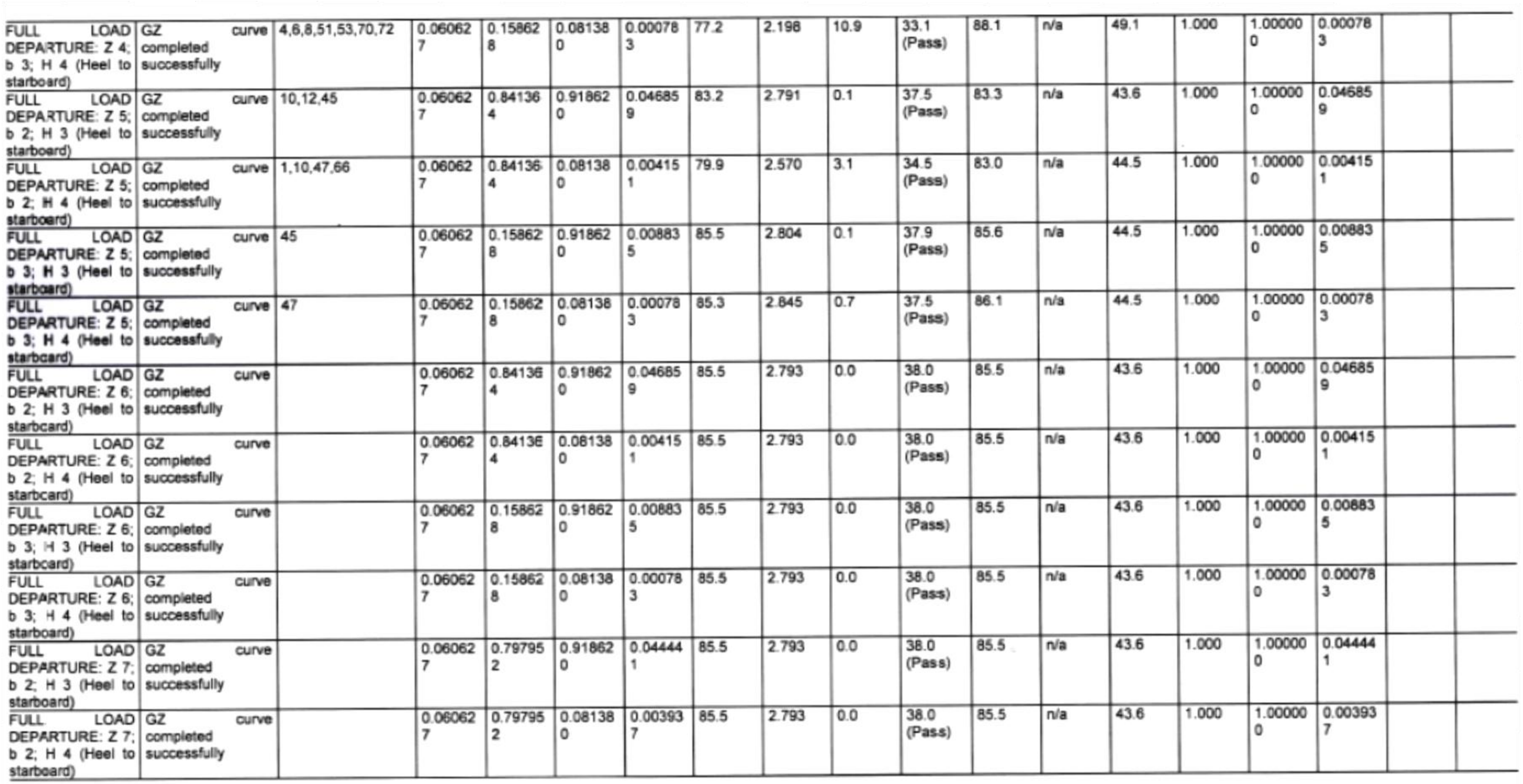
18. Ship Damage Stability (Probabilistic Analysis)

In this chapter, a probabilistic analysis will be done regarding its damage stability by using MAXSURF & HYDROMAX.



FULL LOAD DEPARTURE: Z 2; b 1; H 4 (Heel to starboard)	GZ curve completed successfully	22,23,27,29,31,33,35,37,39,41,43,59,63,65,76	0.045496	0.946865	0.081380	0.003506	80.8	2.565	2.0	33.1 (Pass)	82.8	n/a	42.7	1.000	1.000000	0.003506		
FULL LOAD DEPARTURE: Z 2; b 2; H 3 (Heel to starboard)	GZ curve completed successfully	27,29,31,33,35,59	0.045496	0.053128	0.918620	0.002220	84.7	2.890	1.3	38.0 (Pass)	86.0	n/a	44.5	1.000	1.000000	0.002220		
FULL LOAD DEPARTURE: Z 2; b 2; H 4 (Heel to starboard)	GZ curve completed successfully	27,29,31,33,35,59	0.045496	0.053128	0.081380	0.000197	84.7	2.890	1.3	38.0 (Pass)	86.0	n/a	44.5	1.000	1.000000	0.000197		
FULL LOAD DEPARTURE: Z 3; b 2; H 3 (Heel to starboard)	GZ curve completed successfully		0.028724	0.800426	0.918620	0.021120	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.021120		
FULL LOAD DEPARTURE: Z 3; b 2; H 4 (Heel to starboard)	GZ curve completed successfully	11,15,16,19,20,23,57,59	0.028724	0.800426	0.081380	0.001871	86.0	2.991	-0.5	37.6 (Pass)	86.0	n/a	43.6	1.000	1.000000	0.001871		
FULL LOAD DEPARTURE: Z 3; b 3; H 3 (Heel to starboard)	GZ curve completed successfully	6,8,53,72	0.028724	0.177448	0.918620	0.004682	82.1	2.520	4.4	35.9 (Pass)	86.5	n/a	45.5	1.000	1.000000	0.004682		
FULL LOAD DEPARTURE: Z 3; b 3; H 4 (Heel to starboard)	GZ curve completed successfully		0.028724	0.177448	0.081380	0.000415	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.000415		
FULL LOAD DEPARTURE: Z 3; b 4; H 3 (Heel to starboard)	GZ curve completed successfully	6,8,53,72	0.028724	0.022121	0.918620	0.000584	82.1	2.520	4.4	35.9 (Pass)	86.5	n/a	45.5	1.000	1.000000	0.000584		
FULL LOAD DEPARTURE: Z 4; b 2; H 3 (Heel to starboard)	GZ curve completed successfully	51	0.060627	0.841364	0.918620	0.046859	84.8	2.875	1.9	37.3 (Pass)	86.7	n/a	45.5	1.000	1.000000	0.046859		
FULL LOAD DEPARTURE: Z 4; b 2; H 4 (Heel to starboard)	GZ curve completed successfully	51,53	0.060627	0.841364	0.081380	0.004151	84.2	2.963	3.6	36.8 (Pass)	87.9	n/a	46.4	1.000	1.000000	0.004151		
FULL LOAD DEPARTURE: Z 4; b 3; H 3 (Heel to starboard)	GZ curve completed successfully	4,51,70	0.060627	0.158628	0.918620	0.008835	81.1	2.488	5.6	35.2 (Pass)	86.7	n/a	46.4	1.000	1.000000	0.008835		

Table 113. **Probabilistic Analysis 1/10.** (Maxsurf), (Hydromax)

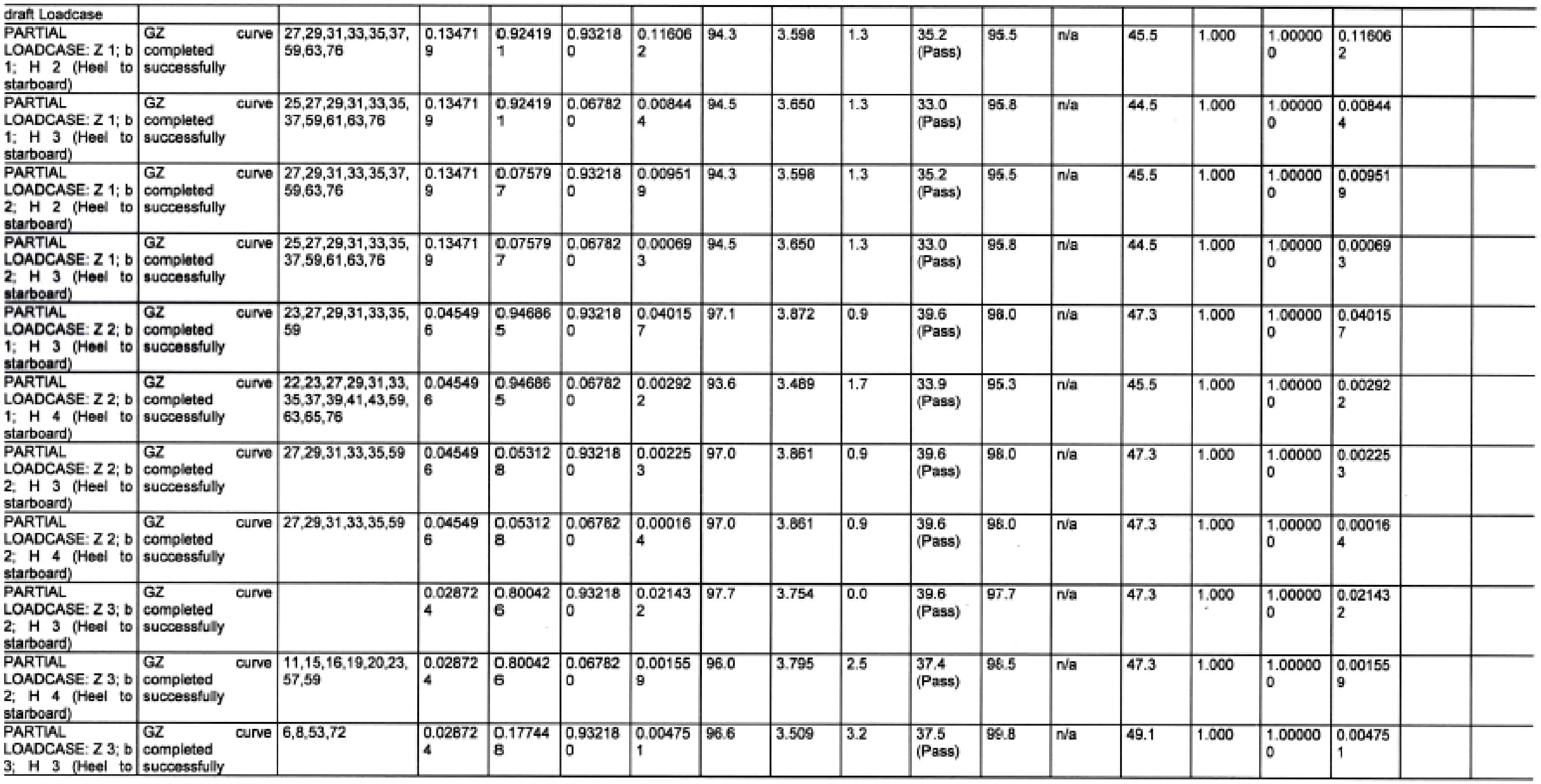


FULL LOAD DEPARTURE: Z 4; b 3; H 4 (Heel to starboard)	GZ curve completed successfully	4,6,8,51,53,70,72	0.060627	0.158628	0.081380	0.000783	77.2	2.198	10.9	33.1 (Pass)	88.1	n/a	49.1	1.000	1.000000	0.000783		
FULL LOAD DEPARTURE: Z 5; b 2; H 3 (Heel to starboard)	GZ curve completed successfully	10,12,45	0.060627	0.841364	0.918620	0.046859	83.2	2.791	0.1	37.5 (Pass)	83.3	n/a	43.6	1.000	1.000000	0.046859		
FULL LOAD DEPARTURE: Z 5; b 2; H 4 (Heel to starboard)	GZ curve completed successfully	1,10,47,66	0.060627	0.841364	0.081380	0.004151	79.9	2.570	3.1	34.5 (Pass)	83.0	n/a	44.5	1.000	1.000000	0.004151		
FULL LOAD DEPARTURE: Z 5; b 3; H 3 (Heel to starboard)	GZ curve completed successfully	45	0.060627	0.158628	0.918620	0.008835	85.5	2.804	0.1	37.9 (Pass)	85.6	n/a	44.5	1.000	1.000000	0.008835		
FULL LOAD DEPARTURE: Z 5; b 3; H 4 (Heel to starboard)	GZ curve completed successfully	47	0.060627	0.158628	0.081380	0.000783	85.3	2.845	0.7	37.5 (Pass)	86.1	n/a	44.5	1.000	1.000000	0.000783		
FULL LOAD DEPARTURE: Z 6; b 2; H 3 (Heel to starboard)	GZ curve completed successfully		0.060627	0.841364	0.918620	0.046859	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.046859		
FULL LOAD DEPARTURE: Z 6; b 2; H 4 (Heel to starboard)	GZ curve completed successfully		0.060627	0.8413E4	0.081380	0.004151	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.004151		
FULL LOAD DEPARTURE: Z 6; b 3; H 3 (Heel to starboard)	GZ curve completed successfully		0.060627	0.158628	0.918620	0.008835	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.008835		
FULL LOAD DEPARTURE: Z 6; b 3; H 4 (Heel to starboard)	GZ curve completed successfully		0.060627	0.158628	0.081380	0.000783	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.000783		
FULL LOAD DEPARTURE: Z 7; b 2; H 3 (Heel to starboard)	GZ curve completed successfully		0.060627	0.797952	0.918620	0.044441	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.044441		
FULL LOAD DEPARTURE: Z 7; b 2; H 4 (Heel to starboard)	GZ curve completed successfully		0.060627	0.797952	0.081380	0.003937	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.003937		

Table 114. Probabilistic Analysis 2/10. (Maxsurf), (Hydromax)

FULL LOAD DEPARTURE: Z 7; b 3; H 3 (Heel to starboard)	GZ curve completed successfully		0.060627	0.202040	0.918620	0.011252	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.011252		
FULL LOAD DEPARTURE: Z 7; b 3; H 4 (Heel to starboard)	GZ curve completed successfully		0.060627	0.202040	0.081380	0.000997	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.000997		
FULL LOAD DEPARTURE: Z 8; b 1; H 3 (Heel to starboard)	GZ curve completed successfully		0.035102	0.483740	0.918620	0.015598	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.015598		
FULL LOAD DEPARTURE: Z 8; b 1; H 5 (Heel to starboard)	GZ curve completed successfully		0.035102	0.483740	1.000000	0.016980	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.016980		
FULL LOAD DEPARTURE: Z 8; b 2; H 3 (Heel to starboard)	GZ curve completed successfully		0.035102	0.516254	0.918620	0.016647	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.016647		
FULL LOAD DEPARTURE: Z 8; b 2; H 5 (Heel to starboard)	GZ curve completed successfully		0.035102	0.516254	1.000000	0.018121	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.018121		
FULL LOAD DEPARTURE: Z 9; b 1; H 3 (Heel to starboard)	GZ curve completed successfully		0.002808	1.000000	0.918620	0.002580	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.002580		
FULL LOAD DEPARTURE: Z 9; b 1; H 5 (Heel to starboard)	GZ curve completed successfully		0.002808	1.000000	1.000000	0.002808	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.002808		
FULL LOAD DEPARTURE: Z10; b 1; H 2 (Heel to starboard)	GZ curve completed successfully		0.039121	0.999990	0.918620	0.035937	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.035937		
FULL LOAD DEPARTURE: Z10; b 1; H 4 (Heel to starboard)	GZ curve completed successfully		0.039121	0.999990	1.000000	0.039121	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.039121		
Attained partial index As						0.599186										0.599186	0.533249	Pass
Partial subdivision																		

Table 115. Probabilistic Analysis 3/10. (Maxsurf), (Hydromax)

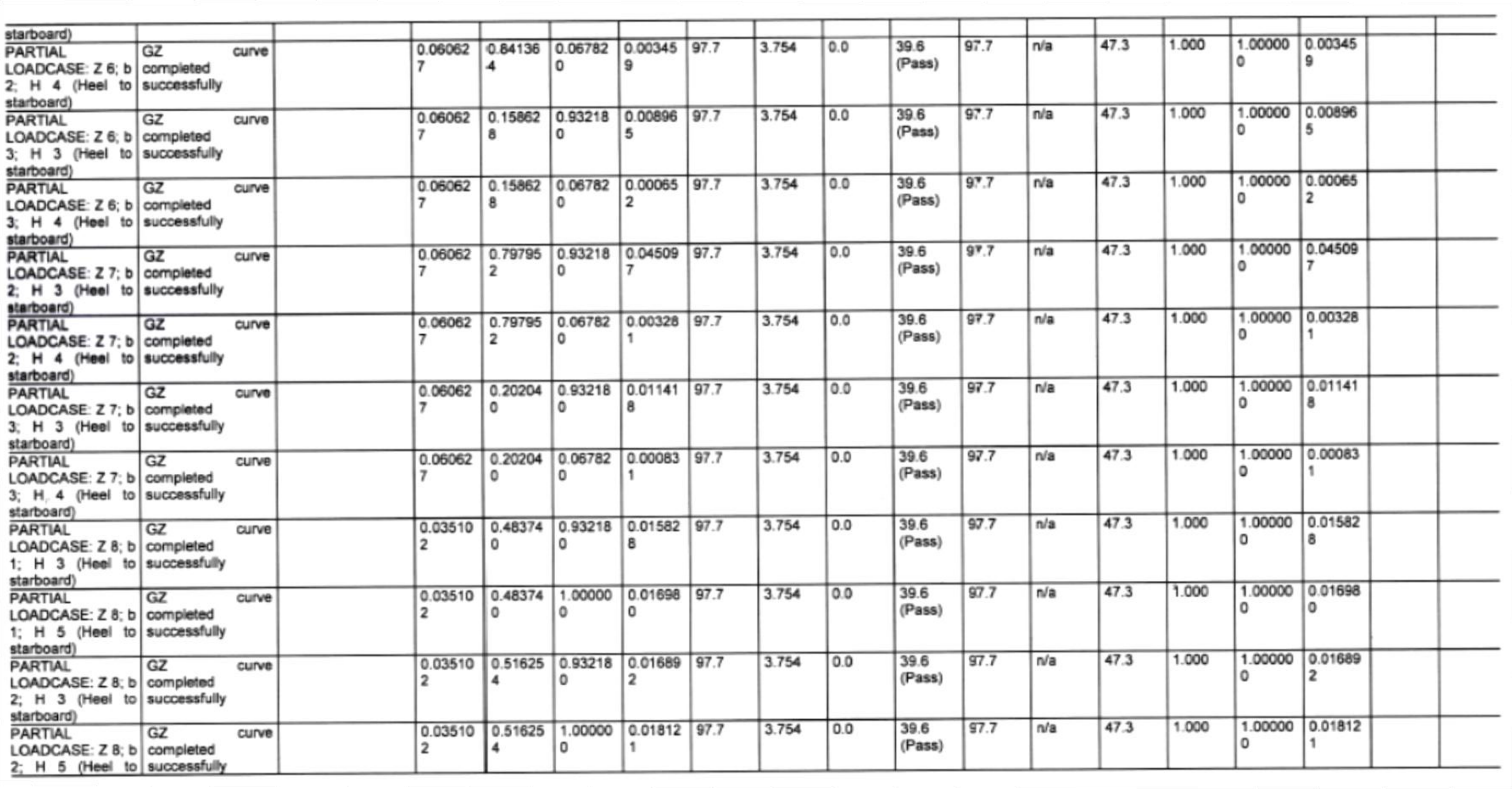


draft Loadcase																		
PARTIAL LOADCASE: Z 1; b 1; H 2 (Heel to starboard)	GZ curve completed successfully	27,29,31,33,35,37,59,63,76	0.134719	0.924191	0.932180	0.116062	94.3	3.598	1.3	35.2 (Pass)	95.5	n/a	45.5	1.000	1.000000	0.116062		
PARTIAL LOADCASE: Z 1; b 1; H 3 (Heel to starboard)	GZ curve completed successfully	25,27,29,31,33,35,37,59,61,63,76	0.134719	0.924191	0.067820	0.008444	94.5	3.650	1.3	33.0 (Pass)	95.8	n/a	44.5	1.000	1.000000	0.008444		
PARTIAL LOADCASE: Z 1; b 2; H 2 (Heel to starboard)	GZ curve completed successfully	27,29,31,33,35,37,59,63,76	0.134719	0.075797	0.932180	0.009519	94.3	3.598	1.3	35.2 (Pass)	95.5	n/a	45.5	1.000	1.000000	0.009519		
PARTIAL LOADCASE: Z 1; b 2; H 3 (Heel to starboard)	GZ curve completed successfully	25,27,29,31,33,35,37,59,61,63,76	0.134719	0.075797	0.067820	0.000693	94.5	3.650	1.3	33.0 (Pass)	95.8	n/a	44.5	1.000	1.000000	0.000693		
PARTIAL LOADCASE: Z 2; b 1; H 3 (Heel to starboard)	GZ curve completed successfully	23,27,29,31,33,35,59	0.045496	0.946865	0.932180	0.040157	97.1	3.872	0.9	39.6 (Pass)	98.0	n/a	47.3	1.000	1.000000	0.040157		
PARTIAL LOADCASE: Z 2; b 1; H 4 (Heel to starboard)	GZ curve completed successfully	22,23,27,29,31,33,35,37,39,41,43,59,63,65,76	0.045496	0.946865	0.067820	0.002922	93.6	3.489	1.7	33.9 (Pass)	95.3	n/a	45.5	1.000	1.000000	0.002922		
PARTIAL LOADCASE: Z 2; b 2; H 3 (Heel to starboard)	GZ curve completed successfully	27,29,31,33,35,59	0.045496	0.053128	0.932180	0.002253	97.0	3.861	0.9	39.6 (Pass)	98.0	n/a	47.3	1.000	1.000000	0.002253		
PARTIAL LOADCASE: Z 2; b 2; H 4 (Heel to starboard)	GZ curve completed successfully	27,29,31,33,35,59	0.045496	0.053128	0.067820	0.000164	97.0	3.861	0.9	39.6 (Pass)	98.0	n/a	47.3	1.000	1.000000	0.000164		
PARTIAL LOADCASE: Z 3; b 2; H 3 (Heel to starboard)	GZ curve completed successfully		0.028724	0.800426	0.932180	0.021432	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.000000	0.021432		
PARTIAL LOADCASE: Z 3; b 2; H 4 (Heel to starboard)	GZ curve completed successfully	11,15,16,19,20,23,57,59	0.028724	0.800426	0.067820	0.001559	96.0	3.795	2.5	37.4 (Pass)	98.5	n/a	47.3	1.000	1.000000	0.001559		
PARTIAL LOADCASE: Z 3; b 3; H 3 (Heel to	GZ curve completed successfully	6,8,53,72	0.028724	0.177448	0.932180	0.004751	96.6	3.509	3.2	37.5 (Pass)	99.8	n/a	49.1	1.000	1.000000	0.004751		

Table 116. **Probabilistic Analysis 4/10.** (Maxsurf), (Hydromax)

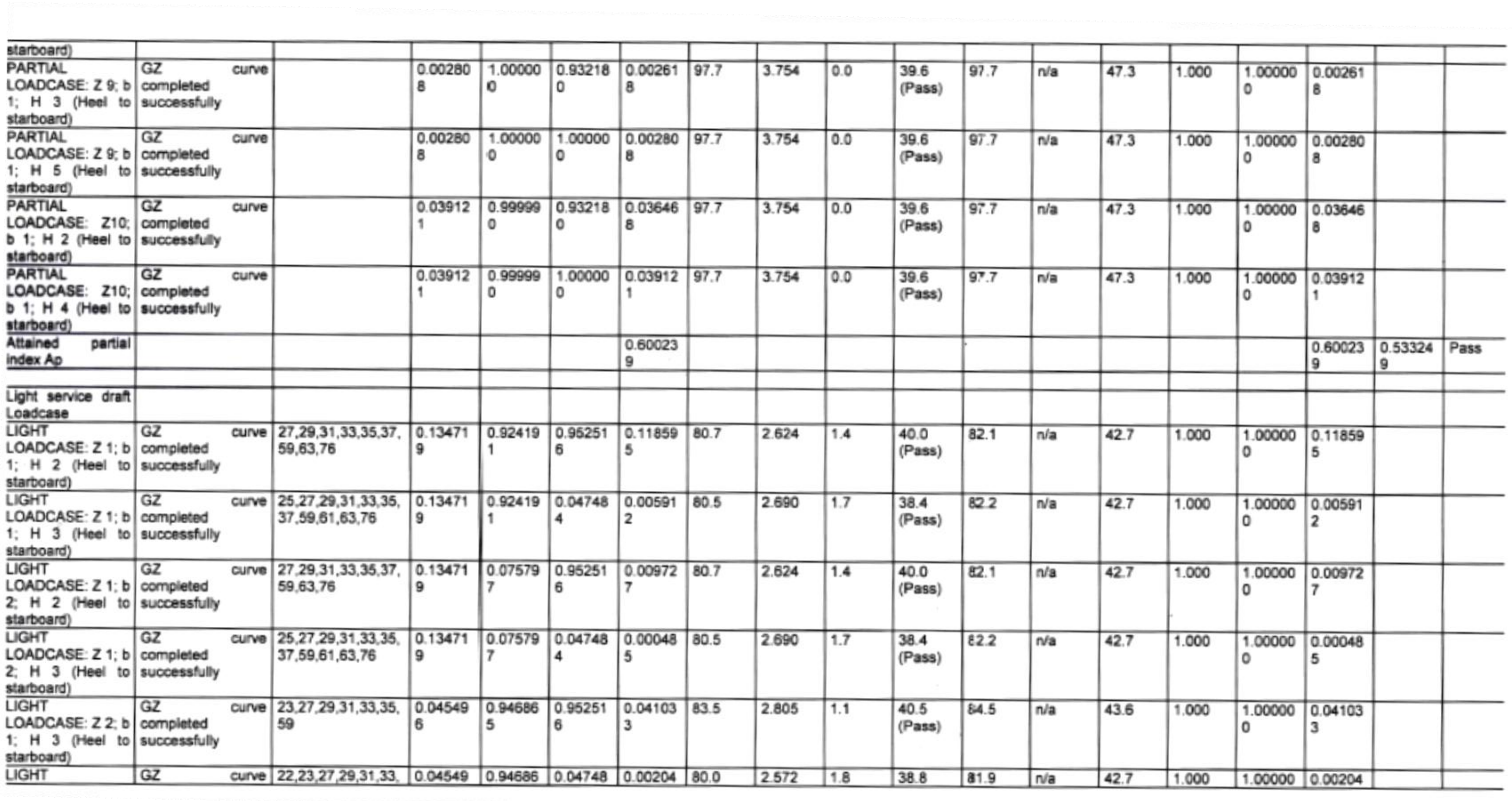
starboard)																		
PARTIAL LOADCASE: Z 3; b 3; H 4 (Heel to starboard)	GZ curve completed successfully		0.028724	0.177448	0.067820	0.000346	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.000000	0.000346		
PARTIAL LOADCASE: Z 3; b 4; H 3 (Heel to starboard)	GZ curve completed successfully	6,8,53,72	0.028724	0.022121	0.932180	0.000592	96.6	3.509	3.2	37.5 (Pass)	99.8	n/a	49.1	1.000	1.000000	0.000592		
PARTIAL LOADCASE: Z 4; b 2; H 3 (Heel to starboard)	GZ curve completed successfully	51	0.060627	0.841364	0.932180	0.047550	97.3	3.859	1.5	38.9 (Pass)	98.7	n/a	49.1	1.000	1.000000	0.047550		
PARTIAL LOADCASE: Z 4; b 2; H 4 (Heel to starboard)	GZ curve completed successfully	51,53	0.060627	0.841364	0.067820	0.003459	96.9	3.969	2.8	38.4 (Pass)	99.7	n/a	50.0	1.000	1.000000	0.003459		
PARTIAL LOADCASE: Z 4; b 3; H 3 (Heel to starboard)	GZ curve completed successfully	4,51,70	0.060627	0.158628	0.932180	0.008965	96.1	3.495	4.0	36.8 (Pass)	100.1	n/a	50.0	1.000	1.000000	0.008965		
PARTIAL LOADCASE: Z 4; b 3; H 4 (Heel to starboard)	GZ curve completed successfully	4,6,8,51,53,70,72	0.060627	0.158628	0.067820	0.000652	94.9	3.236	7.9	34.6 (Pass)	102.9	n/a	52.7	1.000	1.000000	0.000652		
PARTIAL LOADCASE: Z 5; b 2; H 3 (Heel to starboard)	GZ curve completed successfully	10,12,45	0.060627	0.841364	0.932180	0.047550	95.0	3.750	0.1	39.2 (Pass)	95.1	n/a	47.3	1.000	1.000000	0.047550		
PARTIAL LOADCASE: Z 5; b 2; H 4 (Heel to starboard)	GZ curve completed successfully	1,10,47,66	0.060627	0.841364	0.067820	0.003459	93.4	3.571	2.1	36.1 (Pass)	95.5	n/a	48.2	1.000	1.000000	0.003459		
PARTIAL LOADCASE: Z 5; b 3; H 3 (Heel to starboard)	GZ curve completed successfully	45	0.060627	0.158628	0.932180	0.008965	97.6	3.767	0.1	39.5 (Pass)	97.7	n/a	48.2	1.000	1.000000	0.008965		
PARTIAL LOADCASE: Z 5; b 3; H 4 (Heel to starboard)	GZ curve completed successfully	47	0.060627	0.158628	0.067820	0.000652	97.5	3.819	0.6	39.1 (Pass)	98.0	n/a	48.2	1.000	1.000000	0.000652		
PARTIAL LOADCASE: Z 6; b 2; H 3 (Heel to	GZ curve completed successfully		0.060627	0.841364	0.932180	0.047550	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.000000	0.047550		

Table 117. **Probabilistic Analysis 5/10.** (Maxsurf), (Hydromax)



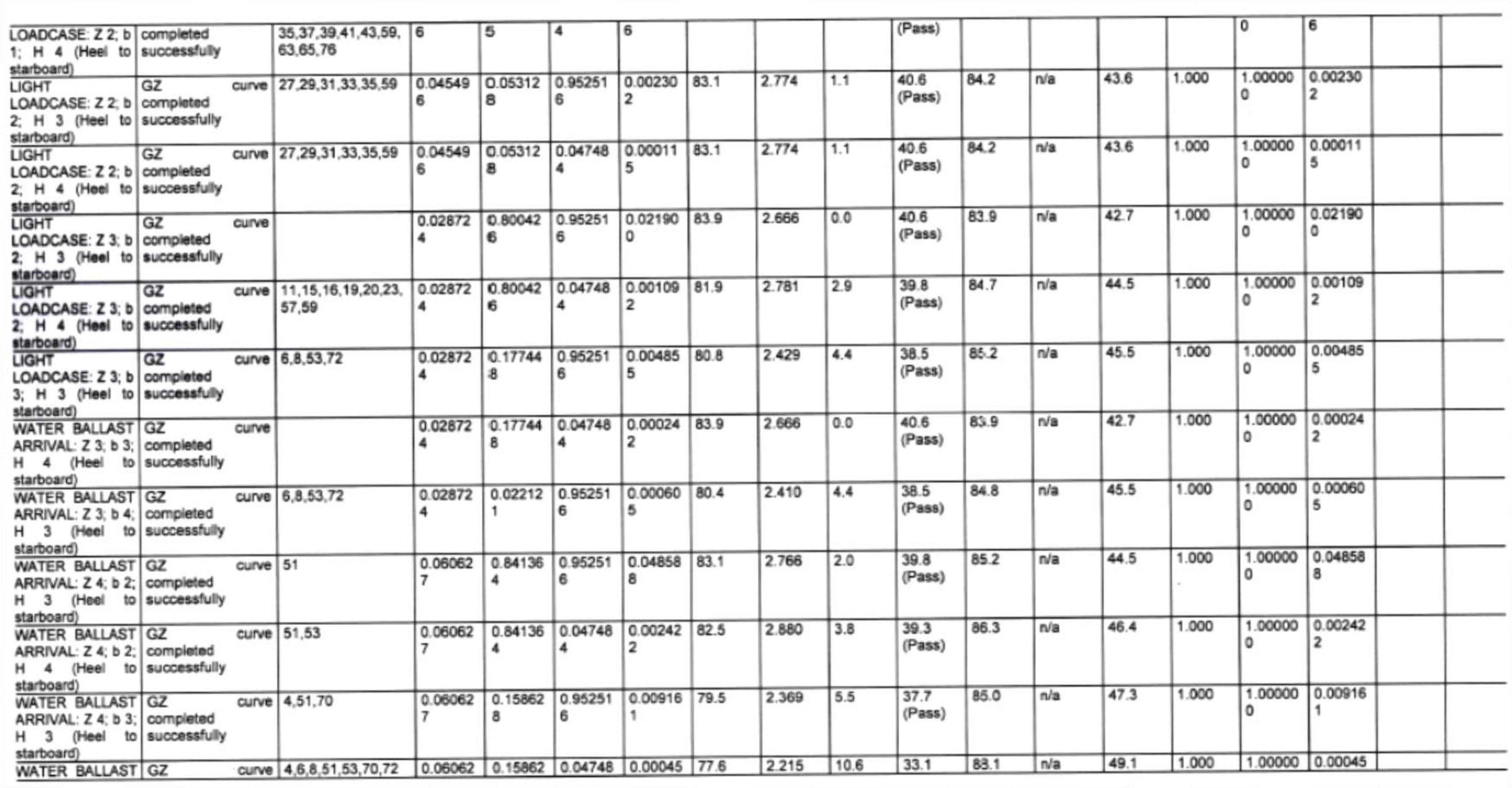
starboard)																		
PARTIAL LOADCASE: Z 6; b 2; H 4 (Heel to starboard)	GZ curve completed successfully		0.06062 7	0.84136 4	0.06782 0	0.00345 9	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.00000 0	0.00345 9		
PARTIAL LOADCASE: Z 6; b 3; H 3 (Heel to starboard)	GZ curve completed successfully		0.06062 7	0.15862 8	0.93218 0	0.00896 5	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.00000 0	0.00896 5		
PARTIAL LOADCASE: Z 6; b 3; H 4 (Heel to starboard)	GZ curve completed successfully		0.06062 7	0.15862 8	0.06782 0	0.00065 2	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.00000 0	0.00065 2		
PARTIAL LOADCASE: Z 7; b 2; H 3 (Heel to starboard)	GZ curve completed successfully		0.06062 7	0.79795 2	0.93218 0	0.04509 7	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.00000 0	0.04509 7		
PARTIAL LOADCASE: Z 7; b 2; H 4 (Heel to starboard)	GZ curve completed successfully		0.06062 7	0.79795 2	0.06782 0	0.00328 1	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.00000 0	0.00328 1		
PARTIAL LOADCASE: Z 7; b 3; H 3 (Heel to starboard)	GZ curve completed successfully		0.06062 7	0.20204 0	0.93218 0	0.01141 8	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.00000 0	0.01141 8		
PARTIAL LOADCASE: Z 7; b 3; H 4 (Heel to starboard)	GZ curve completed successfully		0.06062 7	0.20204 0	0.06782 0	0.00083 1	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.00000 0	0.00083 1		
PARTIAL LOADCASE: Z 8; b 1; H 3 (Heel to starboard)	GZ curve completed successfully		0.03510 2	0.48374 0	0.93218 0	0.01582 8	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.00000 0	0.01582 8		
PARTIAL LOADCASE: Z 8; b 1; H 5 (Heel to starboard)	GZ curve completed successfully		0.03510 2	0.48374 0	1.00000 0	0.01698 0	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.00000 0	0.01698 0		
PARTIAL LOADCASE: Z 8; b 2; H 3 (Heel to starboard)	GZ curve completed successfully		0.03510 2	0.51625 4	0.93218 0	0.01689 2	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.00000 0	0.01689 2		
PARTIAL LOADCASE: Z 8; b 2; H 5 (Heel to	GZ curve completed successfully		0.03510 2	0.51625 4	1.00000 0	0.01812 1	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.00000 0	0.01812 1		

Table 118. **Probabilistic Analysis 6/10.** (Maxsurf), (Hydromax)



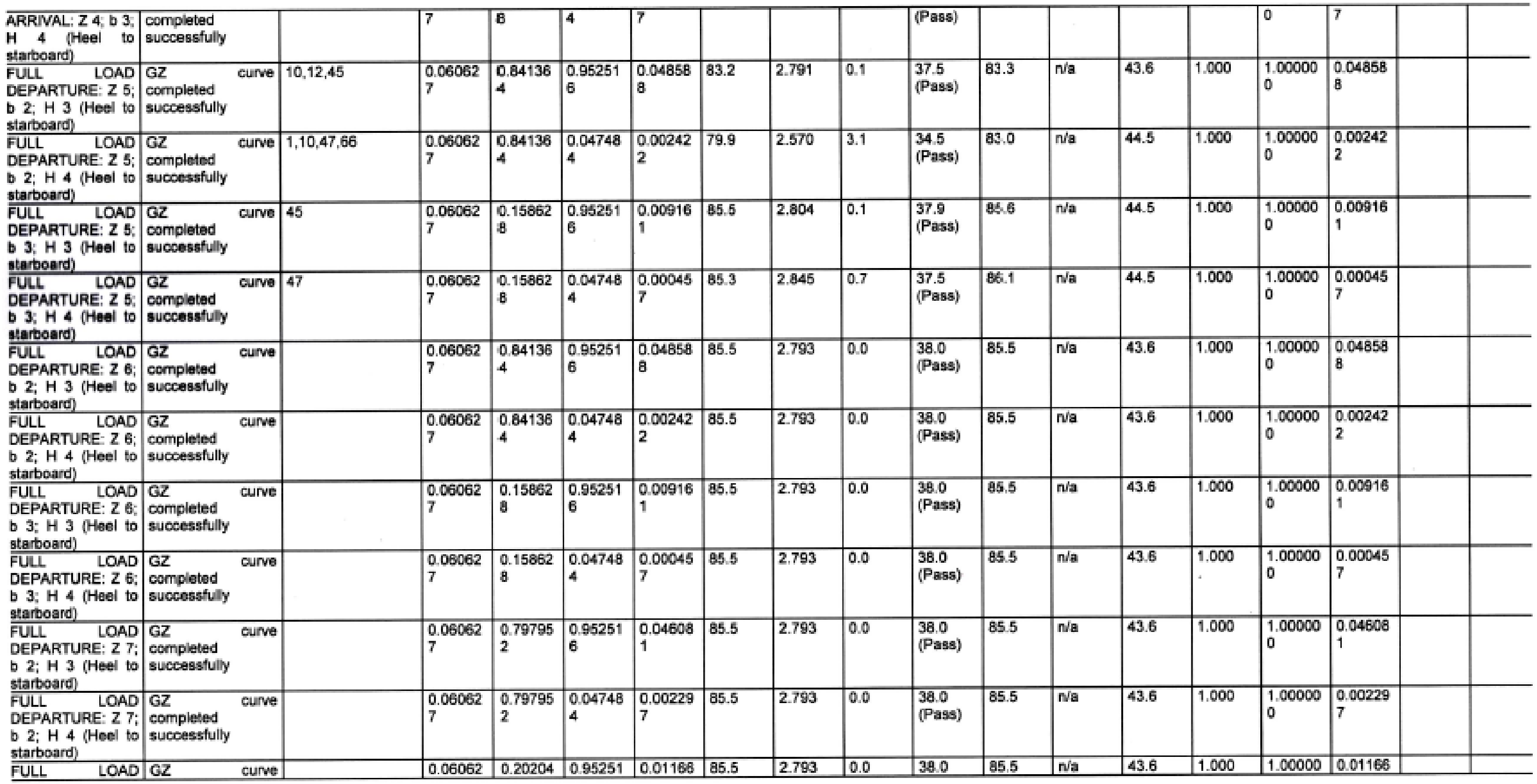
starboard)																		
PARTIAL LOADCASE: Z 9; b 1; H 3 (Heel to starboard)	GZ curve completed successfully		0.002808	1.000000	0.932180	0.002618	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.000000	0.002618		
PARTIAL LOADCASE: Z 9; b 1; H 5 (Heel to starboard)	GZ curve completed successfully		0.002808	1.000000	1.000000	0.002808	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.000000	0.002808		
PARTIAL LOADCASE: Z10; b 1; H 2 (Heel to starboard)	GZ curve completed successfully		0.039121	0.999990	0.932180	0.036468	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.000000	0.036468		
PARTIAL LOADCASE: Z10; b 1; H 4 (Heel to starboard)	GZ curve completed successfully		0.039121	0.999990	1.000000	0.039121	97.7	3.754	0.0	39.6 (Pass)	97.7	n/a	47.3	1.000	1.000000	0.039121		
Attained partial index Ap						0.600239										0.600239	0.533249	Pass
Light service draft Loadcase																		
LIGHT LOADCASE: Z 1; b 1; H 2 (Heel to starboard)	GZ curve completed successfully	27,29,31,33,35,37, 59,63,76	0.134719	0.924191	0.952516	0.118595	80.7	2.624	1.4	40.0 (Pass)	82.1	n/a	42.7	1.000	1.000000	0.118595		
LIGHT LOADCASE: Z 1; b 1; H 3 (Heel to starboard)	GZ curve completed successfully	25,27,29,31,33,35, 37,59,61,63,76	0.134719	0.924191	0.047484	0.005912	80.5	2.690	1.7	38.4 (Pass)	82.2	n/a	42.7	1.000	1.000000	0.005912		
LIGHT LOADCASE: Z 1; b 2; H 2 (Heel to starboard)	GZ curve completed successfully	27,29,31,33,35,37, 59,63,76	0.134719	0.075797	0.952516	0.009727	80.7	2.624	1.4	40.0 (Pass)	82.1	n/a	42.7	1.000	1.000000	0.009727		
LIGHT LOADCASE: Z 1; b 2; H 3 (Heel to starboard)	GZ curve completed successfully	25,27,29,31,33,35, 37,59,61,63,76	0.134719	0.075797	0.047484	0.000485	80.5	2.690	1.7	38.4 (Pass)	82.2	n/a	42.7	1.000	1.000000	0.000485		
LIGHT LOADCASE: Z 2; b 1; H 3 (Heel to starboard)	GZ curve completed successfully	23,27,29,31,33,35, 59	0.045496	0.946865	0.952516	0.041033	83.5	2.805	1.1	40.5 (Pass)	84.5	n/a	43.6	1.000	1.000000	0.041033		
LIGHT	GZ curve	22,23,27,29,31,33,	0.04549	0.94686	0.04748	0.00204	80.0	2.572	1.8	38.8	81.9	n/a	42.7	1.000	1.00000	0.00204		

Table 119. Probabilistic Analysis 7/10. (Maxsurf), (Hydromax)



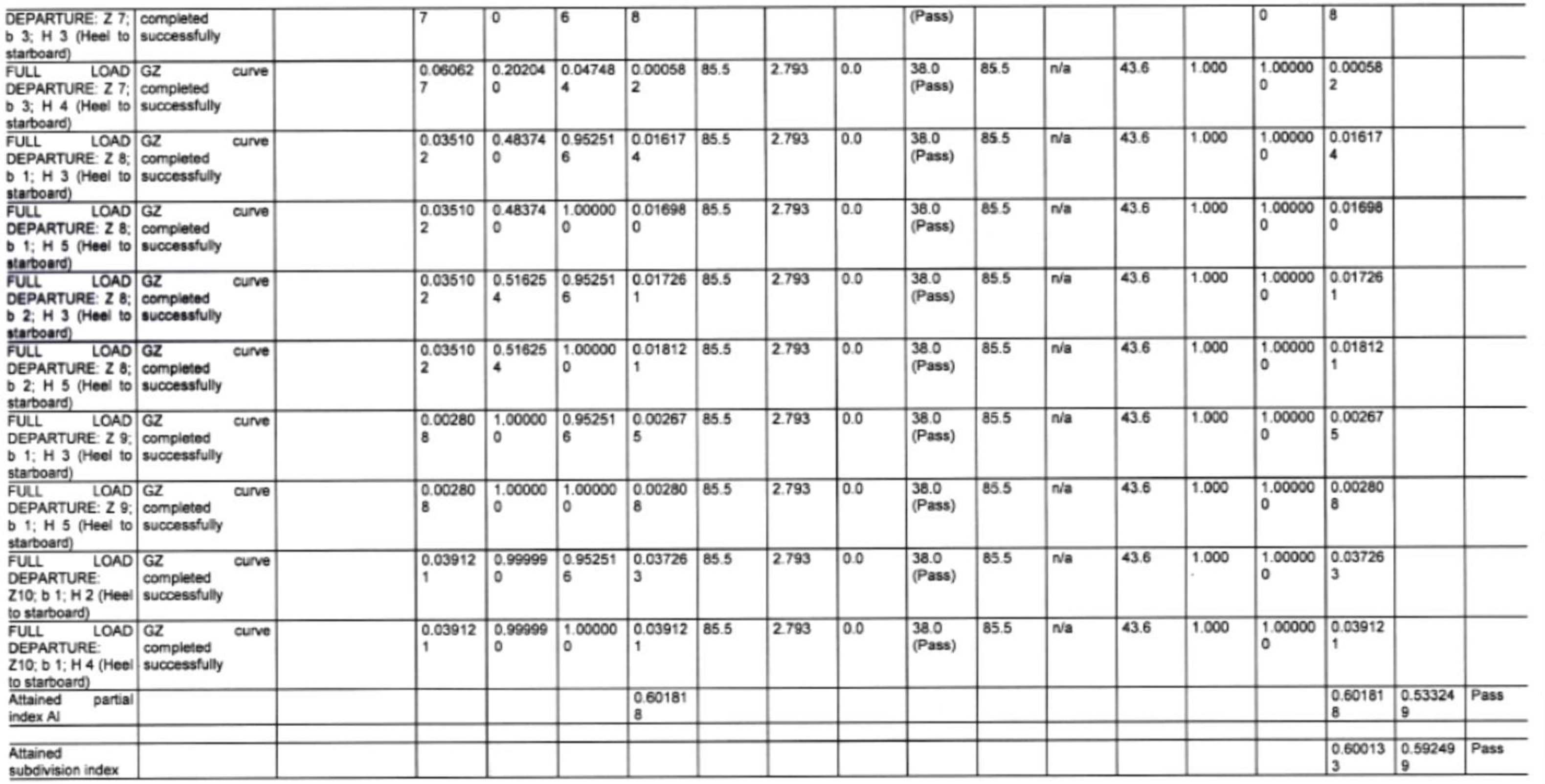
LOADCASE: Z 2; b 1; H 4 (Heel to starboard)	completed successfully	35,37,39,41,43,59, 63,65,76	6	5	4	6				(Pass)					0	6		
LIGHT LOADCASE: Z 2; b 2; H 3 (Heel to starboard)	GZ curve completed successfully	27,29,31,33,35,59	0.045496	0.053128	0.952516	0.002302	83.1	2.774	1.1	40.6 (Pass)	84.2	n/a	43.6	1.000	1.000000	0.002302		
LIGHT LOADCASE: Z 2; b 2; H 4 (Heel to starboard)	GZ curve completed successfully	27,29,31,33,35,59	0.045496	0.053128	0.047484	0.000115	83.1	2.774	1.1	40.6 (Pass)	84.2	n/a	43.6	1.000	1.000000	0.000115		
LIGHT LOADCASE: Z 3; b 2; H 3 (Heel to starboard)	GZ curve completed successfully		0.028724	0.800426	0.952516	0.021900	83.9	2.666	0.0	40.6 (Pass)	83.9	n/a	42.7	1.000	1.000000	0.021900		
LIGHT LOADCASE: Z 3; b 2; H 4 (Heel to starboard)	GZ curve completed successfully	11,15,16,19,20,23, 57,59	0.028724	0.800426	0.047484	0.001092	81.9	2.781	2.9	39.8 (Pass)	84.7	n/a	44.5	1.000	1.000000	0.001092		
LIGHT LOADCASE: Z 3; b 3; H 3 (Heel to starboard)	GZ curve completed successfully	6,8,53,72	0.028724	0.177448	0.952516	0.004855	80.8	2.429	4.4	38.5 (Pass)	85.2	n/a	45.5	1.000	1.000000	0.004855		
WATER BALLAST ARRIVAL: Z 3; b 3; H 4 (Heel to starboard)	GZ curve completed successfully		0.028724	0.177448	0.047484	0.000242	83.9	2.666	0.0	40.6 (Pass)	83.9	n/a	42.7	1.000	1.000000	0.000242		
WATER BALLAST ARRIVAL: Z 3; b 4; H 3 (Heel to starboard)	GZ curve completed successfully	6,8,53,72	0.028724	0.022121	0.952516	0.000605	80.4	2.410	4.4	38.5 (Pass)	84.8	n/a	45.5	1.000	1.000000	0.000605		
WATER BALLAST ARRIVAL: Z 4; b 2; H 3 (Heel to starboard)	GZ curve completed successfully	51	0.060627	0.841364	0.952516	0.048588	83.1	2.766	2.0	39.8 (Pass)	85.2	n/a	44.5	1.000	1.000000	0.048588		
WATER BALLAST ARRIVAL: Z 4; b 2; H 4 (Heel to starboard)	GZ curve completed successfully	51,53	0.060627	0.841364	0.047484	0.002422	82.5	2.880	3.8	39.3 (Pass)	86.3	n/a	46.4	1.000	1.000000	0.002422		
WATER BALLAST ARRIVAL: Z 4; b 3; H 3 (Heel to starboard)	GZ curve completed successfully	4,51,70	0.060627	0.158628	0.952516	0.009161	79.5	2.369	5.5	37.7 (Pass)	85.0	n/a	47.3	1.000	1.000000	0.009161		
WATER BALLAST	GZ curve	4,6,8,51,53,70,72	0.06062	0.15862	0.04748	0.00045	77.6	2.215	10.6	33.1	83.1	n/a	49.1	1.000	1.00000	0.00045		

Table 120. Probabilistic Analysis 8/10. (Maxsurf), (Hydromax)



ARRIVAL: Z 4; b 3; H 4 (Heel to starboard)	completed successfully		7	8	4	7				(Pass)					0	7		
FULL LOAD DEPARTURE: Z 5; b 2; H 3 (Heel to starboard)	GZ curve completed successfully	10,12,45	0.060627	0.841364	0.952516	0.048588	83.2	2.791	0.1	37.5 (Pass)	83.3	n/a	43.6	1.000	1.000000	0.048588		
FULL LOAD DEPARTURE: Z 5; b 2; H 4 (Heel to starboard)	GZ curve completed successfully	1,10,47,66	0.060627	0.841364	0.047484	0.002422	79.9	2.570	3.1	34.5 (Pass)	83.0	n/a	44.5	1.000	1.000000	0.002422		
FULL LOAD DEPARTURE: Z 5; b 3; H 3 (Heel to starboard)	GZ curve completed successfully	45	0.060627	0.158628	0.952516	0.009161	85.5	2.804	0.1	37.9 (Pass)	85.6	n/a	44.5	1.000	1.000000	0.009161		
FULL LOAD DEPARTURE: Z 5; b 3; H 4 (Heel to starboard)	GZ curve completed successfully	47	0.060627	0.158628	0.047484	0.000457	85.3	2.845	0.7	37.5 (Pass)	86.1	n/a	44.5	1.000	1.000000	0.000457		
FULL LOAD DEPARTURE: Z 6; b 2; H 3 (Heel to starboard)	GZ curve completed successfully		0.060627	0.841364	0.952516	0.048588	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.048588		
FULL LOAD DEPARTURE: Z 6; b 2; H 4 (Heel to starboard)	GZ curve completed successfully		0.060627	0.841364	0.047484	0.002422	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.002422		
FULL LOAD DEPARTURE: Z 6; b 3; H 3 (Heel to starboard)	GZ curve completed successfully		0.060627	0.158628	0.952516	0.009161	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.009161		
FULL LOAD DEPARTURE: Z 6; b 3; H 4 (Heel to starboard)	GZ curve completed successfully		0.060627	0.158628	0.047484	0.000457	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.000457		
FULL LOAD DEPARTURE: Z 7; b 2; H 3 (Heel to starboard)	GZ curve completed successfully		0.060627	0.797952	0.952516	0.046081	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.046081		
FULL LOAD DEPARTURE: Z 7; b 2; H 4 (Heel to starboard)	GZ curve completed successfully		0.060627	0.797952	0.047484	0.002297	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.002297		
FULL LOAD	GZ curve		0.06062	0.20204	0.95251	0.01166	85.5	2.793	0.0	38.0	85.5	n/a	43.6	1.000	1.00000	0.01166		

Table 121. Probabilistic Analysis 9/10. (Maxsurf), (Hydromax)



DEPARTURE: Z 7; b 3; H 3 (Heel to starboard)	completed successfully		7	0	6	8				(Pass)					0	8		
FULL LOAD DEPARTURE: Z 7; b 3; H 4 (Heel to starboard)	GZ curve completed successfully		0.060627	0.202040	0.047484	0.000582	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.000582		
FULL LOAD DEPARTURE: Z 8; b 1; H 3 (Heel to starboard)	GZ curve completed successfully		0.035102	0.483740	0.952516	0.016174	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.016174		
FULL LOAD DEPARTURE: Z 8; b 1; H 5 (Heel to starboard)	GZ curve completed successfully		0.035102	0.483740	1.000000	0.016980	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.016980		
FULL LOAD DEPARTURE: Z 8; b 2; H 3 (Heel to starboard)	GZ curve completed successfully		0.035102	0.516254	0.952516	0.017261	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.017261		
FULL LOAD DEPARTURE: Z 8; b 2; H 5 (Heel to starboard)	GZ curve completed successfully		0.035102	0.516254	1.000000	0.018121	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.018121		
FULL LOAD DEPARTURE: Z 9; b 1; H 3 (Heel to starboard)	GZ curve completed successfully		0.002808	1.000000	0.952516	0.002675	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.002675		
FULL LOAD DEPARTURE: Z 9; b 1; H 5 (Heel to starboard)	GZ curve completed successfully		0.002808	1.000000	1.000000	0.002808	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.002808		
FULL LOAD DEPARTURE: Z10; b 1; H 2 (Heel to starboard)	GZ curve completed successfully		0.039121	0.999990	0.952516	0.037263	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.037263		
FULL LOAD DEPARTURE: Z10; b 1; H 4 (Heel to starboard)	GZ curve completed successfully		0.039121	0.999990	1.000000	0.039121	85.5	2.793	0.0	38.0 (Pass)	85.5	n/a	43.6	1.000	1.000000	0.039121		
Attained partial index Al						0.601818										0.601818	0.533249	Pass
Attained subdivision index																0.600133	0.592499	Pass

Table 122. Probabilistic Analysis 10/10. (Maxsurf), (Hydromax)

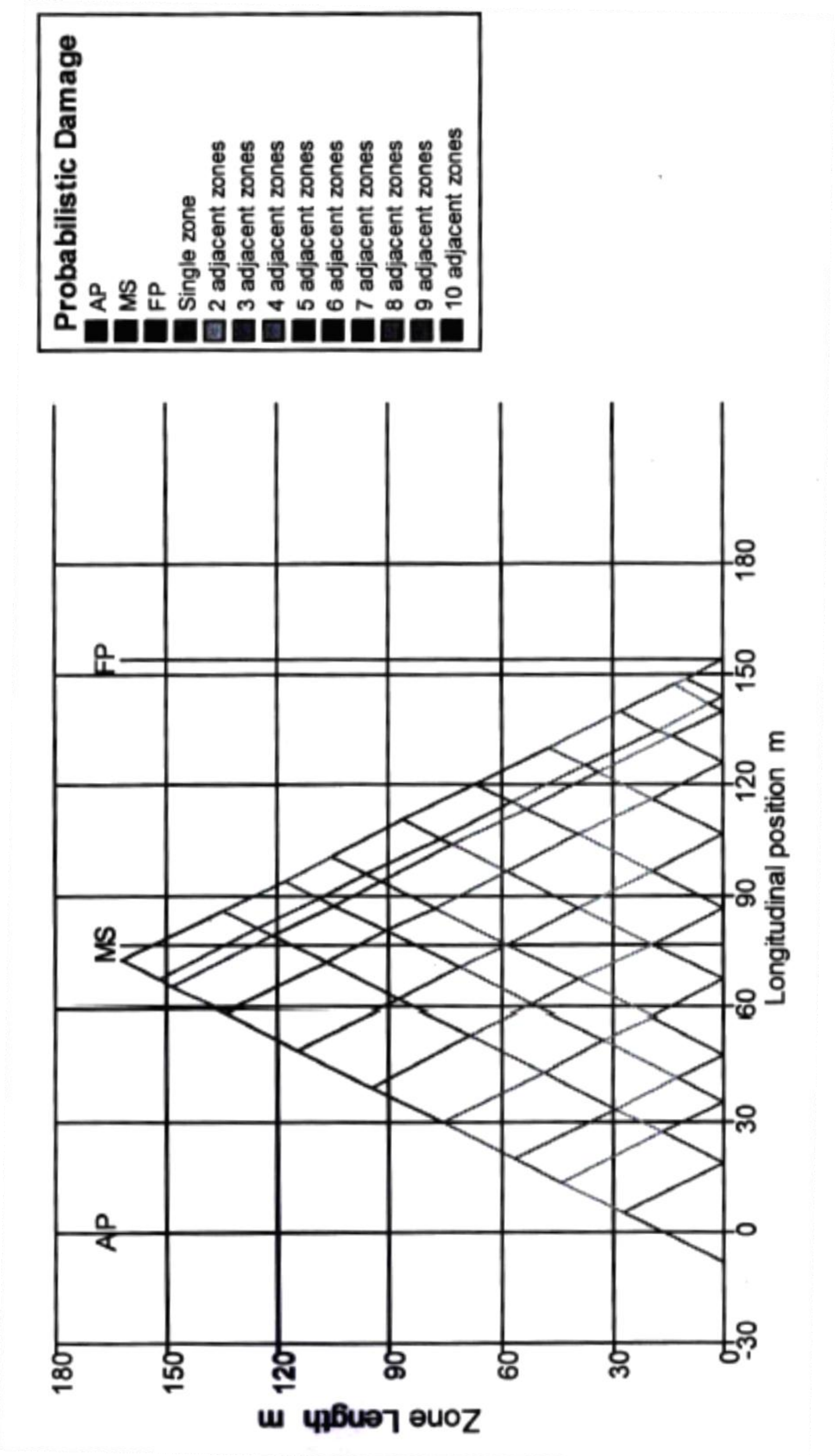


Figure 18. **Probabilistic Analysis - Triangles.** (Maxsurf), (Hydromax)

19. Ship Motions in Regular & IRRegular Waves

In this chapter, the vessels motion in Regular and IRRegular waves will be examined. This will take place by using the code for vessels motions prediction: **(G. Grigoropoulos et al., 1 9 9 4)**.

The theory used is the version of strip theory proposed by Salvesen, Tuck and Faltinsen (1970). The added mass and damping coefficients, Froude–Krylov and sectional diffraction force coefficients area calculated using the three-parameter Extended-Lewis forms, the two-parameter Lewis forms or the bulb forms. **Source: (G. Grigoropoulos et al. , 1 9 9 4)**

For irregular waves, long-crested unidirectional seas are assumed. The user may either describe the ocean spectrum or use the default option, in which case the Bretschneider two-parameter sea spectrum is used for developing, decaying or fully developed seas. Irregular wave results for short-crested seas may be obtained by transferring the mean square of the responses to an output device to be specified by the user. These responses are read by an auxiliary program, which predicts the short-crested responses. **Source: (G. Grigoropoulos et al., 1 9 9 4)**

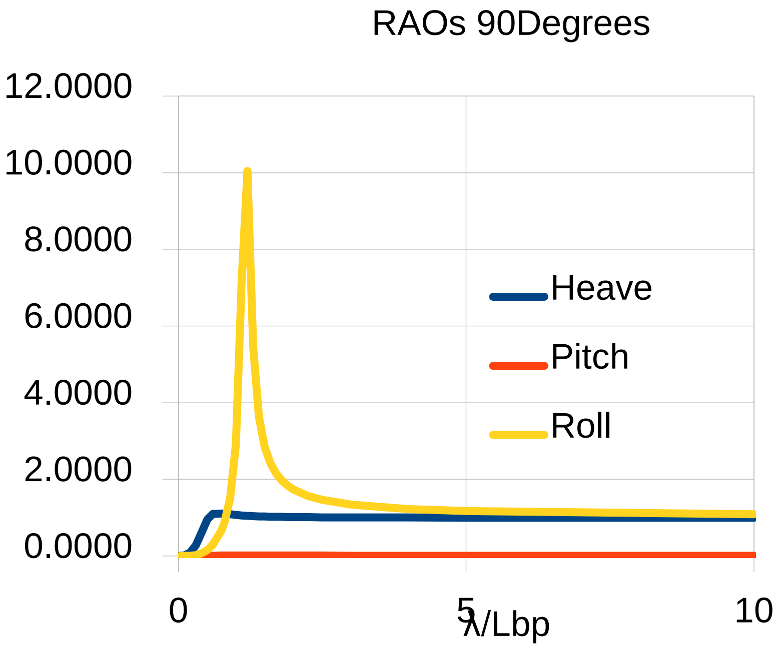


Figure 19. RAOs 90 Degrees – Regular Waves. (G. Grigoropoulos et al., 1 9 9 4)

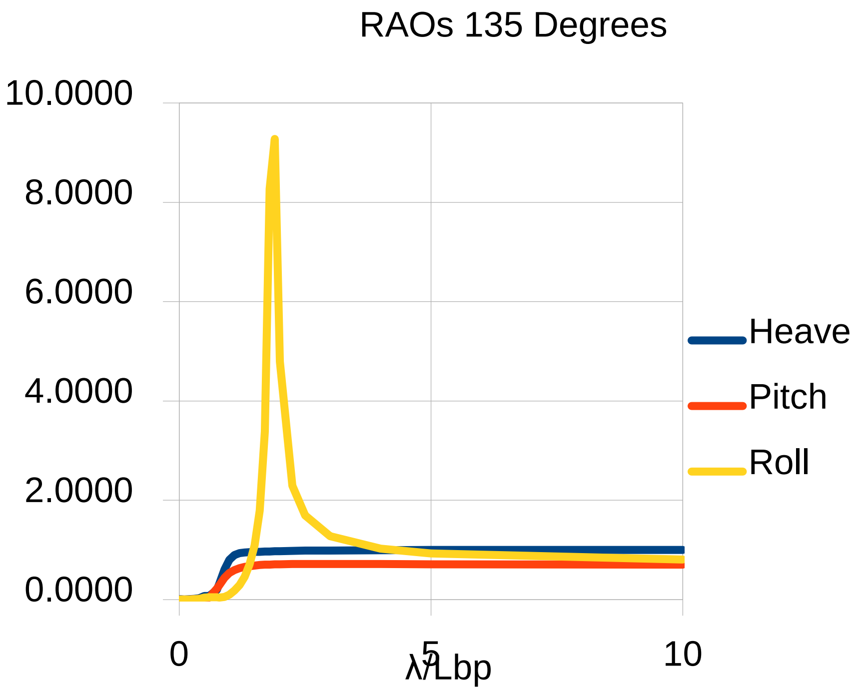


Figure 20. **RAOs 135 Degrees – Regular Waves.** (G. Grigoropoulos et al., 1 9 9 4)

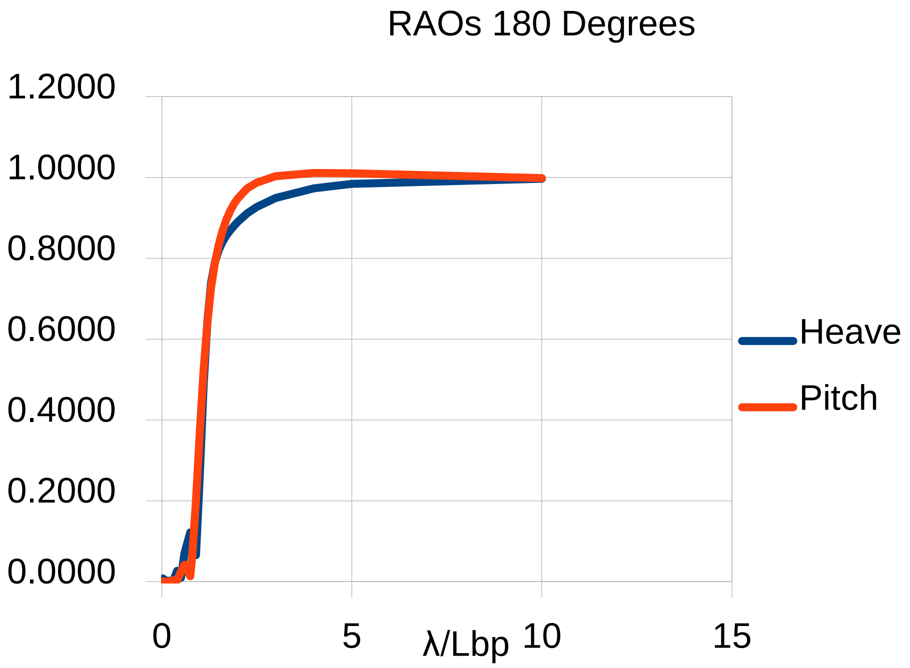


Figure 21. **RAOs 180 Degrees – Regular Waves.** (G. Grigoropoulos et al., 1 9 9 4)

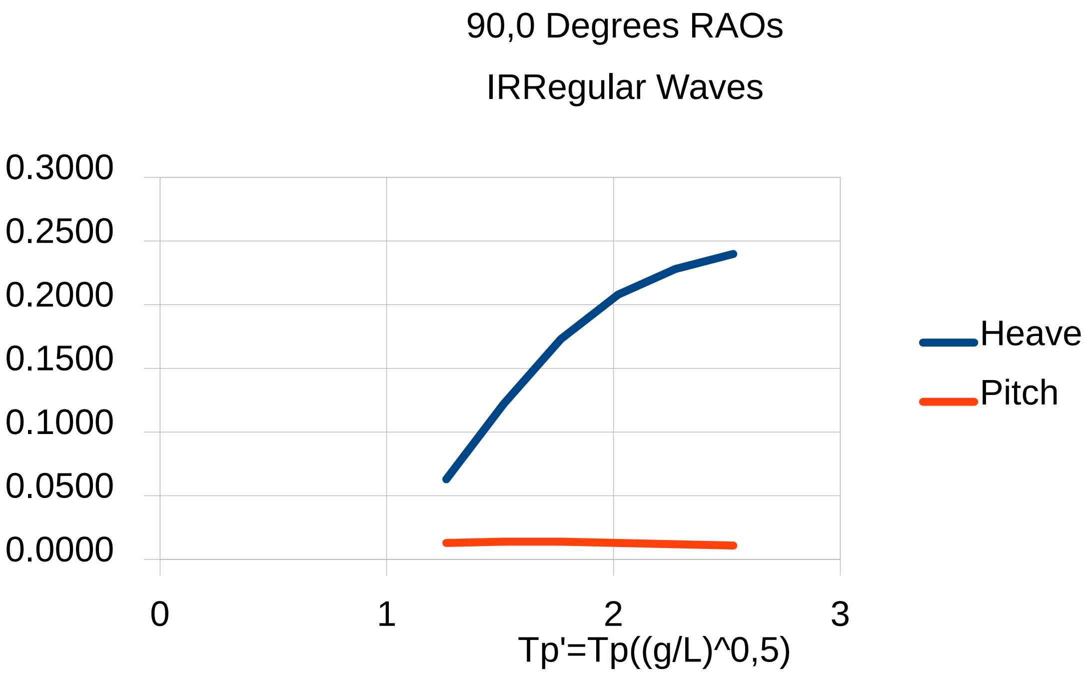


Figure 22. **RAOs 90 Degrees – IRRegular Waves.** (G. Grigoropoulos et al., 1 9 9 4)

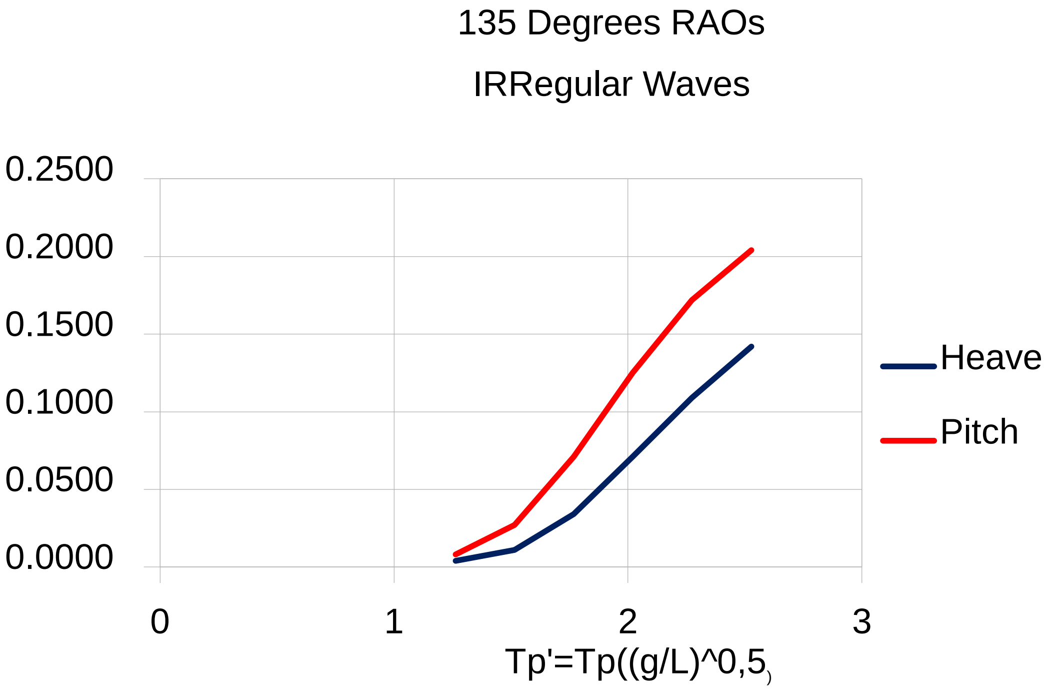


Figure 23. **RAOs 135 Degrees – IRRegular Waves.** (G. Grigoropoulos et al., 1994)

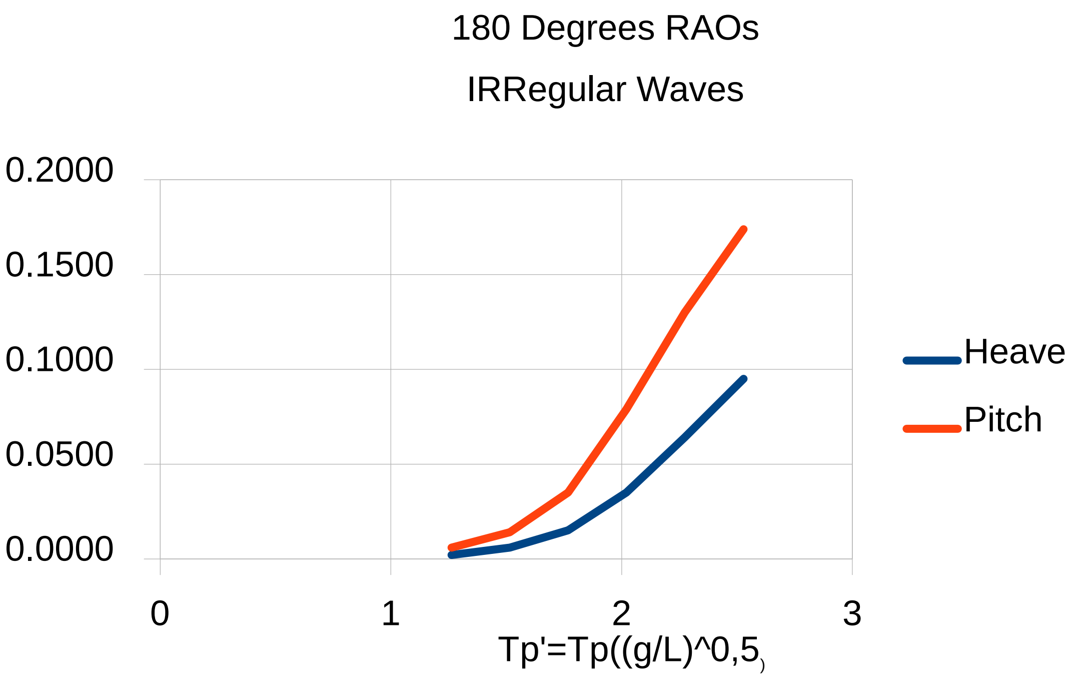


Figure 24. **RAOs 180 Degrees – IRRegular Waves.** (G. Grigoropoulos et al., 1994)

In accordance with (G. Grigoropoulos et al., 1 9 9 4), angle β which is named in the previous figures of this chapter is defined as the following:

Heading angle (β):
β : 0° following seas
β : 90° beam seas
β : 180° head seas

20. Cost Analysis

In this chapter, the acquiring cost of the vessel with its operational cost will be calculated accompanied by the payback period estimation. The first will be calculated by using bibliographical source: (Prof. Manuel Ventura) while the third one by using bibliographical source: (Δημήτριος Παναγιωτακόπουλος, 2005). The operational cost will be calculated according to (Low Sulphur Fuel 380 Piraeus), (Low Sulphur Marine Gas Oil Piraeus), (www.xe.com), (Prof. Manuel Ventura), (www.portbook.gr), (CNG Europe), (World Bank Commodities Price Forecast (nominal US dollars), 2017), (ΔΗΜΟΣΙΑ ΕΠΙΧΕΙΡΗΣΗ ΑΕΡΙΟΥ Α.Ε. ΔΕΠΑ) and (Petrowiki - Stranded gas). It is underlined that in all cases, Mircrosoft and Open Office have been used.

From Bibliographical Source: (Prof. Manuel Ventura), the acquiring cost is calculated as follows:

The power of the natural gas compressors:

$$P_{Compressors} = 104 \cdot 93.25kW = 9698kW = 9.7MW$$

(High Pressure Natural Gas Compressors BAUER COMPRESSORS) Equation 30

The cost of the natural gas compressors:

$$C_{Compressors} = 172.41\$/kW \cdot 9698kW = 1672032\$$$

(Biogas booster compressor/natural gas cylinder filling compressor) Equation 31

The cost of the extra installed diesel generator power due to natural gas compressors operation:

$$C_{ADD\_D/G} = 9698kW \cdot 197.240\$/kW = 1.91 \cdot 10^{6}\$$$

(4000kW generator) Equation 32

The specific pressure bottles cost is:

$$SC_{P.B\_TYPE\_I} = 5\$/l$$

(CNG tanks: Pressure vessel epicenter) Equation 33

The pressure bottles volume is:

$$V_{P.B} = 480 \cdot 14.5 \cdot \pi \cdot \frac{1.2^{2}}{4} = 7871m^{3}$$

Equation 34

The pressure bottles cost is:

$$C_{P.B\_TYPE\_I} = 5\frac{\$}{l} \cdot 7871 m^3 \cdot 1000 \frac{l}{m^3} = 39.35 \cdot 10^6 \$$$ **(CNG tanks: Pressure vessel epicenter) Equation 35**

The vessels steel weight cost is:

$$C_{Steel} = k_1 \cdot W_{Steel}^{k_2} \cdot C_B^{k_3} = 2.666 \cdot \left(6461.4^{0.8837}\right) \cdot \left(0.77^{-0.2336}\right) = 6600 \cdot 10^3 \$$$ **(Prof. Manuel Ventura) Equation 36**

The compressors weight is:

$$W_{Compressors} = 104 \cdot 4.318 = 449.07 t$$ **(High Pressure Natural Gas Compressors BAUER COMPRESSORS) Equation 37**

The pressure bottles weight is:

$$W_{P.B\_TYPE\_I} \cong 1.4 \frac{kg}{l} \cdot 7871 m^3 \cdot 1000 \frac{l}{m^3} \cong 10971 t$$ **(CNG tanks: Pressure vessel epicenter) Equation 38**

The vessels outfit weight is:

$$W_{OT\_TypicalBulker} = 12699 - 449.07 - 10971 = 1279 t$$ **Equation 39**

The vessels outfit weight cost is:

$$C_{TypicalBulker} = k_1 \cdot W_{OT}^{k_2} = 11.966 \cdot \left(1279^{0.9335}\right) = 9510.70 \cdot 10^3 \$$$

(Prof. Manuel Ventura) Equation 40

The machinery cost is:

$$Q_M = k_1 \cdot P_{MCR}^{k_2} = 12.507 \cdot \left(\frac{12000}{746} 1000\right)^{0.647} = 6587.5 \cdot 10^3 \$$$

(Prof. Manuel Ventura) Equation 41

$$Total\ Cost = 6587.5 \cdot 10^3 \$ + 6600 \cdot 10^3 \$ + 9510.70 \cdot 10^3 \$ + 1672032 \$$$

$$+ 1.91 \cdot 10^6 \$ + 39.35 \cdot 10^6 \$ = 65.63 \cdot 10^6 \$$$

The vessels total acquiring cost is:

$$New\ Total\ Cost = 1.1 \cdot 65.63 \cdot 10^6 \$ = 72.2 \cdot 10^6 \$$$ **Equation 42**

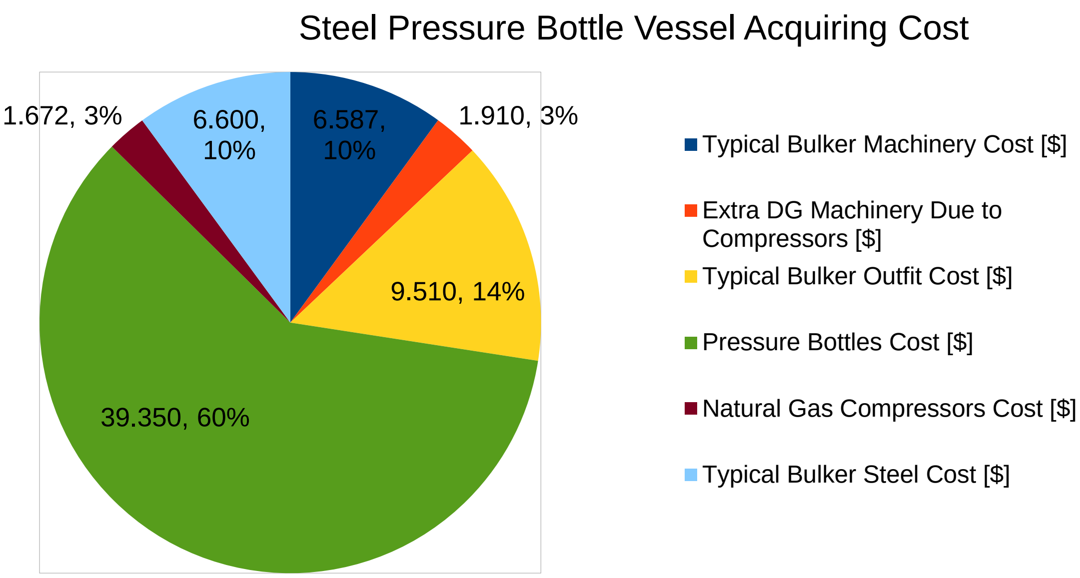


Figure 25. **Steel Pressure Bottle Vessel Acquiring Cost Analysis.**

With the following equations of this chapter, the operating cost of the examined vessel (Steel Pressure Vessel) will be evaluated.

$$Scraping:$$

$$\frac{\$}{LTD} = 253\$/t, LS = 20316t \Rightarrow C_{Scrap} = 253\$/t \cdot 20316t = 5139948\$$$

Equation 43 (Prof. Manuel Ventura)

$$Operational\ Cost:$$

$$C_{Crew} = 45000(25)^{0.95} = 957757.4\$/y = 79813.1\$/month$$

$$C_{Supplies+Lubs} = k_1 \cdot N + k_2(L \cdot B \cdot T)^{0.25} + k_3 P_{MCR}^{0.7} = 3500 \cdot 25 +$$

$$+4000(153.81 \cdot 29.58 \cdot 6.68)^{0.25} + 250\left(\frac{12000 \cdot 1000}{746}\right)^{0.7} = 360327.8\$/y = 30027.31\$/month$$

Equation 44. (Prof. Manuel Ventura)

$$Maintenance + repair:$$

$$C_{M\&R} = k_1 \cdot C_0 + k_2 \cdot P_{MCR}^{0.66} = 0.0035 \cdot 72.20 \cdot 10^6 + 125 \cdot \left(\frac{12000 \cdot 1000}{746}\right)^{0.66} =$$

$$= 327372.73\$/y = 27281.06\$/month$$

Equation 45. (Prof. Manuel Ventura)

$$Insurance\ Cost:$$

$$C_{INS} = k_1 \cdot V_S + k_2 \cdot GT = 0.01 \cdot 15 + 11.50 \cdot 22927 = 263663.53\$/y = 21971.961\$/month$$

Equation 46. (Prof. Manuel Ventura)

$$Administration:$$

$$C_{ADM} = 120000\$/y = 10000\$/month$$

Equation 47. (Prof. Manuel Ventura)

$$Docking\ Cost:$$

$$C_{Dock} = 0.005 \cdot 72.2 \cdot 10^6 = 361000\$/y = 30083.33\$/month$$

Equation 48. (Prof. Manuel Ventura)

For the purposes of the present analysis, the payback period will be calculated for two different natural gas reserves (Normal Natural Gas & Stranded Natural Gas) as well as for two rates of return (5% & 7%).

payload [t]	**1500**
LSIFO 380 Capacity [t]	**1089**
LSMGO Capacity [t]	**819**

LS IFO 380 PRICE [$/t]	**380**	www.shipandbunker.com 09/06/2018 (Low Sulphur Fuel 380 Piraeus)
LS MGO PRICE [$/t]	**500**	www.shipandbunker.com 09/06/2018 (Low Sulphur Marine Gas Oil Piraeus)
Euro/Dollar [208]	**1.1357**	www.xe.com
M & R Cost [$/month]	**27281.06**	(Prof. Manuel Ventura)
Supplies & LO [$/month]	**30027.31**	(Prof. Manuel Ventura)
Insurance Cost [$/month]	**21971.96**	(Prof. Manuel Ventura)
Administration [$/month]	**10000**	(Prof. Manuel Ventura)
Docking Cost [$/month]	**30083.33**	(Prof. Manuel Ventura)
Crew Cost [$/month]	**79813.11**	(Prof. Manuel Ventura)
Port Expenses [E/month]	**2604.133333**	(www.portbook.gr)

CNG present price final customer [E/t]	**870**	(CNG Europe), (www.xe.com)
NG price platform [E/t]	**249.2**	(World Bank Commodities Price Forecast (nominal US dollars), 2017), (ΔΗΜΟΣΙΑ ΕΠΙΧΕΙΡΗΣΗ ΑΕΡΙΟΥ Α.Ε. ΔΕΠΑ), (Petrowiki - Stranded gas), (www.xe.com)
Interest	**0.05**	-

Vessel Obtaining Cost [E]	**63573126.71**
Vessel Scrapping Value [E] [Reference to Present]	**4525797.31**

Net Present Value [E]	11506010.89

Table 123. **Input Data – Normal Gas – 5%.**

It is assumed that every month the vessel needs general bunkering. Cyprus to Cyklades with return < (2 X 923km=1846km) or 1846km/1.852km/sm= 996 sm. (gr.distance24.org) **Endurance 5000sm. It makes one or two routes with return per month. The rest of supplies and fuels are spent during waiting time to be chartered.**
It is supposed that the October of each year the vessel is out of order.
it is also assumed that the expenses and the income of the vessel are kept constant during the time. We suppose that the inflation is zero.

Table 124. **Payback Period Estimation Assumptions.**

Number of year	**2017**	Number of Routes	INCOME & EXPENCES [E/month] FUTURE VALUES			
			LSHFO	LSMGO	SUPPLIES & LO	M & R
1	January	**2**	364374.3946	360570.5732	26439.47345	24021.36127
1	February	**2**	364374.3946	360570.5732	26439.47345	24021.36127
1	March	**2**	364374.3946	360570.5732	26439.47345	24021.36127
1	April	**2**	364374.3946	360570.5732	26439.47345	24021.36127
1	May	**2**	364374.3946	360570.5732	26439.47345	24021.36127
1	June	**1**	364374.3946	360570.5732	26439.47345	24021.36127
1	July	**1**	364374.3946	360570.5732	26439.47345	24021.36127
1	August	**1**	364374.3946	360570.5732	26439.47345	24021.36127
1	September	**1**	364374.3946	360570.5732	26439.47345	24021.36127
1	October	**0**	0	0	0	24021.36127
1	November	**1**	364374.3946	360570.5732	26439.47345	24021.36127
1	December	**1**	364374.3946	360570.5732	26439.47345	24021.36127
1	TOTAL	16				

Table 125. **Operational Expenses – Normal Natural Gas – 5% rate 1/3.**

INCOME & EXPENCES [E/month] FUTURE VALUES			
INSURANCE	ADMINISTRATION	DOCKING	PORT EXPENCES
19346.62323	8805.142203	26488.79986	2604.133333
19346.62323	8805.142203	26488.79986	2604.133333
19346.62323	8805.142203	26488.79986	2604.133333
19346.62323	8805.142203	26488.79986	2604.133333
19346.62323	8805.142203	26488.79986	2604.133333
19346.62323	8805.142203	26488.79986	2604.133333
19346.62323	8805.142203	26488.79986	2604.133333
19346.62323	8805.142203	26488.79986	2604.133333
19346.62323	8805.142203	26488.79986	2604.133333
19346.62323	8805.142203	26488.79986	0
19346.62323	8805.142203	26488.79986	2604.133333
19346.62323	8805.142203	26488.79986	2604.133333

Table 126. **Operational Expenses – Normal Natural Gas – 5% rate 2/3.**

INCOME & EXPENCES [E/month] FUTURE VALUES				
CNG OUTCOME	CNG INCOME	TOTAL EXPENCES [E/month]	TOTAL INCOME [E/month]	INCOME DIFFERENCE [E/t]
747600	2610000	1580250.501	2610000	1029749.499
747600	2610000	1580250.501	2610000	1029749.499
747600	2610000	1580250.501	2610000	1029749.499
747600	2610000	1580250.501	2610000	1029749.499
747600	2610000	1580250.501	2610000	1029749.499
373800	1305000	1206450.501	1305000	98549.49879
373800	1305000	1206450.501	1305000	98549.49879
373800	1305000	1206450.501	1305000	98549.49879
373800	1305000	1206450.501	1305000	98549.49879
0	0	78661.92657	0	-78661.92657
373800	1305000	1206450.501	1305000	98549.49879
373800	1305000	1206450.501	1305000	98549.49879
		15218617.44	20880000	5661382.56
			NPV[E/y]	5391792.914
			TOTAL CNG [t/y]	24000

Table 127. **Operational Expenses – Normal Natural Gas – 5% rate 3/3.**

Doing the same process as it is presented in tables 125, 126 & 127 for the next 20 years, Table 128 is created.

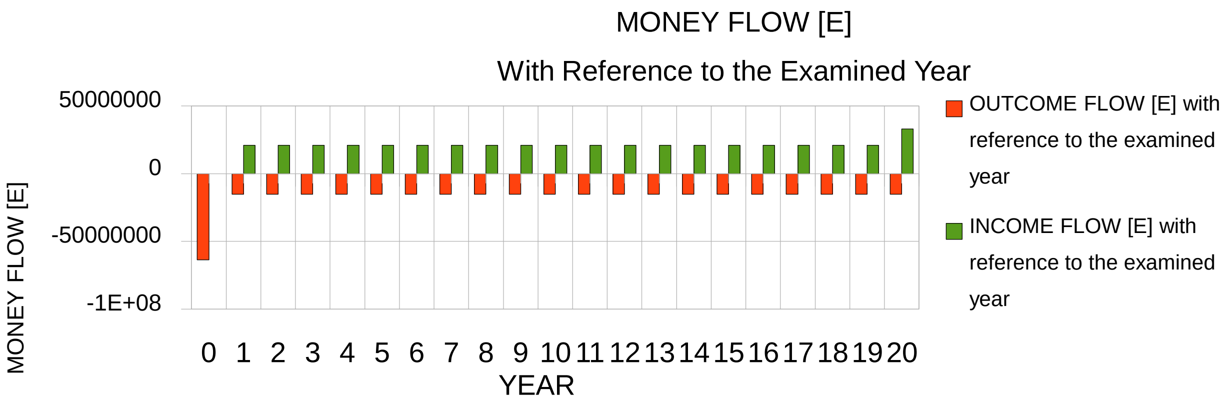


Figure 26. **Money Flow – Normal Natural Gas – 5%.**

YEAR	NET PRESENT VALUE [E] [REFERENCE YEAR 0]	MONEY FLOW [E] with reference to the examined year	OUTCOME FLOW [E] with reference to the examined year	INCOME FLOW [E] with reference to the examined year
0	-63573126.71	-63573126.71	-63573126.71	0
1	-58181333.79	5661382.56	-15218617.44	20880000
2	-53046292.92	5661382.56	-15218617.44	20880000
3	-48155777.81	5661382.56	-15218617.44	20880000
4	-43498144.36	5661382.56	-15218617.44	20880000
5	-39062302.99	5661382.56	-15218617.44	20880000
6	-34837692.16	5661382.56	-15218617.44	20880000
7	-30814253.27	5661382.56	-15218617.44	20880000
8	-26982406.71	5661382.56	-15218617.44	20880000
9	-23333029.03	5661382.56	-15218617.44	20880000
10	-19857431.24	5661382.56	-15218617.44	20880000
11	-16547338.11	5661382.56	-15218617.44	20880000
12	-13394868.47	5661382.56	-15218617.44	20880000
13	-10392516.42	5661382.56	-15218617.44	20880000
14	-7533133.519	5661382.56	-15218617.44	20880000
15	-4809911.709	5661382.56	-15218617.44	20880000
16	-2216367.128	5661382.56	-15218617.44	20880000
17	253675.3306	5661382.56	-15218617.44	20880000
18	2606096.719	5661382.56	-15218617.44	20880000
19	4846498.042	5661382.56	-15218617.44	20880000
20	11506010.89	17669670.17	-15218617.44	32888287.6

Table 128. **Money Flow – Normal Natural Gas – 5%.**

Doing the same process for the same reserves type but for interest 7%, figure 27 and table 129 are created.

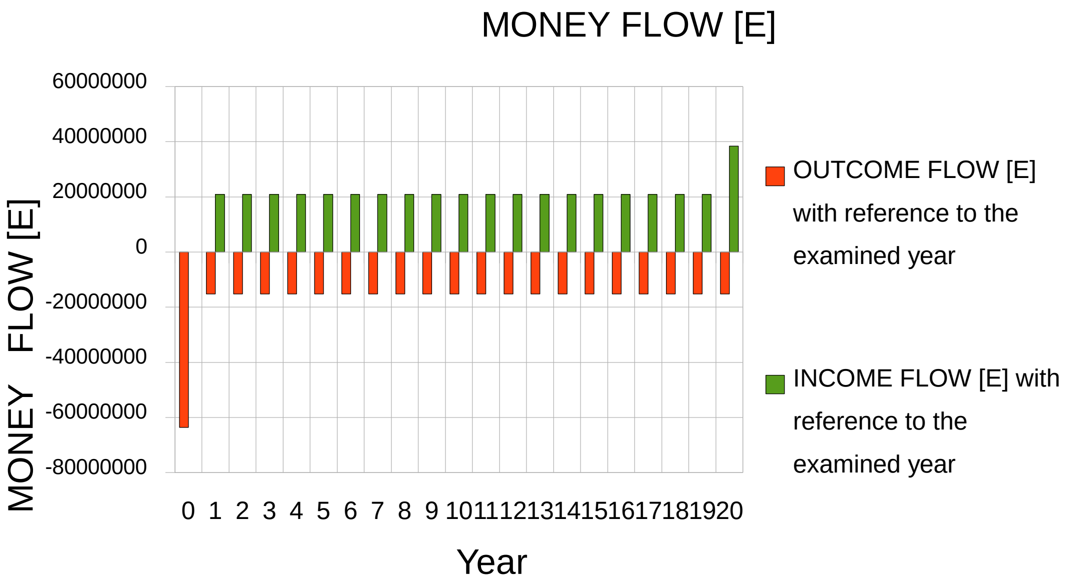


Figure 27. **Money Flow – Normal Natural Gas – 7%.**

YEAR	NET PRESENT VALUE [E] [REFERENCE YEAR 0]	MONEY FLOW [E] with reference year at the examined year	OUTCOME FLOW [E] with reference to the examined year	INCOME FLOW [E] with reference to the examined year
0	-63573126.71	-63573126.71	-63573126.71	0
1	-58282114.97	5661382.56	-15218617.44	20880000
2	-53337244.18	5661382.56	-15218617.44	20880000
3	-48715869.62	5661382.56	-15218617.44	20880000
4	-44396827.97	5661382.56	-15218617.44	20880000
5	-40360340.45	5661382.56	-15218617.44	20880000
6	-36587922.2	5661382.56	-15218617.44	20880000
7	-33062297.68	5661382.56	-15218617.44	20880000
8	-29767321.48	5661382.56	-15218617.44	20880000
9	-26687904.48	5661382.56	-15218617.44	20880000
10	-23809944.66	5661382.56	-15218617.44	20880000
11	-21120262.59	5661382.56	-15218617.44	20880000
12	-18606541.03	5661382.56	-15218617.44	20880000
13	-16257268.54	5661382.56	-15218617.44	20880000
14	-14061686.77	5661382.56	-15218617.44	20880000
15	-12009741.2	5661382.56	-15218617.44	20880000
16	-10092035.05	5661382.56	-15218617.44	20880000
17	-8299786.321	5661382.56	-15218617.44	20880000
18	-6624787.505	5661382.56	-15218617.44	20880000
19	-5059368.051	5661382.56	-15218617.44	20880000
20	929438.0907	23174790.07	-15218617.44	38393407.51

Table 129. **Money Flow – Normal Natural Gas – 7%.**

In the case of the natural gas reserves to be stranded, figures 28 & 29 and tables 130 & 131present the payback period analysis.

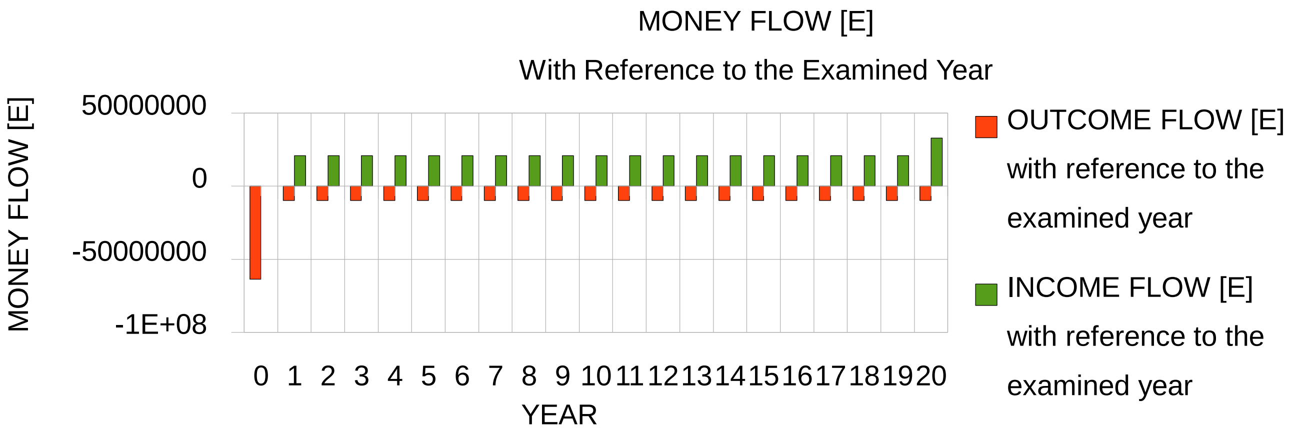


Figure 28. **Money Flow – Stranded Natural Gas – 5%.**

YEAR	NET PRESENT VALUE [E] [REFERENCE YEAR 0]	MONEY FLOW [E] with reference to the examined year	OUTCOME FLOW [E] with reference to the examined year	INCOME FLOW [E] with reference to the examined year
0	-63573126.71	-63573126.71	-63573126.71	0
1	-53056762.36	11042182.56	-9837817.44	20880000
2	-43041177.27	11042182.56	-9837817.44	20880000
3	-33502524.81	11042182.56	-9837817.44	20880000
4	-24418093.89	11042182.56	-9837817.44	20880000
5	-15766254.92	11042182.56	-9837817.44	20880000
6	-7526408.28	11042182.56	-9837817.44	20880000
7	321064.709	11042182.56	-9837817.44	20880000
8	7794848.508	11042182.56	-9837817.44	20880000
9	14912737.84	11042182.56	-9837817.44	20880000
10	21691680.06	11042182.56	-9837817.44	20880000
11	28147815.51	11042182.56	-9837817.44	20880000
12	34296515.94	11042182.56	-9837817.44	20880000
13	40152421.11	11042182.56	-9837817.44	20880000
14	45729473.65	11042182.56	-9837817.44	20880000
15	51040952.26	11042182.56	-9837817.44	20880000
16	56099503.32	11042182.56	-9837817.44	20880000
17	60917171	11042182.56	-9837817.44	20880000
18	65505425.93	11042182.56	-9837817.44	20880000
19	69875192.52	11042182.56	-9837817.44	20880000
20	78562672.3	23050470.17	-9837817.44	32888287.6

Table 130. **Money Flow – Stranded Natural Gas – 5%.**

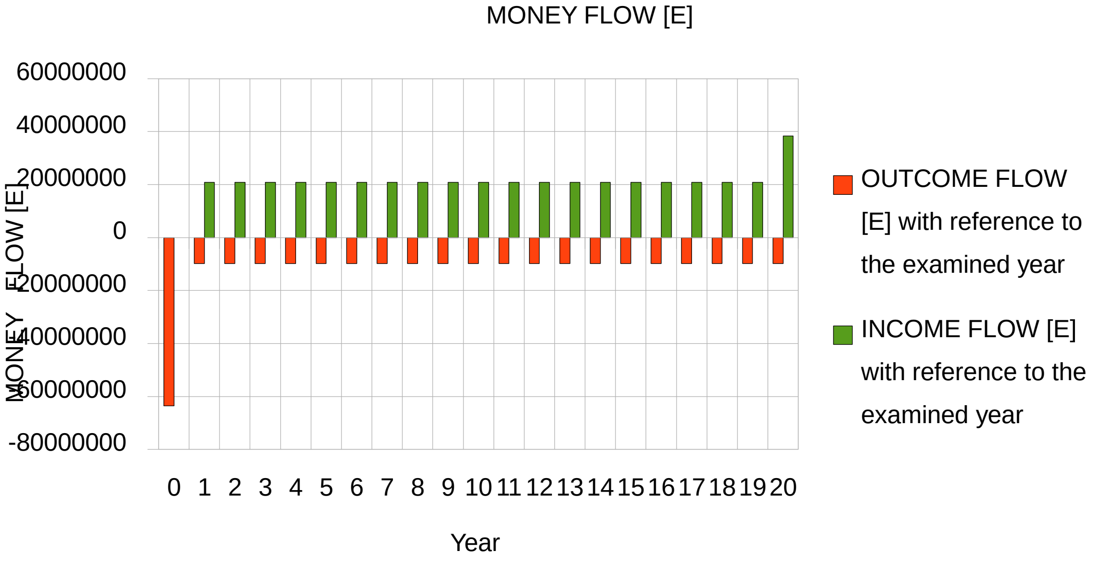


Figure 29. **Money Flow – Stranded Natural Gas – 7%.**

YEAR	NET PRESENT VALUE [E] [REFERENCE YEAR 0]	MONEY FLOW [E] with reference year at the examined year	OUTCOME FLOW [E] with reference to the examined year	INCOME FLOW [E] with reference to the examined year
0	-63573126.71	-63573126.71	-63573126.71	0
1	-53253329.92	11042182.56	-9837817.44	20880000
2	-43608660.03	11042182.56	-9837817.44	20880000
3	-34594949.85	11042182.56	-9837817.44	20880000
4	-26170921.64	11042182.56	-9837817.44	20880000
5	-18297998.09	11042182.56	-9837817.44	20880000
6	-10940125.6	11042182.56	-9837817.44	20880000
7	-4063609.264	11042182.56	-9837817.44	20880000
8	2363041.52	11042182.56	-9837817.44	20880000
9	8369257.20	11042182.56	-9837817.44	20880000
10	13982542.89	11042182.56	-9837817.44	20880000
11	19228604.29	11042182.56	-9837817.44	20880000
12	24131465.4	11042182.56	-9837817.44	20880000
13	28713578.59	11042182.56	-9837817.44	20880000
14	32995927.36	11042182.56	-9837817.44	20880000
15	36998122.48	11042182.56	-9837817.44	20880000
16	40738491.75	11042182.56	-9837817.44	20880000
17	44234163.96	11042182.56	-9837817.44	20880000
18	47501147.34	11042182.56	-9837817.44	20880000
19	50554402.83	11042182.56	-9837817.44	20880000
20	57933709.94	28555590.07	-9837817.44	38393407.51

Table 131. **Money Flow – Stranded Natural Gas – 7%.**

Figures 30 & 31 present the Net Present Value in comparison to the interest for Normal Natural Gas and Stranded Natural Gas respectively.

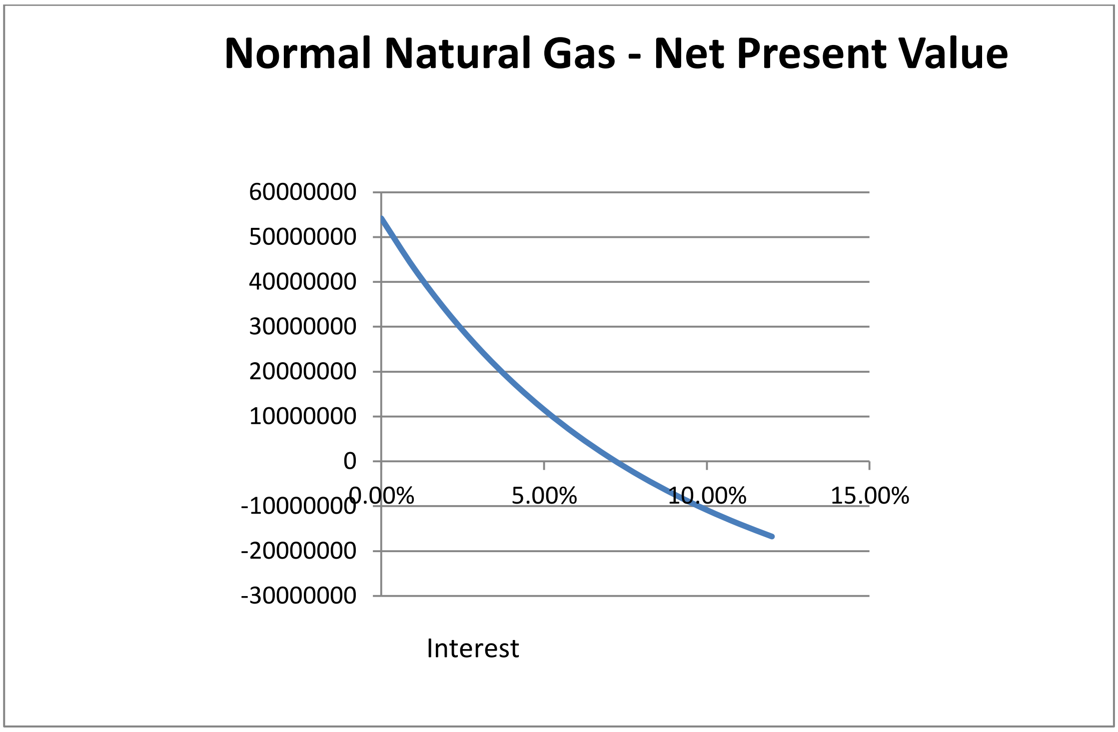


Figure 30. **Net Present Value for various Interests – Normal Natural Gas.**

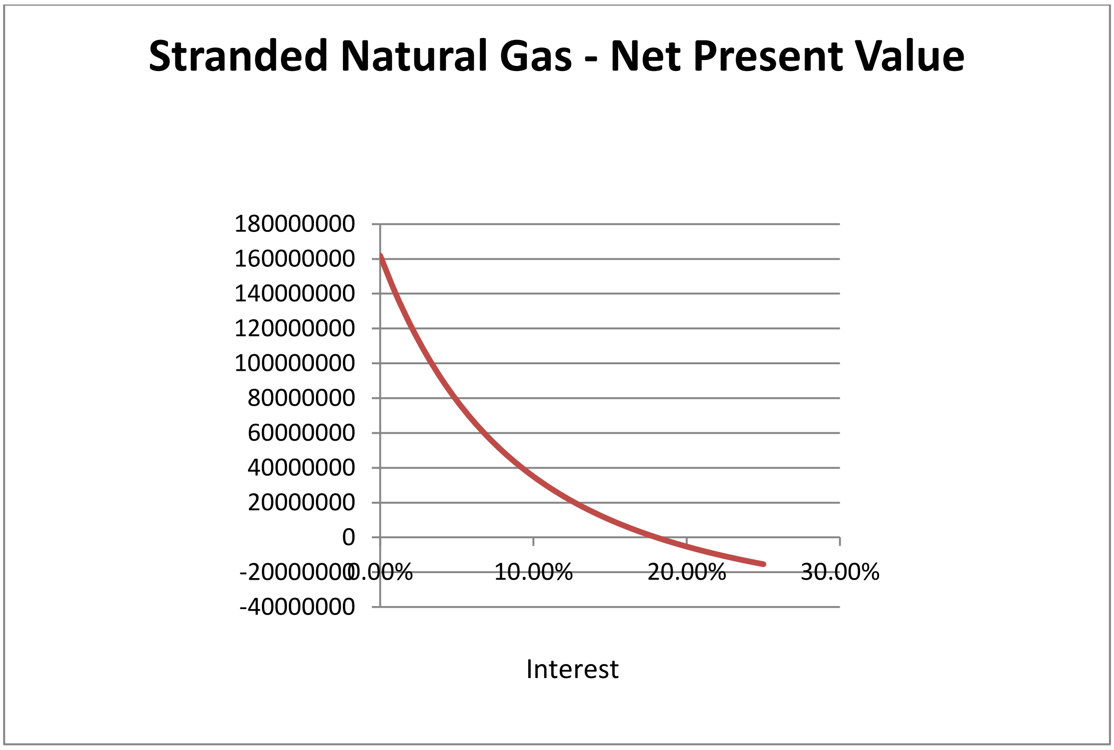


Figure 31. **Net Present Value for various Interests – Stranded Natural Gas.**

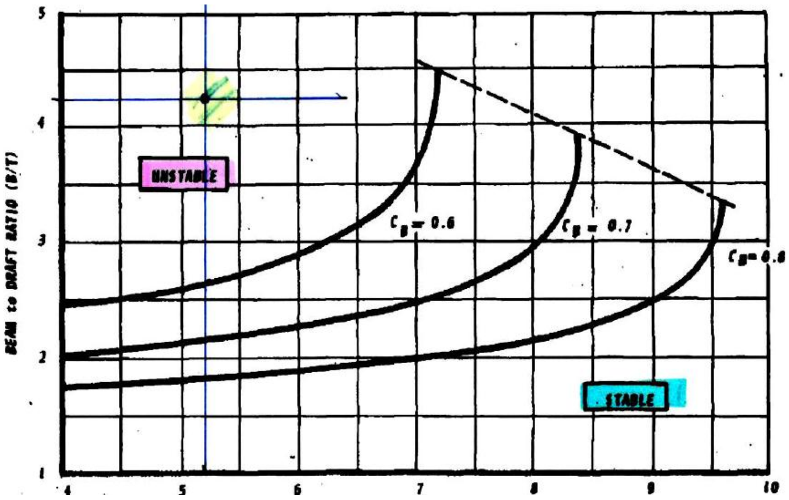
21. Conclusions & Comments

From the previous analysis, it is proved that the construction and the investment of a CNG – Carrier considering marine transportation can be achieved. It is underlined that in stranded gas occasion, the payback period is approximately 7.5 years. It is noted that during cargo discharge, the natural gas decompression can feed our system with electric power. The up to now design is slightly less efficient in comparison with the existing designs in accordance with tables 25 & 28. In detail, the achieved transportation efficiency is approximately 6.3% while in accordance with table 25, the paternal vessels for the same payload give transportation efficiency of 7.5%. So, in forthcoming stages, optimization must be applied. However, because of the fact that the analysis is at the first approximation (pre-estimation), some changes must be done.

The forecastle length must be bigger for a more convenient natural gas compressors arrangement. (Bigger ~20%).

In steel weight calculation, the slightly different Cb (0.77 and not 0.80) and bigger forecastle must be taken into consideration.

Due to small L/B and high B/T, bad route stability is achieved.



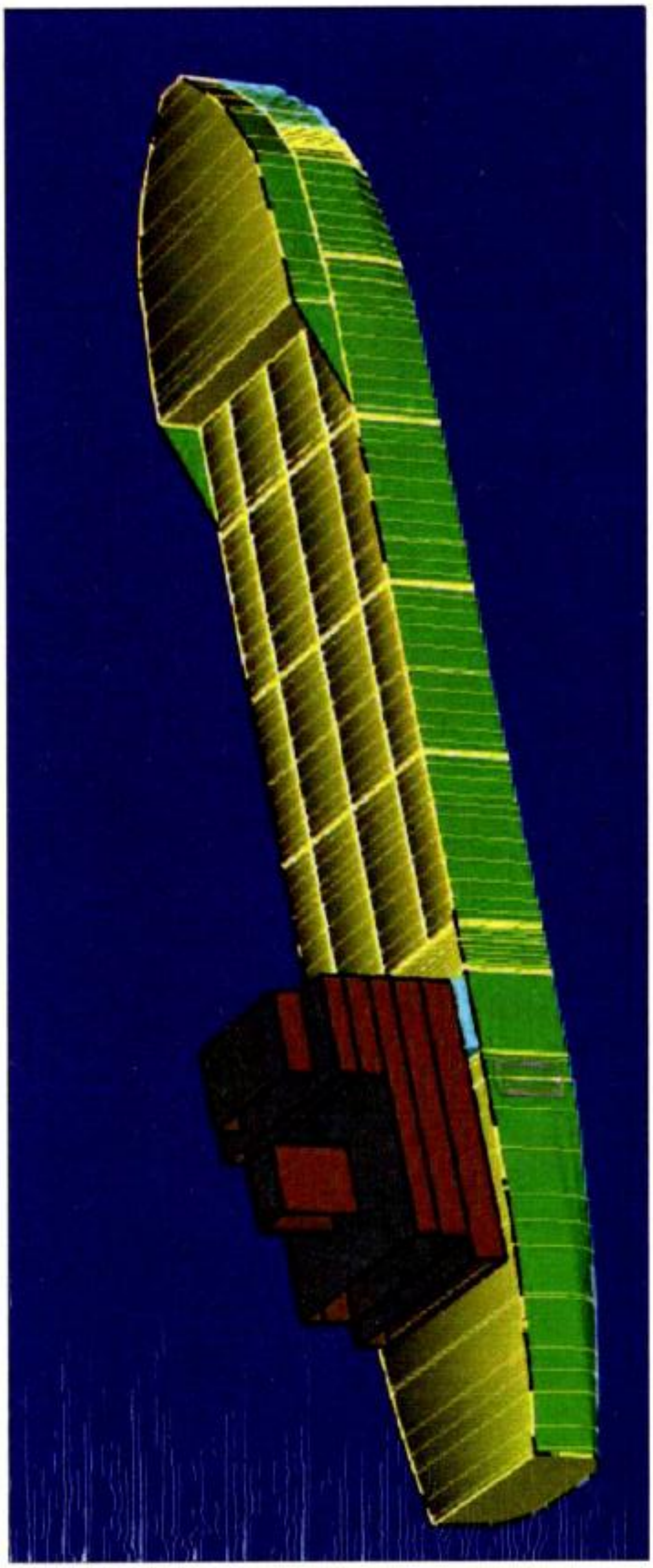
Picture 63. Vessels Instability. (ΚΩΝ/ΝΟΥ ΣΠΥΡΟΥ, 2010)

At the Displacement & Cost Equation, the weight of the two Selective Catalytic Reactors as well as the N.G. pipes (Weight & Cost) must be taken into consideration.

22. Prospects of Future Work

As far as the future prospects are concerned or in other words how the present research analysis can be continued, the following can be placed:

- **Optimization** in the design and in the calculations of basic technical characteristics (second design loop)
- **Coselle Ship Design and Calculation**. In this case a Coselle ship as it has been referred in the first pages of the same cargo capacity should be designed. Despite the lack of data, it remains (Coselle ship) a much cheaper solution. After this, a comparison between the present (steel pressure bottles) and the Coselle ship analysis should take place.
- In the present analysis (steel pressure bottles), should be added the following: First of all thanks to the high metacentric height at Full Load Departure (4.3m), **TEUs on the main deck** can be added. On the top of this, because of the fact that in any examined loading case there is no need for water ballast, most of the **double bottom spaces** can be filled with **fresh water** which is pretty important for the Aegean Sea Islands. It is noted that there is approximately 10 meters freeboard height.
- As it has been underlined earlier, the used **CNG pressure bottles** of **1.2m in diameter** will be **hypothetical** and in this paragraph it is underlined the **importance** of using the **highest diameter pressure bottles** as in this case the **pressure bottles accommodation** becomes **more efficient**. This happens because it is needed **smaller number of pressure bottles** thus **smaller number of 0.38m gaps between the pressure bottles**. So further research regarding **CNG pressure bottles** of **larger diameter** than the up to now existing (1.0m in diameter) **should take place**.



Picture 64. **Ship Model.** (Maxsurf), (Hydromax)

23. Bibliography

Bibliography

www.pacc.com.sg Access Date: 30 August 2017

www.rabaska.net/en/navigation Access Date: 8 October 2016

vriskoapostasi.gr Access Date: 30 August 2017

www.nationsonline.org/oneworld/maps.htm Access Date: 30 August 2017

www.energean.com

www.bunkerindex.com Access Date: 30 August 2017

ΥΔΡΟΔΥΝΑΜΙΚΗ ΠΛΟΙΟΥ (Αντίσταση - Πρόωση) ΣΤΟΙΧΕΙΑ ΓΙΑ ΥΠΟΛΟΓΙΣΜΟΥΣ. (1982). ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΤΜΗΜΑ ΝΑΥΠΗΓΩΝ-ΜΗΧΑΝΟΛΟΓΩΝ

How Safe are Natural Gas Vehicles? Technology Committee Bulletin 28 September 1999 *CLEAN VEHICLE EDUCATION FOUNDATION* www.westport.com Access Date: 30 August 2017

OFFICE of ENERGY EFFICIENCY and RENEWABLE ENERGY Clean Cities Fact Sheet Alternative Fuel Information Series May 2000 U . S . DEPARTMENT of ENERGY May 2000 *Natural Gas Buses: Separating Myth from Fact* www.nrel.gov Access Date: 30 August 2017

Ford Motor Company 2003 (2003) Access Date: 30 August 2017 www.fordservicecontent.com

Βασικές Αρχές Πρόωσης Πλοίων 2004 ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ, ΣΧΟΛΗ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ, ΕΡΓΑΣΤΗΡΙΟ ΝΑΥΤΙΚΗΣ ΜΗΧΑΝΟΛΟΓΙΑΣ

NIST 12 An abbreviated version of NIST REFPROP 2005 *NIST Standard Reference Database 12, Version 5.2 2005* www.nist.gov

The Coast Guard Journal of Safety at Sea PROCEEDINGS of the Marine Safety & Security Council Liquefied Natural Gas Fall 2005 Ensuring its safe and secure marine transportation 2005 *U.S Department of Homeland Security United States Coast Guard* www.uscg.mil hsdl.org

Gas Carriers - Pressure on to be first in CNG race 2 November 2006 Access Date: 28 September 2016 fairplay.ihs.com

GUIDANCE NOTES ON SHIP VIBRATION ABS APRIL 2006 *American Bureau of Shipping* ww2.eagle.org Access Date: 30 August 2017

HAZARDOUS MATERIALS TRANSPORTATION Compliance Basics Series Cylinders what you need to know 11 SEPTEMBER 2006 Retrieved from GUIDE TO HM-220E FINAL RULE EFFECTIVE: http://hazmat.dot.gov , www.phmsa.dot.gov

World's First CNG Carrier Ship Approved for Construction 19 September 2006 Access Date: 28 September 2016 www.greencarcongress.com

Biopact - Towards a green energy pact between Europe and Africa 5 September 2007 *A quick look at CNG ships* global.mongabay.com/news

American Bureau of Shipping (ABS) (2008) *RULES FOR BUILDING AND CLASSING STEEL VESSELS PART 4 VESSEL SYSTEMS AND MACHINERY* www.eagle.org

MARPOL Consolidated Edition 2011 Retrieved from International Maritime Organization 2011: www.imo.org idgca.org Access Date: 8 September 2017

RULES FOR CLASSIFICATION OF Ships PART 5 CHAPTER 15 DNV DET NORSKE VERITAS AS JULY 2011 *SPECIAL SERVICE AND TYPE – ADDITIONAL CLASS Compressed Natural Gas Carriers* rules.dnvgl.com Access Date: 30 August 2017

Advanced Storage Technologies for Hydrogen and Natural Gas Topic Paper #24 1 August 2012 *Working Document of the NPC Future Transportation Fuels Study Made Available August 1, 2012* www.npc.org Access Date: 30 August 2017

Sea NG - COMPRESSED NATURAL GAS Half the density, half the cost, twice the value 28 February 2012 *Floating CNG - A less expensive way to monetize offshore gas Eastern Mediterranean and North Africa Forum*. Rome: www.sea-ng.com www.hebrewenergy.com

Sea NG COMPRESSED NATURAL GAS Floating CNG A less expensive way to monetize offshore gas 24-26 September 2012 *European Mediterranean Oil & Gas E&P Summit Regional gas transportation Larnaca Cyprus, 24-26 September 2012* www.euromedoffshore.com www.coselle.com Access Date: 30 August 2017

ΕΠΙΧΕΙΡΗΣΙΑΚΟ ΠΡΟΓΡΑΜΜΑ ΠΕΡΙΦΕΡΕΙΑΣ ΝΟΤΙΟΥ ΑΙΓΑΙΟΥ ΠΕΡΙΦΕΡΕΙΑ ΝΟΤΙΟΥ ΑΙΓΑΙΟΥ ΙΟΥΝΙΟΣ 2012 ΣΤΡΑΤΗΓΙΚΟΣ ΣΧΕΔΙΑΣΜΟΣ ΑΝΑΘΕΩΡΗΜΕΝΟ ΤΕΥΧΟΣ VI (Κεφάλαιο 11Α) ΑΘΗΝΑ ΠΑΝΤΕΙΟ ΠΑΝΕΠΙΣΤΗΜΙΟ ΚΟΙΝΩΝΙΚΩΝ ΚΑΙ ΠΟΛΙΤΙΚΩΝ ΕΠΙΣΤΗΜΩΝ ΙΝΣΤΙΤΟΥΤΟ ΠΕΡΙΦΕΡΕΙΑΚΗΣ ΑΝΑΠΤΥΞΗΣ: www.nad.gr Access Date: 30 August 2017

CNG and LNG: What's Best for Your Fleet, Powering transportation A Westport and Clean Energy Webinar, Westport 2013 www.westport.com Access Date: 30 August 2017

NIPSCO Energy Symposium October SOUTH SHORE CLEAN CIITES TRANSPORTATION Opportunities with Compressed Natural Gas (CNG) in Northern Indiana! 9 October 2013 *U.S DEPARTMENT OF ENERGY Energy Efficiency & Renewable Energy* www.nipsco.com Access Date: 30 August 2017

ΔΕΛΤΙΟ ΤΥΠΟΥ - ΕΡΕΥΝΑ ΚΑΤΑΝΑΛΩΣΗΣ ΕΝΕΡΓΕΙΑΣ ΣΤΑ ΝΟΙΚΟΚΥΡΙΑ 2011-2012 29 Οκτώβριου 2013 ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ - ΕΛΛΗΝΙΚΗ ΣΤΑΤΙΣΤΙΚΗ ΑΡΧΗ - ΠΕΙΡΑΙΑΣ: www.statistics.gr

Alternative Fuel Tool Kit How to Implement: Compressed Natural Gas (June 2014) nccleantech.ncsu.edu Access Date: 30 August 2017

Costs Associated With Compressed Natural Gas Vehicle Fueling Infrastructure U.S DEPARTMENT OF ENERGY Energy Efficiency & Renewable Energy Clean Cities September 2014 www.afdc.energy.gov Access Date: 30 August 2017

Gas Carriers: Arrangements & Characteristics July 2014 Access Date: 8 October 2016 Rich Delpizzo ABS: www.marinechemist.org www.eagle.com https://yellowdragonblogdotcom.files.wordpress.com

LNG AS SHIP FUEL THE FUTURE – TODAY (2014) *DNV GL No 01 2014* www.dnvgl.com Access Date: 30 August 2017

Natural Gas Vehicles – The Here and Now Technology: A Workshop for New England Sponsored By: Clean Cities Coalitions of Northern New England Clean Cities 20 November 2014 *U.S. Department of Energy* web.uri.edu Access Date: 30 August 2017

VIAVISION VOLKSWAGEN SHAPING THE FUTURE OF MOBILITY September 2014 *SUSTAINABLE MOBILITY WITH NATURAL GAS The CO2-friendly Alternative* www.viavision.org.uk Access Date: 30 August 2017

Αεροπορική... «επιδρομή»! 18 Αυγούστου 2014 www.koinignomi.gr Access Date: 30 August 2017

Argus Marine Fuels Issue 15-167 Tuesday 25 August 2015 www.argusmedia.com

Natural gas prices fall across the world November 2015 *Atradius Economic Research* group.atradius.com

SETE - INTELLIGENCE - Στατιστικό Δελτίο No. 8. Αύγουστος 2015 Retrieved from Ινστιτούτο ΣΕΤΕ Λεωφ. Αμαλίας 34 105 58 Αθήνα: hotelmag.gr www.insete.gr Access Date: 30 August 2017

Wärtsilä to Power World's First CNG Vessel 9 February 2015 Access Date: 30 August 2017 shipandbunker.com

CIMC TODAY Total No. 213. (March 2016) www.cimc.com

IGU - INTERNATIONAL GAS UNION UNION INTERNATIONALE DU GAZ WHOLESALE GAS PRICE SURVEY - 2016 EDITION MAY 2016 *A GLOBAL REVIEW OF PRICE FORMATION MECHANISMS 2005 TO 2015* www.igu.org Access Date: 30 August 2017

IMO Train the Trainer (TTT) Course on Energy Efficient Ship Operation January 2016 Module 2 – Ship Energy Efficiency Regulations and Related Guidelines International Maritime Organization: www.imo.org Access Date: 30 August 2017

WHOLESALE GAS PRICE SURVEY 2016 EDITION INTERNATIONAL GAS UNION UNION INTERNATIONALE DU GAZ MAY 2016 *A GLOBAL REVIEW OF PRICE FORMATION MECHANISMS 2005 TO 2015* www.malaysiangas.com www.igu.org Access Date: 30 August 2017

ΜΕΛΕΤΗ & ΣΧΕΔΙΑΣΗ ΠΛΟΙΩΝ ΕΙΔΙΚΟΥ ΤΥΠΟΥ Σημειώσεις Μαθήματος (2016-2017) *ΠΡΟΓΡΑΜΜΑ ΜΕΤΑΠΤΥΧΙΑΚΩΝ ΣΠΟΥΔΩΝ: "ΝΑΥΤΙΚΗ ΚΑΙ ΘΑΛΑΣΣΙΑ ΤΕΧΝΟΛΟΓΙΑ ΚΑΙ ΕΠΙΣΤΗΜΗ"* ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΣΧΟΛΗ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ

www.google.com Access Date: 30 August 2017

AUTOCAD www.autodesk.eu Access Date: 30 August 2017

Heavy Duty Transit Vehicles - Compressed Natural Gas *NEW FLYER* www.gowithnaturalgas.ca Access Date: 30 August 2017

MathType Access Date: 30 August 2017 www.dessci.com

MATLAB Access Date: 30 August 2017 in.mathworks.com

Microsoft Office Access Date: 30 August 2017 www.microsoft.com

OpenOffice Access Date: 30 August 2017 www.openoffice.org

Rhinoceros *Robert McNeel & Associates* www.rhino3d.com Access Date: 30 August 2017

THE AMERICAN OIL & GAS REPORTER Friday 23 June 2017 www.aogr.com Access Date: 30 August 2017

WinRAR Access Date: 30 August 2017 www.rarlab.com

World Bank Commodities Price Forecast (nominal US dollars) 24 January 2017 pubdocs.worldbank.org Access Date: 30 August 2017

4000kW generator www.alibaba.com

Course stability of a ship towing system in wind Ocean Engineering 64(2013)135–145. *A. Fitriadhy, H.Yasukawa, K.K.Koh*. citeseerx.ist.psu.edu www.sciencedirect.com www.elsevier.com/locate/oceaneng Access Date: 30 August 2017

ADOBE ACROBAT READER www.adobe.com Access Date: 30 August 2017

ANNEX 1, RESOLUTION MSC.194(80) (adopted on 20 May 2005) MSC 80/24/Add.1. *ADOPTION OF AMENDMENTS TO THE INTERNATIONAL CONVENTION FOR THE SAFETY OF LIFE AT SEA, 1974, AS AMENDED International Maritime Organization* www.imo.org Access Date: 30 August 2017

ANNEX 2 RESOLUTION MSC.267(85) (adopted on 4 December 2008) MSC 85/26/Add.1. *ADOPTION OF THE INTERNATIONAL CODE ON INTACT STABILITY, 2008 (2008 IS CODE) International Maritime Organization* www.imo.org

ABS GUIDE FOR VESSELS INTENDED TO CARRY COMPRESSED NATURAL GASES IN BULK (APRIL 2005 (Updated February 2014)) *American Bureau of Shipping ABS* preview.eagle.org Access Date: 30 August 2017

RAILROAD COMMISSION OF TEXAS REGULATIONS FOR COMPRESSED NATURAL GAS AND LIQUEFIED NATURAL GAS January 2013 *BARRY T. SMITHERMAN, DAVID PORTER, CHRISTI CRADDICK* www.rrc.state.tx.us Access Date: 30 August 2017

Natural Gas for Cars and Trucks: Options and Challenges Bill Canis, Robert Pirog, Brent D. Yacobucci *Congressional Research Service 7-5700* 19 November 2014 www.crs.gov R43791 fas.org Access Date: 30 August 2017

Compressed Natural Gas (CNG) Shipping in Indonesia: Opportunities ahead 17 September 2015 *Bima Putrajaya President Director of PT Pelayaran Bahtera Adhiguna 2nd Small LNG Shipping Conference* Bali: www.lng-world.com Access Date: 30 August 2017

Biogas booster compressor/natural gas cylinder filling compressor www.alibaba.com Access Date: 30 August 2017

TGE - Marine Gas Engineering *New generation of modern LNG carriers with type C cargo tanks and LNG propulsion system Björn Munko* www.tge-marine.com

Probabilistic damage stability verification on Passenger Yacht Code motor yacht EMship UNIVERSITA DEGLI STUDI DI GENOVA *Presente // Blanka Ascic, Mentor // prof. Dario Boote, Tutor // Emanuele Camporese* La Spezia: 10 February 2015 m120.emship.eu Access Date: 30 August 2017

Marine Transportation of LNG *Intertanko Conference Bob Curt Ship Acquisition Manager, QatargasII, Development* 29 March 2004 www.marad.dot.gov Access Date: 30 August 2017

Bulk Carriers International Shipholding Corp Vessel: Bulk Americas: www.yumpu.com Access Date: 30 August 2017

Transitions in Natural Gas Systems, including Transportation FAPESP-NERC Workshop on Sustainable Gas Future 25 February 2015 Faculty of Mechanical Eng. & Center for Petroleum Studies (FEM & Cepetro) University of Campinas -UNICAMP- FAPESP-NERC Workshop on Sustainable Gas Future: www.fapesp.br Access Date: 30 August 2017

CNG Europe cngeurope.com Access Date: 30 August 2017

CNG Fuel System Inspector - Study Guide Sponsored by: *National Energy Technology Laboratory U.S. Department of Energy DE-FC26-05NT42608 Contract Manager: Clean Vehicle Education Foundation Point of Contact: Doug Horne* www.afdc.energy.gov Access Date: 30 August 2017

CNG pressure vessels 28 September 2016 www.xperion-energy.de/home.html

cng tank container alibaba.com

CNG tanks: Pressure vessel epicenter www.compositesworld.com

Common Structural Rules for Bulk Carriers Status and Guidance ABS ww2.eagle.org , www.axelzone.ro Access Date: 30 August 2017

COMPOSITE CYLINDERS LARGE DIAMETER CATALINA COMPOSITES Company Brochure DIVISION OF CATALINA CYLINDERS INC.: catalinacomposites.com , www.catalinacylinders.com Access Date: 30 August 2017

COMPOSITE PRESSURE VESSELS STRUCTURAL Pentair Water COMPOSITE VS. STEEL www.pentairwatertreatment.com , www.salamenterprisesllc.com Access Date: 30 August 2017

Compressed natural gas en.wikipedia.org Access Date: 30 August 2017

Compressed natural gas carrier opens options for remote, marginal fields *Offshore* www.offshore-mag.com/

Compressed Natural Gas: A New Environmental Risk? XL Group Insurance Environmental xlcatlin.com Access Date: 30 August 2017

Containers and pressure vessels for CNG, biogas or hydrogen storage and transport www.uac.no Access Date: 30 August 2017

Coselle TM CNG Ships www.coselle.com Access Date: 30 August 2017

CROFT PRODUCTION SYSTEMS www.croftsystems.net Access Date: 30 August 2017

Current Natural Gas Vehicle Statistics www.iangv.org Access Date: 30 August 2017

Cylinders for high pressure gases *Tenaris* www.tenaris.com Access Date: 30 August 2017

CYLINDERS FOR USE WITH SCOTT SAFETY SELF-CONTAINED BREATHING APPARATUS SCOTT SAFETY: www.scottsafety.com Access Date: 30 August 2017

D.G.M. Watson *PRACTICAL SHIP DESIGN VOLUME 1.* ELSEVIER OCEAN ENGINEERING BOOK SERIES

COSELLE CNG: Economics and Opportunities *A New Way to Ship Natural Gas By Sea David G. Stenning Cran & Stenning Technology Inc. Calgary, AB, Canada, 403263-6397 GASTECH 2000 Houston Texas, USA* November 2000 www.ivt.ntnu.no Access Date: 30 August 2017

THE COSELLE CNG CARRIER THE SHIPMENT OF NATURAL GAS BY SEA IN COMPRESSED FORM *David Stenning, P.Eng. & James A. Cran, MSc Principals, Cran & Stenning Technology Inc.* Calgary, Alberta, Canada: http://www.onepetro.org

A simpler way ? David Stenning, John Fitzpatrick and Dr. Mark Trebble, Sea NG Corp. Canada *describe the benefits of floating compressed natural gas RE-PRINTED FROM LNG INDUSTRY* Autumn 2011 www.coselle.com Access Date: 30 August 2017

DIAMOND 53 - HANDYMAX BULK CARRIER Stability Information Manual (Including longitudinal strength) *DIAMOND 53 – HANDYMAX BULK CARRIER M/S SPAR SCORPIO Chengxi Shipyard Newbuilding No. 4210* www.nautinst.org Access Date: 30 August 2017

STRALIS CNG (COMPRESSED NATURAL GAS) (EDITION 2010) *SUPPLEMENT TO BODYBUILDER INSTRUCTIONS HEAVY RANGE IVECO* ibb.iveco.com Access Date: 30 August 2017

EEDI Energy Efficiency Design Index *MAN Diesel & Turbo* www.marine.man.eu Access Date: 30 August 2017

Role of Stranded Gas in Increasing Global Gas Supplies Emil D. Attanasi, Philip A. Freeman *Open-File Report 2013–1044 U.S. U.S. Department of the Interior U.S. Geological Survey* pubs.usgs.gov Access Date: 30 August 2017

Role of Stranded Gas in Increasing Global Gas Supplies USGS By Emil D. Attanasi and Philip A. Freeman *U.S. Department of the Interior U.S. Geological Survey Open-File Report 2013–1044* pubs.usgs.gov Access Date: 30 August 2017

Energy Efficiency & Renewable Energy U.S DEPARTMENT OF ENERGY Natural Gas Basics www.afdc.energy.gov Access Date: 30 August 2017

Erik Sonne Ravn Probabilistic Damage Stability of Ro-Ro Ships DTU - Technical University of Denmark *Department of Mechanical Engineering Erik Sonne Ravn PhD thesis* February 2003 orbit.dtu.dk Access Date: 30 August 2017

European Commission Corporate Communication April 2012 *The use of the EU emblem in the context of EU programmes Guidelines for beneficiaries and other third parties* eacea.ec.europa.eu Access Date: 4 September 2017

VECTOR MECHANICS for ENGINEERS in SI Units Dynamics Ferdinand P. Beer, E. Russell Johnston Jr., William E. Clausen Seventh Edition In SI Units

Fiat Panda www.fiat.gr

FOSSIL ENERGY STUDY GUIDE: NATURAL GAS energy.gov www.fe.doe.gov Access Date: 30 August 2017

SEAKEEPING PREDICTION PROGRAM SPP-86 OCTOBER 1994 G. J. Grigoropoulos Dr Naval Architect, T. A. Loukakis Director LSMH ATHENS: NATIONAL TECHNICAL UNIVERSITY OF ATHENS DEPARTMENT OF NAVAL ARCHITECTURE AND MARINE ENG. LABORATORY FOR SHIP AND MARINE HYDRODYNAMICS HEROON POLYTECHNIOU 9, 157 73 ZOGRAFOS, TEL. 772 1060, 772 1036, FAX 772 1032

Divry's New ENGLISH-GREEK and GREEK-ENGLISH HANDY DICTIONARY REVISED EDITION Edited by G.C. DIVRY and C.G. DIVRY. NEW YORK 293 SEVENTH AVENUE: D.C.DIVRY, INC., Publishers.

gr.distance24.org

Ship Design for Efficiency and Economy Second edition H. Schneekluth and V. Bertram 1998 BUTTERWORTH - HEINEMANN.

RATIONALIZING THE PRACTICE OF PROBABILISTIC DAMAGE STABILITY CALCULATIONS 2003 Herbert J. Koelman, Jakob Pinkster *Int. Shipbuild. Progr., 50, no. 3 (2003) pp. 239-253* content.iospress.com Access Date: 30 August 2017

High Pressure Natural Gas Compressors BAUER COMPRESSORS Putting You on the Road to a Clean Future 5 –125 HP 5000 PSIG 5 –161 SCFM: www.skcryogenics.com Access Date: 30 August 2017

HiPer-tex™ fibre: the lightweight, low cost, high pressure cylinder solution 3B fibreglass company: www.3B-fibreglass.com Access Date: 30 August 2017

http://www.kline.co.jp

Wolfram Mathematica https://www.wolfram.com

Hydromax maxsurf.net

Hydromax Windows User Manual wk.baidu.com Access Date: 30 August 2017

Honda' experience and perspective on CNG powered Vehicles 13 December 2012 Ichiro Sakai *American Honda Motor MSTRS meeting* www.epa.gov Access Date: 30 August 2017

Implementing Energy Efficiency Design Index (EEDI) *IRCLASS Indian Register of Shipping* www.irclass.org Access Date: 30 August 2017

International Gas Union (IGU) UNION INTERNATIONALE DU GAZ Natural Gas Conversion Guide *News, views and knowledge on gas - worldwide* www.igu.org agnatural.pt Access Date: 30 August 2017

INTERNATIONAL MARITIME ORGANIZATION (IMO) *EXPLANATORY NOTES TO THE INTERNATIONAL CODE ON INTACT STABILITY 2008 Ref. T1/2.03 MSC.1/Circ.1281 9 December 2008* imo.udhb.gov.tr Access Date: 30 August 2017

INTERNATIONAL MARITIME ORGANIZATION (IMO) DEVELOPMENT OF EXPLANATORY NOTES FOR HARMONIZED SOLAS CHAPTER II-1. *PASSENGER SHIP SAFETY HARMONIZATION OF DAMAGE STABILITY PROVISIONS IN OTHER IMO INSTRUMENTS REVISION OF RESOLUTION A.266(VIII) REVISION OF MSC/CIRC.650 Report of the SDS Working Group SUB-COMMITTEE ON STABILITY AND LOAD LINES AND ON FISHING VESSELS SAFETY* www.imo.org www.mpa.gov.sg

Israel and Cyprus: In search of solutions to natural gas challenges in the Eastern Mediterranean www.greeknewsonline.com Access Date: 30 August 2017

AN APPROXIMATE POWER PREDICTION METHOD *J. Holtrop and G.G.J. Mennen* Netherlands Ship Model Basin, (Marin), Wageningen, The Netherlands

INTRODUCTION IN SHIP HYDROMECHANICS Lecture MT519 Draft Edition April 2002 *J.M.J. Journée and Jakob Pinkster Delft University of Technology* www.shipmotions.nl Access Date: 30 August 2017

Design Challenges for Development of Compressed Natural Gas Carriers ResearchGate May 2009 *James M. G. Weiss Newton Reis de Moura*. https://www.researchgate.net/publication/279515738 Access Date: 30 August 2017

WÄRTSILÄ ENCYCLOPEDIA OF SHIP TECHNOLOGY BY JAN BABICZ *Second Edition 2015* maredu.gunet.gr www.wartsila.com Access Date: 30 August 2017

Wärtsilä waterjets offer powerful and versatile propulsion solutions *WÄRTSILÄ TECHNICAL JOURNAL 02.2011 Jeroen de Cock, Teus van Beek, Leendert Muilwijk, Rob Verbeek, Joeri Poelmann* cdn.wartsila.com Access Date: 30 August 2017

Marine Waterjet Propulsion SNAME Transactions, Vol. 101, 1993, pp. 275-335 John Allison, Member, Band, Lavis, Severna Park, Maryland www.sname.org Access Date: 30 August 2017

Probabilistic versus Deterministic Damage Stability *Jonathan Strachan Burness Corlett Three Quays BCTQ The Maritime Consultants* www.bctq.com Access Date: 30 August 2017

ΜΕΛΕΤΗ ΚΑΙ ΣΧΕΔΙΑΣΗ ΑΛΙΕΥΤΙΚΟΥ ΣΚΑΦΟΥΣ Οκτώβριος 2014 *dspace.lib.ntua.gr Kasem.F.Osman, Επιβλέπων Καθηγητής: Γ. ΖΑΡΑΦΩΝΙΤΗΣ.* Αθήνα: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ, ΣΧΟΛΗ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ, ΔΙΕΠΙΣΤΗΜΟΝΙΚΟ - ΔΙΑΠΑΝΕΠΙΣΤΗΜΙΑΚΟ ΠΡΟΓΡΑΜΜΑ ΜΕΤΑΠΤΥΧΙΑΚΩΝ ΣΠΟΥΔΩΝ «ΝΑΥΤΙΚΗ ΚΑΙ ΘΑΛΑΣΣΙΑ ΤΕΧΝΟΛΟΓΙΑ ΚΑΙ ΕΠΙΣΤΗΜΗ» Μεταπτυχιακή Εργασία Access Date: 30 August 2017.

HYDROSTATICAL PROPERTIES CALCULATION PROGRAM LABORATORY FOR SHIP AND MARINE HYDRODYNAMICS NTUA NATIONAL TECHNICAL UNIVERSITY OF ATHENS DEPARTMENT OF NAVAL ARCHITECTURE AND MARINE ENG. LABORATORY FOR SHIP AND MARINE HYDRODYNAMICS HEROON POLYTECHNIOU 9, 157 73 ZOGRAFOS, TEL. 772 1060, 772 1036, FAX 772 1032

Liquefied natural gas en.wikipedia.org Access Date: 30 August 2017

Liquefied Natural Gas: Understanding the Basic Facts *DEPARTMENT OF ENERGY, UNITED STATES OF AMERICA* energy.gov Access Date: 30 August 2017

LNG / CNG GAS INNOVATIONS High Purity Hydrocarbons www.gasinnovations.com Access Date: 30 August 2017

LNG carrier www.wikipedia.org Access Date: 30 August 2017

Low Sulphur Fuel 380 Piraeus 9 June 2017 www.shipandbunker.com

Low Sulphur Marine Gas Oil Piraeus 9 June 2017 www.shipandbunker.com

LPG and Natural Gas as Alternative Energy Sources for the Pacific www.theprif.org

MAN 51/60DF *Project Guide – Marine Four-stroke dual fuel engines compliant with IMO Tier II / IMO Tier III MAN Diesel & Turbo* marine.man.eu

MAN L35/44DF *Project Guide – Marine Four-stroke dual fuel engines compliant with IMO Tier II MAN Diesel & Turbo* marine.man.eu

Monetization options for Africa's conventional, stranded and flared natural gas resources Manfred Boeckmann 8-9 April 2013 *7th German-Africa Energy Forum 2013 RWE The energy to lead* Hamburg: www.energyafrica.de Access Date: 30 August 2017

Map of Mediterranean Sea www.worldatlas.com Access Date: 30 August 2017

Marine CNG Trade: The Time has Come www.coselle.com Access Date: 30 August 2017

Marine Engine IMO Tier II and Tier III *Programme 2017 MAN Diesel & Turbo Second Edition* www.marine.man.eu Access Date: 30 August 2017

Marine Engine IMO Tier II Programme 2014 MAN Diesel & Turbo

Marine Engine IMO Tier ll and Tier lll Programme MAN Diesel & Turbo 2016 *Programme 2nd edition 2016 MAN Diesel & Turbo* marine.man.eu

Maxsurf - Integrated Naval Architecture & Ship Construction Software maxsurf.net

Maxsurf Windows Version User Manual www.scribd.com Access Date: 30 August 2017

MB50's "LIQUID MUD" RANT *Experts Agree: U.S. Can Move Forward with Exporting LNG* mb50.wordpress.com/tag/flng/ Access Date: 30 August 2017

MANEUVERING AND CONTROL OF MARINE VEHICLES *Michael S. Triantafyllou, Franz S. Hover, Department of Ocean Engineering Massachusetts Institute of Technology Cambridge, Cambridge, Massachusetts USA* https://ocw.mit.edu Access Date: 30 August 2017

Advanced Language Practice English Grammar and Vocabulary *Michael Vince with Peter Sunderland* Macmillan

Microsoft Windows 7 www.microsoft.com

Refuel Colorado Fleets GARFIELD CLEAN ENERGY *Mike Ogburn Energy Engineer Heather McGregor Technical Writer Compressed Natural Gas:Benefits for Vehicle Fleets* www.CleanEnergyEconomy.net www.garfield-county.com Access Date: 30 August 2017

Module 2: Ship Energy Efficiency Regulations and Related Guidelines IMO INTERNATIONAL MARITIME ORGANIZATION Train the Trainer Course Energy Efficient Ship Operation: www.imo.org Access Date: 30 August 2017

National Natural Gas Market Overview: World LNG Landed Prices *World LNG Estimated Landed Prices: Apr-17 Federal Energy Regulatory Commission • Market Oversight* www.ferc.gov Access Date: 30 August 2017

Natural Gas Field Development and Environmental Issues Indonesia *Research and Development Centre for Oil and Gas Technology "LEMIGAS" Ministry of Energy and Mineral Resources Republic of Indonesia* www.ccop.or.th/ Access Date: 30 August 2017

Natural Gas Vehicles for America FACT SHEET NGVAMERICA *A Comparison of Compressed Natural Gas and Propane* ngvamerica.org Access Date: 30 August 2017

New marine propulsion concept with booster motor MARINE PROPULSION ABB Review 3/1997 https://library.e.abb.com

Newcomer aims to create Russian CNG-carrier fleet intari.com Access Date: 30 August 2017

Oil & Gas Financial Journal www.ogfj.com/index.html Access Date: 30 August 2017

OIL & GAS FINANCIAL JOURNAL OCTOBER 2016 *THE EXECUTIVE PUBLICATION FOR THE OIL AND GAS INDUSTRY* www.ogfj.com/index.html Access Date: 30 August 2017

Probabilistic Damage Stability June 2015 *Ole Martin Djupvik NTNU - Trondheim Norwegian University of Science and Technology* https://brage.bibsys.no Access Date: 30 August 2017

ABS Development of a Guide for Compressed Natural Gas Carriers *P. Rynn H. Patel J. Gaughan ABS TECHNICAL PAPERS 2005 ABS, Houston, Texas* citeseerx.ist.psu.edu Access Date: 30 August 2017

EEDI explained (!) *PANOS ZACHARIADIS ATLANTIC BULK CARRIERS MANAGEMENT LTD GREEK SECTION Dec. 15th, 2011 Athens* https://higherlogicdownload.s3.amazonaws.com Access Date: 30 August 2017

Parker CNG Vehicle and Fueling System Solutions Helping create a sustainable future ENGINEERING YOUR SUCCESS *Parker* www.parker.com Access Date: 30 August 2017

THE NEXT GENERATION OF LARGE LNG CARRIERS FOR LONG DISTANCE AND HARSH ENVIRONMENTS Peter G. Noble Chief Naval Architect ConocoPhillips: www.ivt.ntnu.no Access Date: 30 August 2017

Petrowiki - Stranded gas www.petrowiki.org/Stranded_gas Access Date: 30 August 2017

Liquefied natural gas storage tank stratification/rollover alarm management *Pieter Versluijs WÄRTSILÄ TECHNICAL JOURNAL 02.2010* www.wartsila.com twentyfour7.studio.crasman.fi Access Date: 30 August 2017

Costs Estimate, Ship Design I MSc in Marine Engineering and Naval Architecture, Prof. Manuel Ventura www.mar.ist.utl.pt Access Date: 30 August 2017

Q-Max www.wikipedia.org Access Date: 30 August 2017

Q-VP 650 Quantum Virtual Pipeline Trailers *The Highest Capacity Natural Gas Trailers in the Industry QUANTUM TECHNOLOGIES* www.qtww.com Access Date: 30 August 2017

CNG Storage & Transportation by sea for energy demand peak shaving: the Gresik/Lombok pilot project *R. Longo, M. Suryadi Mardjoeki, A. Sidanta* www.academia.edu Access Date: 30 August 2017

Resources to Reserves 2013 *Oil, Gas and Coal Technologies for the Energy Markets of the Future International Energy Agency iea* www.iea.org Access Date: 30 August 2017

CNG Industry Players in Indonesia “Are they ready for the shift to public transportation sector?” 28 August 2012 *Presentation on GLG webcast Robbi R. Sukardi, MBA Managing Director PT. Raja Rafa Samudra* Jakarta: rajarafasamudra.com Access Date: 30 August 2017

STABILITY INVESTIGATION DAMAGED SHIPS *Rodrigo Pérez Fernández Journal of Marine Science and Technology, Vol. 23, No. 4, pp. 399-406 (2015) DOI: 10.6119/JMST-013-0719-1* jmst.ntou.edu.tw Access Date: 30 August 2017

Royal Dutch Shell plc .com *Stranded natural gas reserves* royaldutchshellplc.com Access Date: 30 August 2017

Sea NG *Marine CNG Overview* www.coselle.com/marine-cng/overview

Seatrade Maritime News Indonesia's PT PLN orders world's first CNG carrier in China www.seatrade-maritime.com

Section: Appendix A Lower and Higher Heating Values of Gas, Liquid and Solid Fuels cta.ornl.gov/bedb www.researchgate.net Access Date: 30 August 2017

Can Indonesia's policy of reconfiguring its energy mix by increasing natural gas usage support its initiatives to reform energy subsidies? November 2014 *THE OXFORD INSTITUTE FOR ENERGY STUDIES Siew Hua Seah University of OXFORD* www.oxfordenergy.org Access Date: 30 August 2017

NATURAL GAS EXPORT OPTIONS FOR ISRAEL AND CYPRUS *The German Marshall Fund of the United States MEDITERRANEAN PAPER SERIES 2013 Simon Henderson* www.washingtoninstitute.org Access Date: 30 August 2017

SOLAS Consolidated Edition, 2012 Consolidated text of the International Convention for the Safety of Life at Sea, 1974, and its Protocol of 1988: articles, annexes and certificates Current version 1 January 2012: www.idgca.org Access Date: 30 August 2017

Standard cubic foot WIKIPEDIA: en.m.wikipedia.org

Standard Cubic Foot Of Natural Gas Conversion Chart Convert-me.com Access Date: 30 August 2017

Standard cubic foot WIKIPEDIA 20 September 2017 en.m.wikipedia.org

The Energy Efficiency Design Index (EEDI) *Stefan Krüger TU Hamburg- Harburg Institute of ship design and ship safety Technische Universitat Hamburg- Harburg* www.ship-efficiency.org Access Date: 30 August 2017

Compressed Natural Gas Fueling Agreement Pacific Gas and Electric Company Gas Sample Form No. 79-753 Steven Malnight 2015 *San Francisco, California* www.pge.com Access Date: 30 August 2017

Storage cascade for CNG station 28 September 2016 Zhongyou Tongyong Luxi Natural Gas Equipment Co., Ltd: www.luxicng.com

STORAGE SYSTEM SOLUTIONS UN and ASME BAUER COMPRESSORS: www.bauercomp.com Access Date: 30 August 2017

Stranded gas www.infratechnology.com Access Date: 30 August 2017

STUDIES ON THE FEASIBILITY AND USE OF LNG AS A FUEL FOR SHIPPING AIR POLLUTION AND ENERGY EFFICIENCY STUDY SERIES *Safe, secure and efficient shipping on clean oceans IMO, INTERNATIONAL MARITIME ORGANIZATION 2016* www.imo.org Access Date: 30 August 2017

T/75 Low Tempressure Cryogenic CNG Tank Container www.alibaba.com

THEORY, ANALYSIS, AND DESIGN METHODOLOGY FOR SHIP MANEUVERABILITY *Takeshi Fuwa, Tatsuo Kashiwadani SHIPS AND OFFSHORE STRUCTURES* www.eolss.net Access Date: 30 August 2017

The Next Generation of Marine Gas Storage and Transportation www.enersea.com/cng-technology/

LOW PRESSURE STORAGE OF NATURAL GAS FOR VEHICULAR APPLICATIONS Tim Burchell and Mike Rogers 2000 Oak Ridge National Laboratory www.researchgate.net Access Date: 30 August 2017

Trinidad & Tobago National Petroleum Marketing Company Limited www.np.co.tt

wa era western australian energy research alliance *Annual Report 2007 building on collaboration* www.waera.com.au Access Date: 30 August 2017

Wärtsilä Encyclopedia of Marine Technology *Wärtsilä* www.wartsila.com/encyclopedia Access Date: 30 August 2017

WARTSILA PROPULSION SYSTEMS cdn.wartsila.com Access Date: 30 August 2017

WARTSILA Propulsors *MIDSIZE WATERJETS PRODUCT GUIDE* cdn.wartsila.com Access Date: 30 August 2017

WARTSILA SOLUTIONS FOR MARINE AND OIL & GAS MARKETS 2013 WARTSILA

Wärtsilä Solutions for Marine and Oil & Gas Markets WÄRTSILÄ www.wartsila.com

WARTSILA Thrusters Wartsila cdn.wartsila.com Access Date: 30 August 2017

Wärtsilä to power world's first CNG carrier www.marinelog.com Access Date: 30 August 2017

Wärtsilä Waterjets *WARTSILA Propulsors* cdn.wartsila.com Access Date: 30 August 2017

Indonesia Upstream Natural Gas Policy & LNG Outlook SPECIAL TASK FORCE FOR UPSTREAM OIL AND GAS BUSINESS ACTIVITIES (SKK MIGAS) 9 September 2013 *Widhyawan Prawiraatmadja Deputy Chairman for Commercial Management 2nd LNG Producer – Consumer Conference* Tokyo: aperc.ieej.or.jp Access Date: 30 August 2017

WIKIPEDIA Heat of combustion http://en.wikipedia.org/wiki/Heat_of_combustion Access Date: 30 August 2017

www.all4yachting.com/maps/mykonos.htm Access Date: 30 August 2017

www.all4yachting.com/maps/syros.htm Access Date: 30 August 2017

www.all4yachting.com/maps/tinos.htm Access Date: 30 August 2017

www.portbook.gr Access Date: 30 August 2017

www.xe.com Access Date: 30 August 2017

Risk Management for CNG based Vehicles December 2011 Yousaf Saeed, Khalil Ahmed, M. Saleem Khan, Umer Farooq *Conference Paper* https://www.researchgate.net/publication/230785318 Access Date: 30 August 2017

ΜΕΛΕΤΗ & ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ ΙΙ (Γενική Διάταξη, Ενδιαίτηση και Εξοπλισμός) 2004 Πανεπιστημιακές Σημειώσεις (3η ανανεωμένη έκδοση) Α. Παπανικολάου Καθηγητής Ε.Μ.Π. Αθήνα: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ Τμήμα Ναυπηγών Μηχανολόγων Μηχανικών Εργαστήριο Μελέτης Πλοίου

ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ (4η ανανεωμένη έκδοση) 2005 Καθηγητής: Α. Παπανικολάου, Επιστ. Συνεργάτης: Κ. Αναστασόπουλος ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΤΜΗΜΑ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ ΕΡΓΑΣΤΗΡΙΟ ΜΕΛΕΤΗΣ ΠΛΟΙΟΥ

ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ ΙΙ ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ ΓΕΝΙΚΗ ΔΙΑΤΑΞΗ, ΕΝΔΙΑΙΤΗΣΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ (3η ανανεωμένη έκδοση) 2006 Καθηγητής: Α. Παπανικολάου, Επιστ. Συνεργάτης: Κ. Αναστασόπουλος ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΤΜΗΜΑ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ ΕΡΓΑΣΤΗΡΙΟ ΜΕΛΕΤΗΣ ΠΛΟΙΟΥ

ΘΕΜΑ ΜΕΛΕΤΗΣ ΚΑΙ ΣΧΕΔΙΑΣΗΣ ΠΛΟΙΟΥ 2007 Καθηγητής: Α. Παπανικολάου, Επιστ. Συνεργάτης: Κ. Αναστασόπουλος ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΤΜΗΜΑ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ ΕΡΓΑΣΤΗΡΙΟ ΜΕΛΕΤΗΣ ΠΛΟΙΟΥ

ΤΑΣΕΙΣ ΤΗΣ ΤΟΥΡΙΣΤΙΚΗΣ ΚΙΝΗΣΗΣ 2008-2015, 2015 ΕΛΛΗΝΙΚΟΣ ΟΡΓΑΝΙΣΜΟΣ ΤΟΥΡΙΣΜΟΥ Αλέξης Χατζηδάκης ΕΘΝΙΚΟ ΤΥΠΟΓΡΑΦΕΙΟ ΑΘΗΝΑ: www.visitgreece.gr www.gnto.gov.gr Access Date: 30 August 2017

ΜΑΘΗΜΑΤΙΚΑ ΘΕΤΙΚΗΣ ΚΑΙ ΤΕΧΝΟΛΟΓΙΚΗΣ ΚΑΤΕΥΘΥΝΣΗΣ Ανδρεαδάκης Στυλιανός, Κατσαργύρης Βασίλειος, Μέτης Στέφανος, Μπρουχούτας Κων/νος, Παπασταυρίδης Σταύρος, Πολύζος Γεώργιος *ΠΑΙΔΑΓΩΓΙΚΟ ΙΝΣΤΙΤΟΥΤΟ Γ' ΤΑΞΗ ΕΝΙΑΙΟΥ ΛΥΚΕΙΟΥ* ΟΡΓΑΝΙΣΜΟΣ ΕΚΔΟΣΕΩΣ ΔΙΔΑΚΤΙΚΩΝ ΒΙΒΛΙΩΝ ΑΘΗΝΑ ΥΠΟΥΡΓΕΙΟ ΕΘΝΙΚΗΣ ΠΑΙΔΕΙΑΣ ΚΑΙ ΘΡΗΣΚΕΥΜΑΤΩΝ

Απογραφή 2011: Ο πληθυσμός των Κυκλάδων ανά Δημοτική ενότητα www.naxosnow.gr

ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ Οκτώβριος 2015 Καθηγητής Απόστολος Δ. Παπανικολάου, Επιμέλεια: Αιμιλία Γ. Αλησαφάκη, Ελευθερία Σ. Ηλιοπούλου, Γεώργιος Ι. Παπατζανάκης ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΣΧΟΛΗ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ ΕΡΓΑΣΤΗΡΙΟ ΜΕΛΕΤΗΣ ΠΛΟΙΟΥ

Μελέτη Πλοίου ΤΟΜΟΣ Α: ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ *ΑΠΟΣΤΟΛΟΥ Δ. ΠΑΠΑΝΙΚΟΛΑΟΥ Καθηγητή Ε.Μ.Π.* ΕΚΔΟΣΕΙΣ ΣΥΜΕΩΝ

Μελέτη Πλοίου ΤΟΜΟΣ Β: ΕΓΧΕΙΡΙΔΙΟ ΜΕΛΕΤΗΣ *ΑΠΟΣΤΟΛΟΥ Δ. ΠΑΠΑΝΙΚΟΛΑΟΥ Καθηγητή Ε.Μ.Π.* ΕΚΔΟΣΕΙΣ ΣΥΜΕΩΝ

ΑΠΟΤΕΛΕΣΜΑΤΑ ΠΡΩΤΟΓΕΝΟΥΣ ΕΡΕΥΝΑΣ ΤΟΥΡΙΣΤΙΚΗΣ ΑΓΟΡΑΣ ΤΩΝ ΚΥΚΛΑΔΩΝ [Α.Π. 1091] ΓΙΑ ΤΗΝ ΑΝΑΠΤΥΞΙΑΚΗ ΕΤΑΙΡΕΙΑ ΚΥΚΛΑΔΩΝ Α.Ε. ΑΠΟ ΤΗΝ CENTRUM research traveldailynews.gr Access Date: 30 August 2017

Αύξηση επιβατικής κίνησης στα ελληνικά αεροδρόμια 2014 www.ypa.gr Access Date: 30 August 2017

ΔΥΝΑΜΙΚΗ ΣΥΜΠΕΡΙΦΟΡΑ ΠΛΟΙΩΝ ΣΕ ΚΥΜΑΤΙΣΜΟΥΣ ΜΕΡΟΣ Β: ΕΦΑΡΜΟΓΕΣ ΣΤΗ ΣΧΕΔΙΑΣΗ ΚΑΙ ΤΗ ΛΕΙΤΟΥΡΓΙΑ ΤΟΥ ΠΛΟΙΟΥ ΣΗΜΕΙΩΣΕΙΣ ΓΙΑ ΤΟΥΣ ΣΠΟΥΔΑΣΤΕΣ ΤΟΥ ΠΡΟΓΡΑΜΜΑΤΟΣ ΜΕΤΑΠΤΥΧΙΑΚΩΝ ΣΠΟΥΔΩΝ ΑΠΡΙΛΙΟΣ 2004 *Γ.Ι. ΓΡΗΓΟΡΟΠΟΥΛΟΣ, Αναπλ. Καθηγητής ΕΜΠ* ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΤΜΗΜΑ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ

ΔΥΝΑΜΙΚΗ ΣΥΜΠΕΡΙΦΟΡΑ ΠΛΟΙΩΝ ΣΕ ΚΥΜΑΤΙΣΜΟΥΣ ΜΕΡΟΣ Α: ΘΕΩΡΗΤΙΚΗ ΑΝΑΛΥΣΗ ΣΗΜΕΙΩΣΕΙΣ ΓΙΑ ΤΟΥΣ ΣΠΟΥΔΑΣΤΕΣ ΤΟΥ ΠΡΟΓΡΑΜΜΑΤΟΣ ΜΕΤΑΠΤΥΧΙΑΚΩΝ ΣΠΟΥΔΩΝ ΟΚΤΩΒΡΙΟΣ 1998 *Γ.Ι. ΓΡΗΓΟΡΟΠΟΥΛΟΣ, Επ. Καθηγητής ΕΜΠ, Γ.Α. ΑΘΑΝΑΣΟΥΛΗΣ, Καθηγητής ΕΜΠ* ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΤΜΗΜΑ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ

Σημειώσεις ΑΝΤΙΣΤΑΣΗΣ ΠΛΟΙΟΥ Γ.Κ. ΠΟΛΙΤΗ ΑΝΑΠΛΗΡΩΤΗ ΚΑΘΗΓΗΤΗ Ε.Μ.Π., Φ.Α. ΣΚΑΜΝΕΛΗ ΝΑΥΠΗΓΟΥ ΜΗΧΑΝΟΛΟΓΟΥ ΜΗΧΑΝΙΚΟΥ Ε.Μ.Π. 23/11/2005 ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΣΧΟΛΗ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ

ΣΥΝΗΘΕΙΣ ΔΙΑΦΟΡΙΚΕΣ ΕΞΙΣΩΣΕΙΣ *Γ.Ν. ΠΑΝΤΕΛΙΔΗ, Δ. Χ. ΚΡΑΒΒΑΡΙΤΗ, Ν.Σ. ΧΑΤΖΗΣΑΒΒΑ Β' ΕΚΔΟΣΗ* ΑΘΗΝΑ: ΕΚΔΟΣΕΙΣ ΖΗΤΗ

ΠΡΟΩΣΗ ΠΛΟΙΟΥ 2η Έκδοση Μάιος 2005 *Γερασίμου Κ. Πολίτη Αναπληρωτή Καθηγητή*

ΘΕΜΑ ΜΕΛΕΤΗΣ ΚΑΙ ΣΧΕΔΙΑΣΗΣ ΠΛΟΙΟΥ ΓΕΩΡΓΙΟΣ ΔΗΜΟΠΟΥΛΟΣ 1998 ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΤΜΗΜΑ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ

Μελέτη & Σχεδίαση Πλοίων Νέας Τεχνολογίας Σημειώσεις Μαθήματος 2016 Εθνικό Μετσόβιο Πολυτεχνείο, Σχολή Ναυπηγών Μηχανολόγων Μηχανικών

ΣΥΣΤΗΜΙΚΗ ΜΕΘΟΔΟΛΟΓΙΑ ΚΑΙ ΤΕΧΝΙΚΗ ΟΙΚΟΝΟΜΙΚΗ Δημήτριος Χ. Παναγιωτακόπουλος 2005, ΘΕΣΣΑΛΟΝΙΚΗ: ΕΚΔΟΣΕΙΣ ΖΥΓΟΣ

ΟΡΟΛΟΓΙΑ ΚΑΙ ΜΟΝΑΔΕΣ ΒΙΟΜΗΧΑΝΙΑΣ ΦΥΣΙΚΟΥ ΑΕΡΙΟΥ ΔΗΜΟΣΙΑ ΕΠΙΧΕΙΡΗΣΗ ΑΕΡΙΟΥ Α.Ε. ΔΕΠΑ www.depa.gr Access Date: 30 August 2017

Διαδραστικός χάρτης με τα στοιχεία της απογραφής της Σύρου www.syrostoday.gr Access Date: 30 August 2017

ΔΙΕΘΝΕΙΣ ΤΟΥΡΙΣΤΙΚΕΣ ΑΦΙΞΕΙΣ ΣΤΑ ΚΥΡΙΟΤΕΡΑ ΑΕΡΟΔΡΟΜΙΑ, ΙΑΝ - ΔΕΚ 2014/2013 - ΠΡΟΣΩΡΙΝΑ ΣΤΟΙΧΕΙΑ sete.gr Access Date: 30 August 2017

Διεθνείς Αεροπορικές Αφίξεις 2015-2016 : Απολογισμός 2015 & Προγραμματισμός (Slots) 2016. *SETE INTELLIGENCE - Μάρτιος 2015 Δρ. Άρης Ίκκος ISHC Επιστημονικός Διευθυντής, Ευαγγελία Λάμπρου Ερευνήτρια – Στατιστικολόγος Ινστιτούτο ΣΕΤΕ Λεωφ. Αμαλίας 34 - 105 58 Αθήνα* www.insete.gr www.sete.gr Access Date: 30 August 2017

ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ ΝΟΜΟΣ ΚΥΚΛΑΔΩΝ ΔΗΜΟΤΙΚΟ ΛΙΜΕΝΙΚΟ ΤΑΜΕΙΟ ΘΗΡΑΣ *ΑΠΟΦΑΣΕΙΣ ΚΑΘΟΡΙΣΜΟΥ ΤΕΛΩΝ ΟΙΚΟΝΟΜΙΚΟΥ ΕΤΟΥΣ 2016* www.santoriniports.gr Access Date: 30 August 2017

Επιβατική κίνηση ελληνικών αεροδρομίων (2011) www.airliners.gr Access Date: 30 August 2017

MATLAB 6 ΓΙΑ ΜΗΧΑΝΙΚΟΥΣ ΕΥΑΓΓΕΛΟΣ Β. ΧΑΤΖΙΚΟΣ 2003 ΘΕΣΣΑΛΟΝΙΚΗ: ΕΚΔΟΣΕΙΣ ΤΖΙΟΛΑ

Η ΔΙΑΔΡΟΜΗ ΑΠΟΓΡΑΦΗ ΠΛΗΘΥΣΜΟΥ 2011 τελικά αποτελέσματα www.i-diadromi.gr Access Date: 30 August 2017

ΥΔΡΟΣΤΑΤΙΚΗ ΚΑΙ ΕΥΣΤΑΘΕΙΑ ΠΛΟΙΟΥ ΤΟΜΟΣ Α 2000 *ΘΟΔΩΡΟΥ Α. ΛΟΥΚΑΚΗ ΚΑΘΗΓΗΤΗ Ε.Μ.ΠΟΛΥΤΕΧΝΕΙΟΥ, ΓΕΩΡΓΙΟΥ Δ. ΤΖΑΜΠΙΡΑ ΚΑΘΗΓΗΤΗ Ε.Μ.ΠΟΛΥΤΕΧΝΕΙΟΥ, ΠΑΡΙ Σ. ΠΕΡΡΑ ΕΠ. ΚΑΘΗΓΗΤΗ Ε.Μ.ΠΟΛΥΤΕΧΝΕΙΟΥ* ΑΘΗΝΑ

ΝΑΥΤΙΚΕΣ ΜΗΧΑΝΕΣ ΤΕΥΧΟΣ 1 2005 ΓΕΝΙΚΑ. ΚΙΝΗΤΗΡΕΣ DIESEL *Ι.Π. ΙΩΑΝΝΙΔΗ ΚΑΘΗΓΗΤΗ ΕΜΠ ΤΡΙΤΗ ΕΚΔΟΣΗ ΑΝΑΤΥΠΩΣΗ 2005* ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΣΧΟΛΗ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ

ΜΕΘΟΔΟΣ ΓΙΑ ΤΗΝ ΚΑΤΑΣΤΡΩΣΗ ΘΕΡΜΙΚΟΥ ΙΣΟΛΟΓΙΣΜΟΥ ΝΑΥΤΙΚΩΝ ΠΡΟΩΣΤΗΡΙΩΝ ΕΓΚΑΤΑΣΤΑΣΕΩΝ ΑΤΜΟΥ 1998 *ΕΠΙΜΕΛΕΙΑ: Ι.Π.ΙΩΑΝΝΙΔΗ ΚΑΘΗΓΗΤΗ Ε.Μ.Π.* ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΤΜΗΜΑ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ

ΔΙΑΦΟΡΙΚΕΣ ΕΞΙΣΩΣΕΙΣ 2003 *ΙΩΑΝΝΗ Π. ΚΡΟΚΟΥ ΑΡΝΟΣ Studies & Publishing* Αθήνα

Κυκλάδες ΧΑΡΤΗΣ ΚΥΚΛΑΔΩΝ www.golden-greece.gr Access Date: 30 August 2017

ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ ΙΙ ΣΤΟΙΧΕΙΑ ΛΕΠΤΟΜΕΡΟΥΣ ΜΕΛΕΤΗΣ ΚΑΙ ΣΧΕΔΙΑΣΗΣ ΠΛΟΙΟΥ ΜΕΡΟΣ Β' ΣΗΜΕΙΩΣΕΙΣ ΔΙΔΑΣΚΟΝΤΟΣ Νοέμβριος 2004 *ΕΠΙΜΕΛΕΙΑ: ΚΩΝ/ΝΟΣ ΣΠΥΡΟΥ ΑΝΑΠΛ. ΚΑΘΗΓΗΤΗΣ* ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΤΟΜΕΑΣ ΜΕΛΕΤΗΣ ΠΛΟΙΟΥ ΚΑΙ ΘΑΛΑΣΣΙΩΝ ΜΕΤΑΦΟΡΩΝ ΣΧΟΛΗ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ Ε.Μ.Π.

«ΑΣΦΑΛΕΙΑ ΤΟΥ ΠΛΟΙΟΥ ΕΝΑΝΤΙ ΚΑΤΑΚΛΙ(Υ)ΣΗΣ ΚΑΙ ΚΑΝΟΝΙΣΜΟΙ ΑΣΦΑΛΕΙΑΣ» ΔΙΑΤΜΗΜΑΤΙΚΟ ΜΕΤΑΠΤΥΧΙΑΚΟ ΠΡΟΓΡΑΜΜΑ ΣΠΟΥΔΩΝ: ΝΑΥΤΙΚΗ/ΘΑΛΑΣΣΙΑ ΤΕΧΝΟΛΟΓΙΑ ΚΑΙ ΕΠΙΣΤΗΜΗ ΣΗΜΕΙΩΣΕΙΣ ΜΑΘΗΜΑΤΟΣ ΡΟΗΣ Ι Οκτώβριος 2012 *Κων/νος Σπύρου Καθηγητής Ε.Μ.Π.* ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΣΧΟΛΗ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ ΤΟΜΕΑΣ ΜΕΛΕΤΗΣ ΠΛΟΙΟΥ ΚΑΙ ΘΑΛΑΣΣΙΩΝ ΜΕΤΑΦΟΡΩΝ

ΣΧΕΔΙΑΣΗ ΠΛΟΙΩΝ ΓΙΑ ΕΛΙΚΤΙΚΟΤΗΤΑ ΚΑΙ ΔΥΝΑΜΙΚΗ ΕΥΣΤΑΘΕΙΑ ΣΗΜΕΙΩΣΕΙΣ ΔΙΔΑΣΚΟΝΤΟΣ Οκτώβριος 2010 *ΚΩΝ/ΝΟΥ ΣΠΥΡΟΥ ΚΑΘΗΓΗΤΗ* ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ, ΣΧΟΛΗ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ, ΤΟΜΕΑΣ ΜΕΛΕΤΗΣ ΠΛΟΙΟΥ ΚΑΙ ΘΑΛΑΣΣΙΩΝ ΜΕΤΑΦΟΡΩΝ

ΑΝΤΟΧΗ ΠΛΟΙΟΥ 1999 *Μ. ΣΑΜΟΥΗΛΙΔΗΣ Επ. Καθηγητής* ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΤΜΗΜΑ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ

ΠΑΡΑΡΤΗΜΑ ΠΡΩΤΟ ΤΗΣ ΕΠΙΣΗΜΗΣ ΕΦΗΜΕΡΙΔΑΣ ΤΗΣ ΔΗΜΟΚΡΑΤΙΑΣ ΝΟΜΟΘΕΣΙΑ, Ν. 11/86 Αρ. 2116 της 14ης ΦΕΒΡΟΥΑΡΙΟΥ 1986 www.cylaw.org Access Date: 30 August 2017

ΣΗΜΕΙΩΣΕΙΣ ΨΥΞΗΣ Α' ΚΑΙ Β' ΜΕΡΟΣ 2003 *Σ. ΧΑΤΖΗΔΑΚΗΣ* ΑΘΗΝΑ: ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΣΧΟΛΗ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ ΤΟΜΕΑΣ ΘΕΡΜΟΤΗΤΑΣ

Το Νέο Κυπριακό Σύστημα Φόρου Χωρητικότητας DEPARTMENT OF MERCHANT SHIPPING REPUBLIC OF CYPRUS www.mcw.gov.cy

ΥΠΗΡΕΣΙΑ ΠΟΛΙΤΙΚΗΣ ΑΕΡΟΠΟΡΙΑΣ ΚΡΑΤΙΚΟΣ ΑΕΡΟΛΙΜΕΝΑΣ ΣΥΡΟΥ "ΔΗΜΗΤΡΙΟΣ ΒΙΚΕΛΑΣ" *ΣΤΑΤΙΣΤΙΚΑ ΣΤΟΙΧΕΙΑ* www.ypa.gr

ΚΑΙΝΟΤΟΜΟΣ ΜΕΘΟΔΟΣ ΘΑΛΑΣΣΙΑΣ ΜΕΤΑΦΟΡΑΣ ΦΥΣΙΚΟΥ ΑΕΡΙΟΥ ΣΕ ΣΥΜΠΙΕΣΜΕΝΗ ΜΟΡΦΗ (ΑΥΤΟΝΟΜΟ ΠΛΟΙΟ ΜΕΤΑΦΟΡΑΣ ΣΥΜΠΙΕΣΜΕΝΟΥ ΦΥΣΙΚΟΥ ΑΕΡΙΟΥ) Νοέμβριος 2016 *Χ. Σαρηγιαννίδης* casari@otenet.gr

ΜΕΘΟΔΟΣ ΠΡΟΜΕΛΕΤΗΣ ΝΑΥΤΙΚΩΝ ΣΥΣΤΗΜΑΤΩΝ ΜΕ ΚΙΝΗΤΗΡΕΣ DIESEL Μετάφραση: Χρήστος Ι. Παπαδόπουλος, Επιμέλεια: Χρίστος Αθ. Φραγκόπουλος In *The Society of Naval Architects and Marine Engineers* ΠΑΝΕΠΙΣΤΗΜΙΑΚΕΣ ΕΚΔΟΣΕΙΣ Ε.Μ.Π.

Ενεργειακά Συστήματα Πλοίου Τεύχος Β' 2007 Χρίστος Αθ. Φραγκόπουλος Αθήνα: Σχολή Ναυπηγών Μηχανολόγων Μηχανικών Εκδόσεις Εθνικού Μετσοβίου Πολυτεχνείου

ΨΥΞΗ ΚΑΙ ΕΡΓΑΣΤΗΡΙΟ ΣΗΜΕΙΩΣΕΙΣ ΜΑΘΗΜΑΤΟΣ ΕΘΝΙΚΟ ΜΕΤΣΟΒΙΟ ΠΟΛΥΤΕΧΝΕΙΟ ΣΧΟΛΗ ΝΑΥΠΗΓΩΝ ΜΗΧΑΝΟΛΟΓΩΝ ΜΗΧΑΝΙΚΩΝ

A STATISTICAL RE-ANALYSIS OF RESISTANCE AND PROPULSION DATA *J. Holtrop* Maritime Research Institute Netherlands, Wageningen, The Netherlands

RESOLUTION MSC.391(95) (adopted on 11 June 2015) ADOPTION OF THE INTERNATIONAL CODE OF SAFETY FOR SHIPS USING GASES OR OTHER LOW-FLASHPOINT FUELS (IGF CODE) www.imo.org Access Date: 1 December 2017

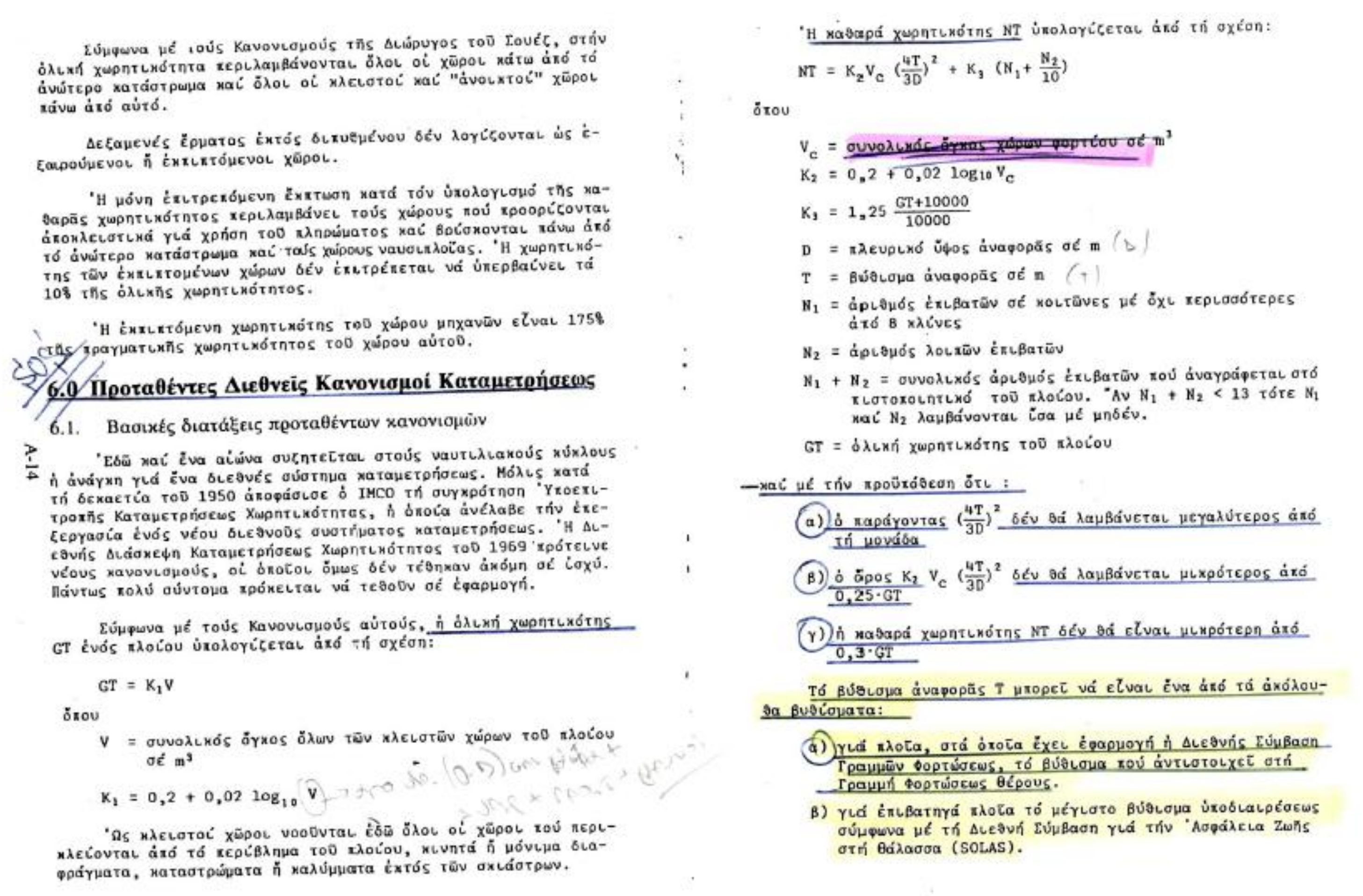
RESOLUTION MSC.370(93) (adopted on 22 May 2014) AMENDMENTS TO THE INTERNATIONAL CODE FOR THE CONSTRUCTION AND EQUIPMENT OF SHIPS CARRYING LIQUEFIED GASES IN BULK (IGC CODE) www.imo.org Access Date: 1 December 2017

INTERNATIONAL MARITIME DANGEROUS GOODS CODE (IMDG CODE) Incorporating Amendment 33-06 Volume 1 (2006 Edition) London: INTERNATIONAL MARITIME ORGANIZATION https://law.resource.org Access Date: 1 December 2017

INTERNATIONAL MARITIME DANGEROUS GOODS CODE (IMDG CODE) Volume 2 Incorporating Amendment 33-06 (2006 Edition) London: INTERNATIONAL MARITIME ORGANIZATION https://law.resource.org Access Date: 1 December 2017

M.K. Graf, H.-G. Hillenbrand, C.J. Heckmann, K.A. Niederhoff *High-strength large-diameter pipe for long-distance high pressure gas pipelines* Honolulu, Hawaii, USA ISOPE 2003 EUROPIPE The world trusts us. 26-30 May 2003 www.bergpipe.com Access Date: 1/12/2017

24. Appendix A (Tonnage & Equipment Number)



Σύμφωνα μέ τούς Κανονισμούς τῆς Διώρυγος τοῦ Σουέζ, στήν ὁλική χωρητικότητα περιλαμβάνονται ὅλοι οἱ χῶροι κάτω ἀπό τό ἀνώτερο κατάστρωμα καί ὅλοι οἱ κλειστοί καί "ἀνοικτοί" χῶροι πάνω ἀπό αὐτό.

Δεξαμενές ἕρματος ἐκτός διπυθμένου δέν λογίζονται ὡς ἐξαιρούμενοι ἤ ἐκπιπτόμενοι χῶροι.

Ἡ μόνη ἐπιτρεπόμενη ἔκπτωση κατά τόν ὑπολογισμό τῆς καθαρᾶς χωρητικότητος περιλαμβάνει τούς χώρους πού προορίζονται ἀποκλειστικά γιά χρήση τοῦ πληρώματος καί βρίσκονται πάνω ἀπό τό ἀνώτερο κατάστρωμα καί τούς χώρους ναυσιπλοΐας. Ἡ χωρητικότης τῶν ἐκπιπτομένων χώρων δέν ἐπιτρέπεται νά ὑπερβαίνει τά 10% τῆς ὁλικῆς χωρητικότητος.

Ἡ ἐκπιπτόμενη χωρητικότης τοῦ χώρου μηχανῶν εἶναι 175% τῆς πραγματικῆς χωρητικότητος τοῦ χώρου αὐτοῦ.

6.0 Προταθέντες Διεθνεῖς Κανονισμοί Καταμετρήσεως

6.1. Βασικές διατάξεις προταθέντων κανονισμῶν

A-14

Ἐδῶ καί ἕνα αἰώνα συζητεῖται στούς ναυτιλιακούς κύκλους ἡ ἀνάγκη γιά ἕνα διεθνές σύστημα καταμετρήσεως. Μόλις κατά τή δεκαετία τοῦ 1950 ἀποφάσισε ὁ IMCO τή συγκρότηση Ὑποεπιτροπῆς Καταμετρήσεως Χωρητικότητας, ἡ ὁποία ἀνέλαβε τήν ἐπεξεργασία ἑνός νέου διεθνοῦς συστήματος καταμετρήσεως. Ἡ Διεθνής Διάσκεψη Καταμετρήσεως Χωρητικότητος τοῦ 1969 πρότεινε νέους κανονισμούς, οἱ ὁποῖοι ὅμως δέν τέθηκαν ἀκόμη σέ ἰσχύ. Πάντως πολύ σύντομα πρόκειται νά τεθοῦν σέ ἐφαρμογή.

Σύμφωνα μέ τούς Κανονισμούς αὐτούς, ἡ ὁλική χωρητικότης GT ἑνός πλοίου ὑπολογίζεται ἀπό τή σχέση:

$$GT = K_1 V$$

ὅπου

V = συνολικός ὄγκος ὅλων τῶν κλειστῶν χώρων τοῦ πλοίου σέ m^3

$K_1 = 0{,}2 + 0{,}02 \log_{10} V$ [illegible]

Ὡς κλειστοί χῶροι νοοῦνται ἐδῶ ὅλοι οἱ χῶροι πού περικλείονται ἀπό τό περίβλημα τοῦ πλοίου, κινητά ἤ μόνιμα διαφράγματα, καταστρώματα ἤ καλύμματα ἐκτός τῶν σκιάστρων.

Ἡ καθαρά χωρητικότης NT ὑπολογίζεται ἀπό τή σχέση:

$$NT = K_2 V_c \left(\frac{4T}{3D}\right)^2 + K_3 \left(N_1 + \frac{N_2}{10}\right)$$

ὅπου

V_c = ~~συνολικός ὄγκος χώρων φορτίου σέ m^3~~

$K_2 = 0{,}2 + 0{,}02 \log_{10} V_c$

$K_3 = 1{,}25 \dfrac{GT+10000}{10000}$

D = πλευρικό ὕψος ἀναφορᾶς σέ m (D)

T = βύθισμα ἀναφορᾶς σέ m (T)

N_1 = ἀριθμός ἐπιβατῶν σέ κοιτῶνες μέ ὄχι περισσότερες ἀπό 8 κλίνες

N_2 = ἀριθμός λοιπῶν ἐπιβατῶν

$N_1 + N_2$ = συνολικός ἀριθμός ἐπιβατῶν πού ἀναγράφεται στό πιστοποιητικό τοῦ πλοίου. Ἄν $N_1 + N_2 < 13$ τότε N_1 καί N_2 λαμβάνονται ἴσα μέ μηδέν.

GT = ὁλική χωρητικότης τοῦ πλοίου

—καί μέ τήν προϋπόθεση ὅτι :

α) ὁ παράγοντας $\left(\frac{4T}{3D}\right)^2$ δέν θά λαμβάνεται μεγαλύτερος ἀπό τή μονάδα

β) ὁ ὅρος $K_2 V_c \left(\frac{4T}{3D}\right)^2$ δέν θά λαμβάνεται μικρότερος ἀπό $0{,}25 \cdot GT$

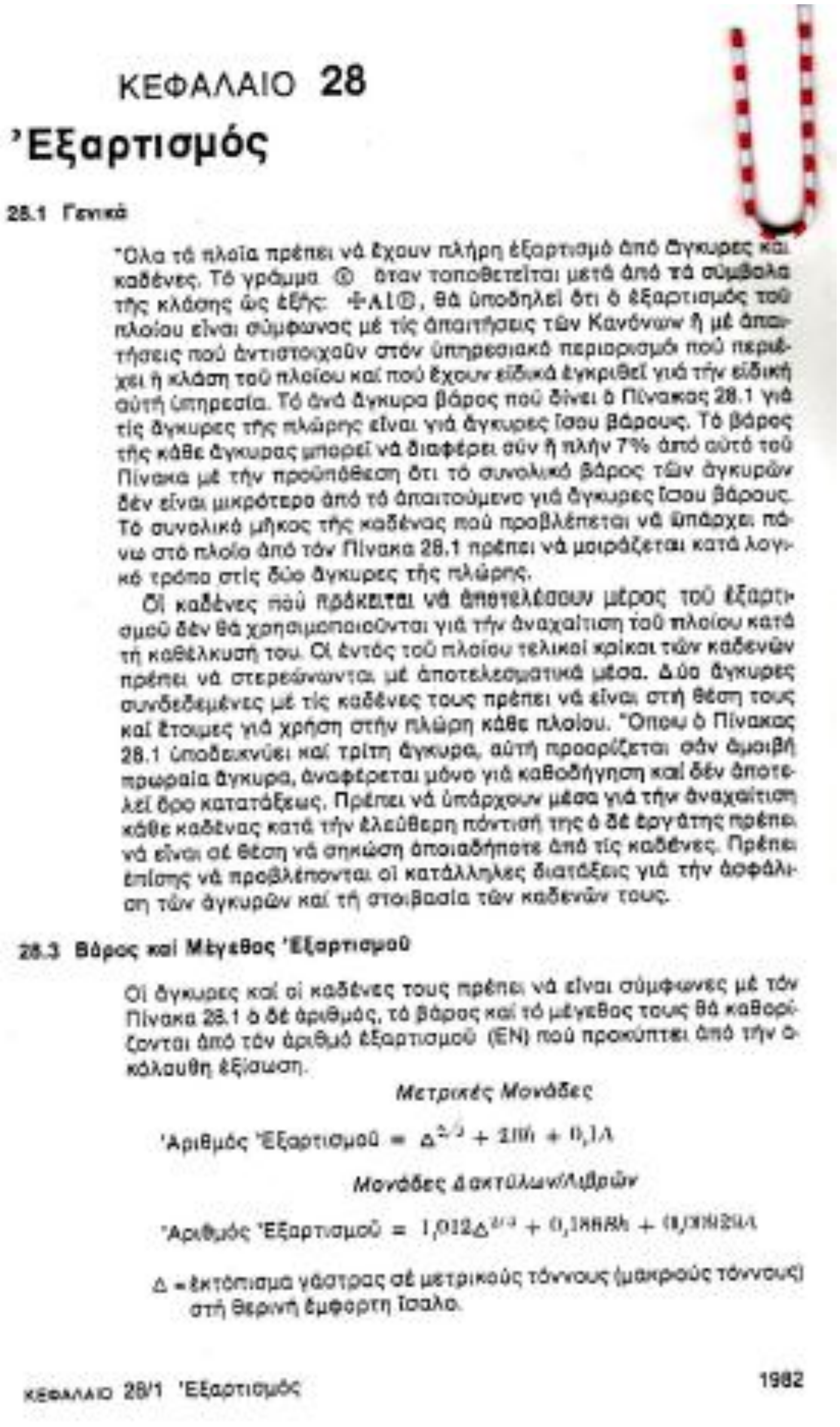
γ) ἡ καθαρά χωρητικότης NT δέν θά εἶναι μικρότερη ἀπό $0{,}3 \cdot GT$

Τό βύθισμα ἀναφορᾶς T μπορεῖ νά εἶναι ἕνα ἀπό τά ἀκόλουθα βυθίσματα:

α) γιά πλοῖα, στά ὁποῖα ἔχει ἐφαρμογή ἡ Διεθνής Σύμβαση Γραμμῶν Φορτώσεως, τό βύθισμα πού ἀντιστοιχεῖ στή Γραμμή Φορτώσεως θέρους.

β) γιά ἐπιβατηγά πλοῖα τό μέγιστο βύθισμα ὑποδιαιρέσεως σύμφωνα μέ τή Διεθνή Σύμβαση γιά τήν Ἀσφάλεια Ζωῆς στή Θάλασσα (SOLAS).

Picture 44. **Gross and Net Tonnage Mathematical Model.** Source: (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)



ΚΕΦΑΛΑΙΟ 28

’Εξαρτισμός

28.1 Γενικά

Ὅλα τά πλοῖα πρέπει νά ἔχουν πλήρη ἐξαρτισμό ἀπό ἄγκυρες καί καδένες. Τό γράμμα Ⓔ ὅταν τοποθετεῖται μετά ἀπό τά σύμβολα τῆς κλάσης ὡς ἑξῆς: ✠A1Ⓔ, θά ὑποδηλεῖ ὅτι ὁ ἐξαρτισμός τοῦ πλοίου εἶναι σύμφωνος μέ τίς ἀπαιτήσεις τῶν Κανόνων ἤ μέ ἀπαιτήσεις πού ἀντιστοιχοῦν στόν ὑπηρεσιακό περιορισμό πού περιέχει ἡ κλάση τοῦ πλοίου καί πού ἔχουν εἰδικά ἐγκριθεῖ γιά τήν εἰδική αὐτή ὑπηρεσία. Τό ἀνά ἄγκυρα βάρος πού δίνει ὁ Πίνακας 28.1 γιά τίς ἄγκυρες τῆς πλώρης εἶναι γιά ἄγκυρες ἴσου βάρους. Τό βάρος τῆς κάθε ἄγκυρας μπορεῖ νά διαφέρει σύν ἤ πλήν 7% ἀπό αὐτό τοῦ Πίνακα μέ τήν προϋπόθεση ὅτι τό συνολικό βάρος τῶν ἀγκυρῶν δέν εἶναι μικρότερο ἀπό τό ἀπαιτούμενο γιά ἄγκυρες ἴσου βάρους. Τό συνολικό μῆκος τῆς καδένας πού προβλέπεται νά ὑπάρχει πάνω στό πλοῖο ἀπό τόν Πίνακα 28.1 πρέπει νά μοιράζεται κατά λογικό τρόπο στίς δύο ἄγκυρες τῆς πλώρης.

Οἱ καδένες πού πρόκειται νά ἀποτελέσουν μέρος τοῦ ἐξαρτισμοῦ δέν θά χρησιμοποιοῦνται γιά τήν ἀναχαίτιση τοῦ πλοίου κατά τή καθέλκυσή του. Οἱ ἐντός τοῦ πλοίου τελικοί κρίκοι τῶν καδενῶν πρέπει νά στερεώνωνται μέ ἀποτελεσματικά μέσα. Δύο ἄγκυρες συνδεδεμένες μέ τίς καδένες τους πρέπει νά εἶναι στή θέση τους καί ἕτοιμες γιά χρήση στήν πλώρη κάθε πλοίου. Ὅπου ὁ Πίνακας 28.1 ὑποδεικνύει καί τρίτη ἄγκυρα, αὐτή προορίζεται σάν ἀμοιβή πρωραία ἄγκυρα, ἀναφέρεται μόνο γιά καθοδήγηση καί δέν ἀποτελεῖ ὅρο κατατάξεως. Πρέπει νά ὑπάρχουν μέσα γιά τήν ἀναχαίτιση κάθε καδένας κατά τήν ἐλεύθερη πόντισή της ὁ δέ ἐργάτης πρέπει νά εἶναι σέ θέση νά σηκώση ὁποιαδήποτε ἀπό τίς καδένες. Πρέπει ἐπίσης νά προβλέπονται οἱ κατάλληλες διατάξεις γιά τήν ἀσφάλιση τῶν ἀγκυρῶν καί τή στοιβασία τῶν καδενῶν τους.

28.3 Βάρος καί Μέγεθος ’Εξαρτισμοῦ

Οἱ ἄγκυρες καί οἱ καδένες τους πρέπει νά εἶναι σύμφωνες μέ τόν Πίνακα 28.1 ὁ δέ ἀριθμός, τό βάρος καί τό μέγεθος τους θά καθορίζονται ἀπό τόν ἀριθμό ἐξαρτισμοῦ (EN) πού προκύπτει ἀπό τήν ἀκόλουθη ἐξίσωση.

Μετρικές Μονάδες

$$\text{’Αριθμός ’Εξαρτισμοῦ} = \Delta^{2/3} + 2Bh + 0{,}1A$$

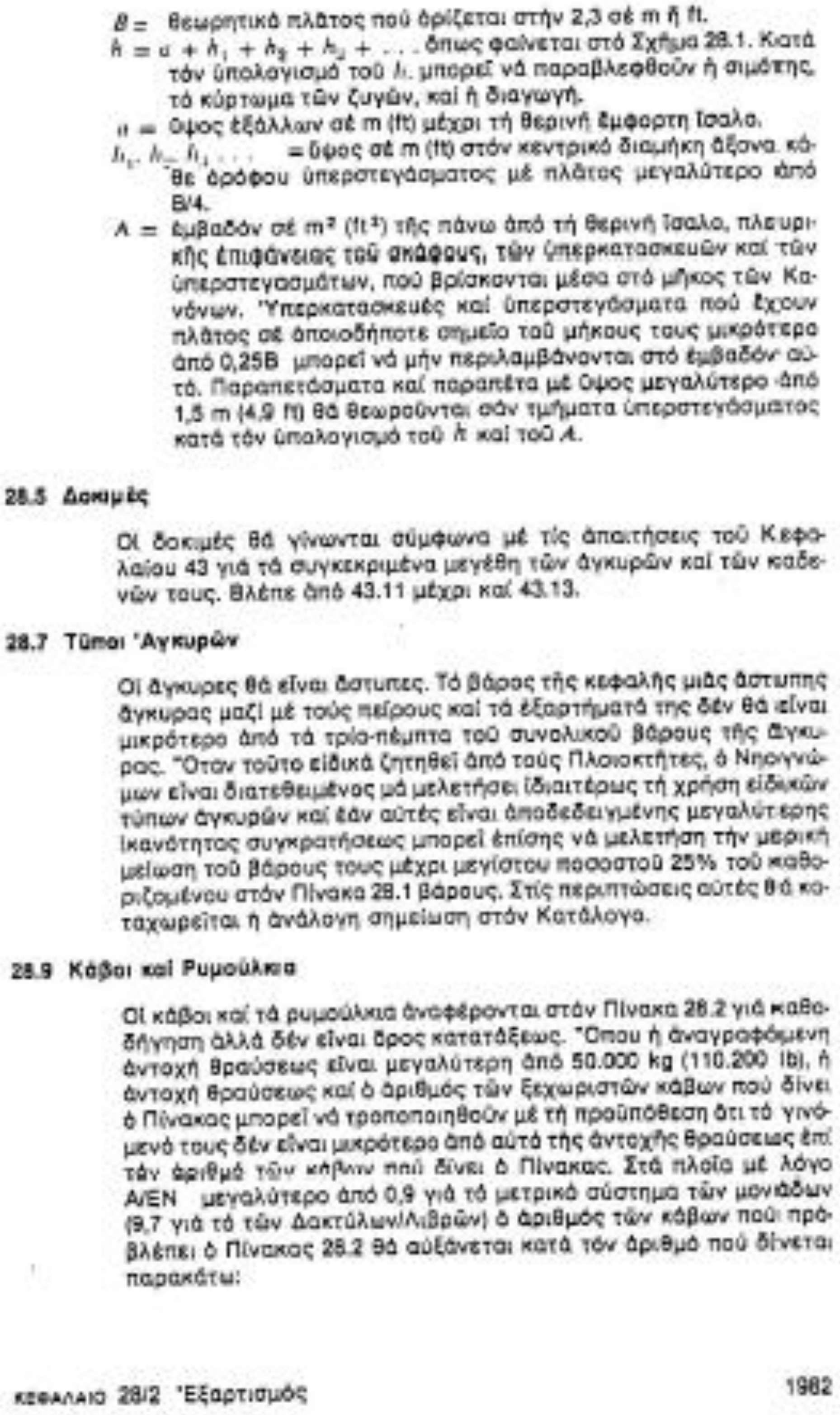
Μονάδες Δακτύλων/Λιβρῶν

$$\text{’Αριθμός ’Εξαρτισμοῦ} = 1{,}012\Delta^{2/3} + 0{,}186Bh + 0{,}0929A$$

Δ = ἐκτόπισμα γάστρας σέ μετρικούς τόννους (μακρούς τόννους) στή θερινή ἔμφορτη ἴσαλο.

ΚΕΦΑΛΑΙΟ 28/1 ’Εξαρτισμός 1982

Picture 45. **Equipment Number 1/5.** Source: (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)



$B =$ θεωρητικό πλάτος πού ὁρίζεται στήν 2,3 σέ m ἤ ft.

$h = a + h_1 + h_2 + h_3 + \ldots$ ὅπως φαίνεται στό Σχῆμα 28.1. Κατά τόν ὑπολογισμό τοῦ h, μπορεῖ νά παραβλεφθοῦν ἡ σιμότης, τό κύρτωμα τῶν ζυγῶν, καί ἡ διαγωγή.

$a =$ ὕψος ἐξάλλων σέ m (ft) μέχρι τή θερινή ἔμφορτη ἴσαλο.

$h_1, h_2, h_3, \ldots$ = ὕψος σέ m (ft) στόν κεντρικό διαμήκη ἄξονα κάθε ὀρόφου ὑπερστεγάσματος μέ πλάτος μεγαλύτερο ἀπό B/4.

$A =$ ἐμβαδόν σέ m^2 (ft^2) τῆς πάνω ἀπό τή θερινή ἴσαλο, πλευρικῆς ἐπιφάνειας τοῦ σκάφους, τῶν ὑπερκατασκευῶν καί τῶν ὑπερστεγασμάτων, πού βρίσκονται μέσα στό μῆκος τῶν Κανόνων. Ὑπερκατασκευές καί ὑπερστεγάσματα πού ἔχουν πλάτος σέ ὁποιοδήποτε σημεῖο τοῦ μήκους τους μικρότερο ἀπό 0,25B μπορεῖ νά μήν περιλαμβάνονται στό ἐμβαδόν αὐτό. Παραπετάσματα καί παραπέτα μέ ὕψος μεγαλύτερο ἀπό 1,5 m (4,9 ft) θά θεωροῦνται σάν τμήματα ὑπερστεγάσματος κατά τόν ὑπολογισμό τοῦ h καί τοῦ A.

28.5 Δοκιμές

Οἱ δοκιμές θά γίνωνται σύμφωνα μέ τίς ἀπαιτήσεις τοῦ Κεφαλαίου 43 γιά τά συγκεκριμένα μεγέθη τῶν ἀγκυρῶν καί τῶν καδενῶν τους. Βλέπε ἀπό 43.11 μέχρι καί 43.13.

28.7 Τῦποι Ἀγκυρῶν

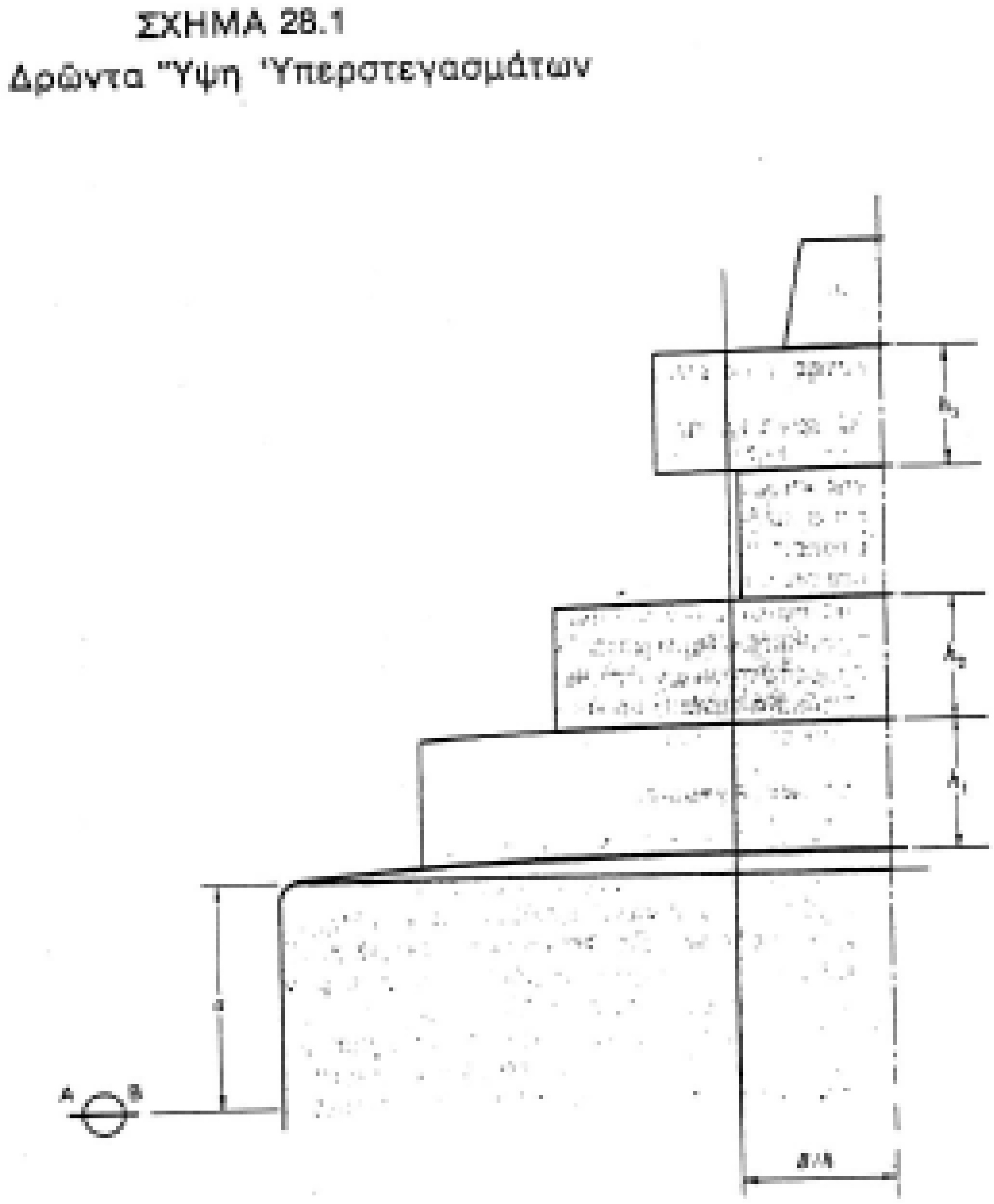
Οἱ ἄγκυρες θά εἶναι ἄστυπες. Τό βάρος τῆς κεφαλῆς μιᾶς ἄστυπης ἄγκυρας μαζί μέ τούς πείρους καί τά ἐξαρτήματά της δέν θά εἶναι μικρότερο ἀπό τά τρία-πέμπτα τοῦ συνολικοῦ βάρους τῆς ἄγκυρας. Ὅταν τοῦτο εἰδικά ζητηθεῖ ἀπό τούς Πλοιοκτῆτες, ὁ Νηογνώμων εἶναι διατεθειμένος νά μελετήσει ἰδιαιτέρως τή χρήση εἰδικῶν τύπων ἀγκυρῶν καί ἐάν αὐτές εἶναι ἀποδεδειγμένης μεγαλύτερης ἱκανότητος συγκρατήσεως μπορεῖ ἐπίσης νά μελετήση τήν μερική μείωση τοῦ βάρους τους μέχρι μεγίστου ποσοστοῦ 25% τοῦ καθοριζομένου στόν Πίνακα 28.1 βάρους. Στίς περιπτώσεις αὐτές θά καταχωρεῖται ἡ ἀνάλογη σημείωση στόν Κατάλογο.

28.9 Κάβοι καί Ρυμούλκια

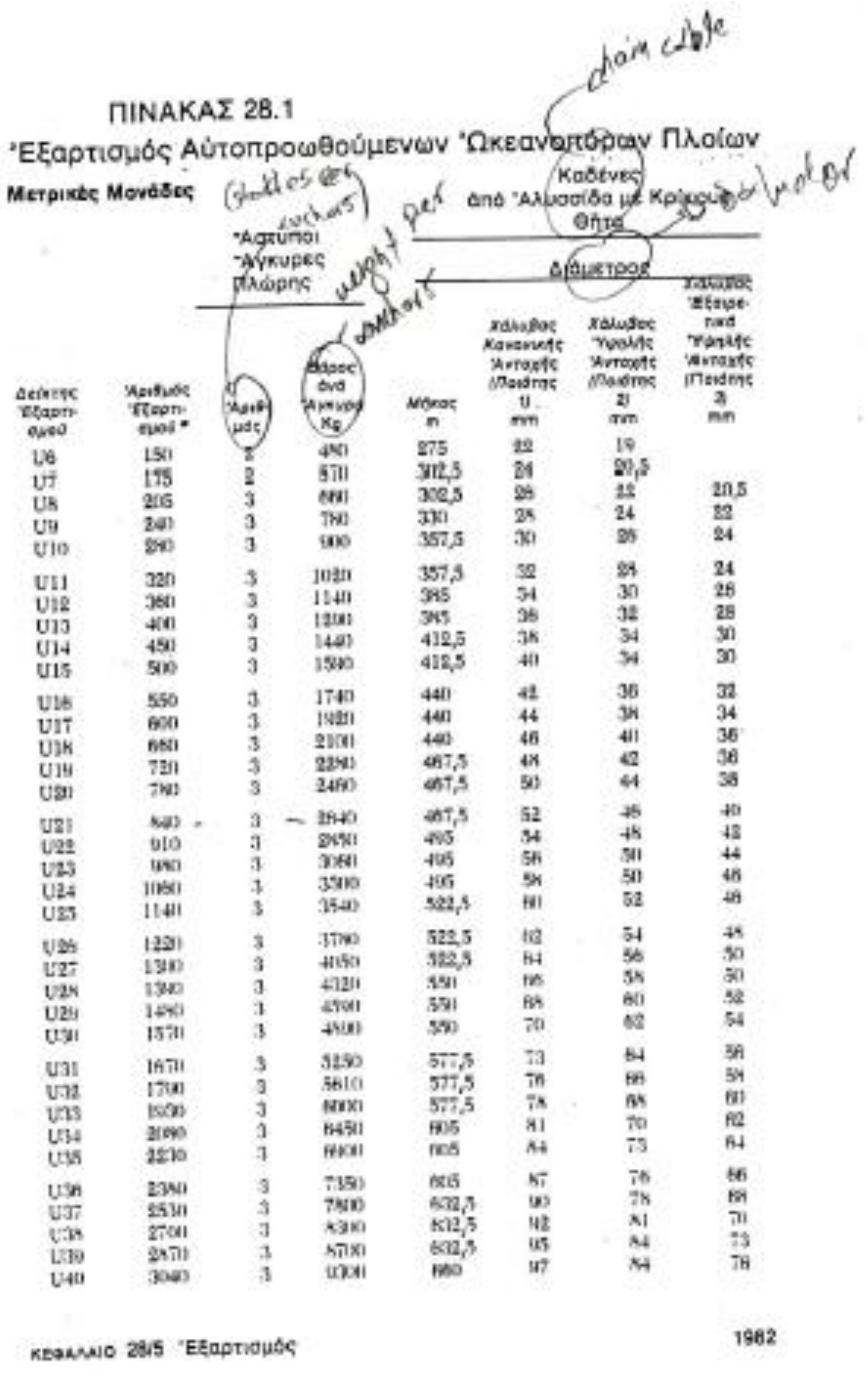
Οἱ κάβοι καί τά ρυμούλκια ἀναφέρονται στόν Πίνακα 28.2 γιά καθοδήγηση ἀλλά δέν εἶναι ὅρος κατατάξεως. Ὅπου ἡ ἀναγραφόμενη ἀντοχή θραύσεως εἶναι μεγαλύτερη ἀπό 50.000 kg (110.200 lb), ἡ ἀντοχή θραύσεως καί ὁ ἀριθμός τῶν ξεχωριστῶν κάβων πού δίνει ὁ Πίνακας μπορεῖ νά τροποποιηθοῦν μέ τή προϋπόθεση ὅτι τά γινόμενά τους δέν εἶναι μικρότερα ἀπό αὐτά τῆς ἀντοχῆς θραύσεως ἐπί τόν ἀριθμό τῶν κάβων πού δίνει ὁ Πίνακας. Στά πλοῖα μέ λόγο A/EN μεγαλύτερο ἀπό 0,9 γιά τό μετρικό σύστημα τῶν μονάδων (9,7 γιά τό τῶν Δακτύλων/Λιβρῶν) ὁ ἀριθμός τῶν κάβων πού προβλέπει ὁ Πίνακας 28.2 θά αὐξάνεται κατά τόν ἀριθμό πού δίνεται παρακάτω:

ΚΕΦΑΛΑΙΟ 28/2 Ἐξαρτισμός 1982

Picture 46. Equipment Number 2/5. Source: (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)



Picture 47. **Equipment Number 3/5.** Source: (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)



chain cable

ΠΙΝΑΚΑΣ 28.1

Ἐξαρτισμός Αὐτοπροωθούμενων Ὠκεανοπόρων Πλοίων

Μετρικές Μονάδες

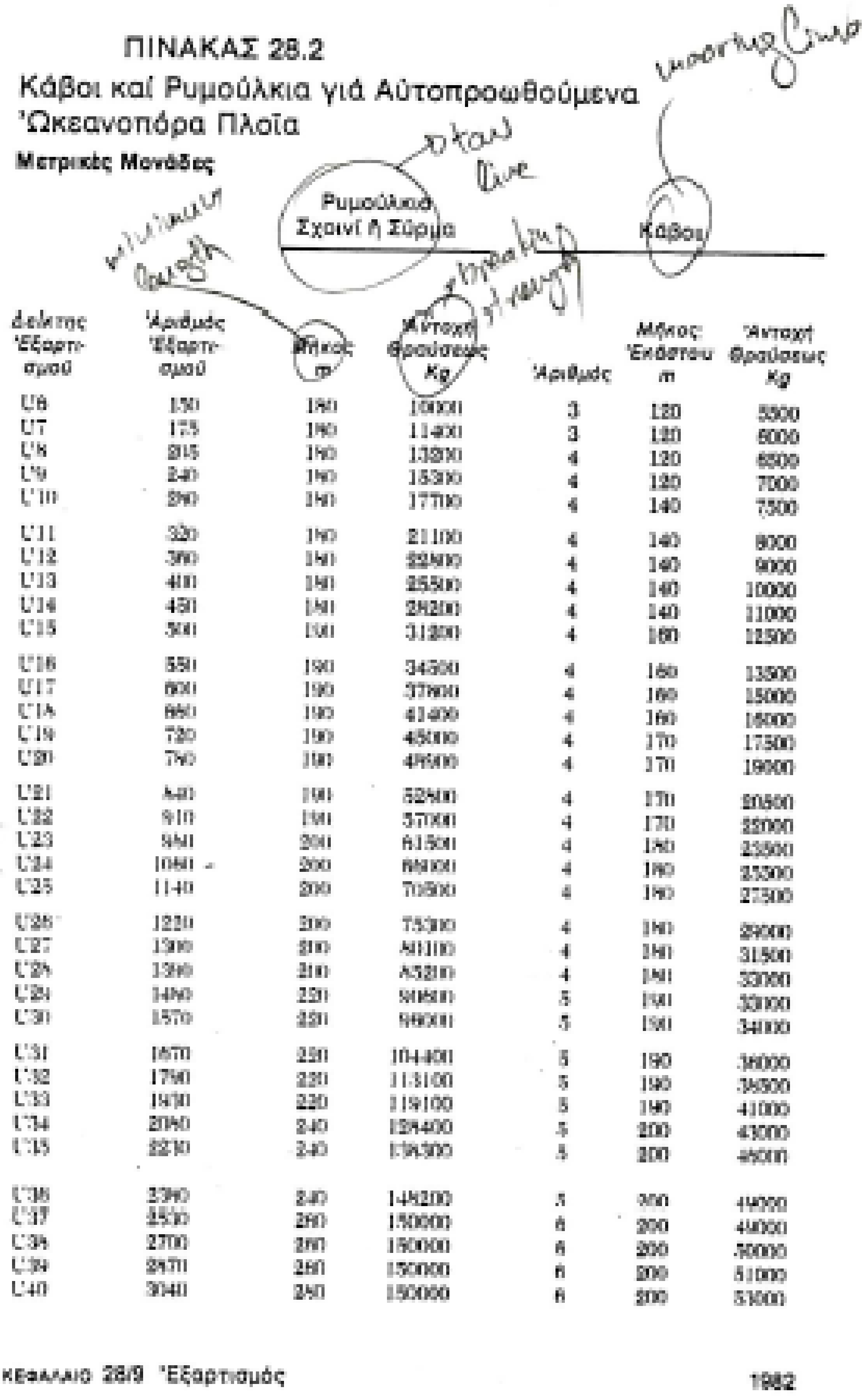
(Stockless anchors)

weight per anchor

Δείκτης Ἐξαρτισμοῦ	Ἀριθμός Ἐξαρτισμοῦ *	Ἄστυποι Ἄγκυρες Πλώρης: Ἀριθμός	Ἄστυποι Ἄγκυρες Πλώρης: Βάρος ἀνά Ἄγκυρα Kg	Καδένες ἀπό Ἀλυσσίδα μέ Κρίκους Θήτα: Μῆκος m	Καδένες: Διάμετρος: Χάλυβας Κανονικῆς Ἀντοχῆς /Ποιότης 1) mm	Καδένες: Διάμετρος: Χάλυβας Ὑψηλῆς Ἀντοχῆς /Ποιότης 2) mm	Καδένες: Διάμετρος: Χάλυβας Ἐξαιρετικά Ὑψηλῆς Ἀντοχῆς /Ποιότης 3) mm
U6	150	2	480	275	22	19	
U7	175	2	570	302,5	24	20,5	
U8	205	3	660	302,5	26	22	20,5
U9	240	3	780	330	28	24	22
U10	280	3	900	357,5	30	26	24
U11	320	3	1020	357,5	32	28	24
U12	360	3	1140	385	34	30	26
U13	400	3	1290	385	36	32	28
U14	450	3	1440	412,5	38	34	30
U15	500	3	1590	412,5	40	34	30
U16	550	3	1740	440	42	36	32
U17	600	3	1920	440	44	38	34
U18	660	3	2080	440	46	40	36
U19	720	3	2280	467,5	48	42	36
U20	780	3	2460	467,5	50	44	38
U21	840	3	2640	467,5	52	46	40
U22	910	3	2850	495	54	48	42
U23	980	3	3060	495	56	50	44
U24	1060	3	3300	495	58	50	46
U25	1140	3	3540	522,5	60	52	48
U26	1220	3	3780	522,5	62	54	48
U27	1300	3	4050	522,5	64	56	50
U28	1390	3	4320	550	66	58	50
U29	1480	3	4590	550	68	60	52
U30	1570	3	4890	550	70	62	54
U31	1670	3	5250	577,5	73	64	56
U32	1790	3	5610	577,5	76	66	58
U33	1930	3	6000	577,5	78	68	60
U34	2080	3	6450	605	81	70	62
U35	2230	3	6900	605	84	73	64
U36	2380	3	7350	605	87	76	66
U37	2530	3	7800	632,5	90	78	68
U38	2700	3	8300	632,5	92	81	70
U39	2870	3	8700	632,5	95	84	73
U40	3040	3	9300	660	97	87	76

ΚΕΦΑΛΑΙΟ 28/5 Ἐξαρτισμός 1982

Picture 48. **Equipment Number 4/5.** Source: (Α. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)



ΠΙΝΑΚΑΣ 28.2

Κάβοι καί Ρυμούλκια γιά Αὐτοπροωθούμενα Ὠκεανοπόρα Πλοῖα

Μετρικές Μονάδες

mooring line

tow line

minimum length

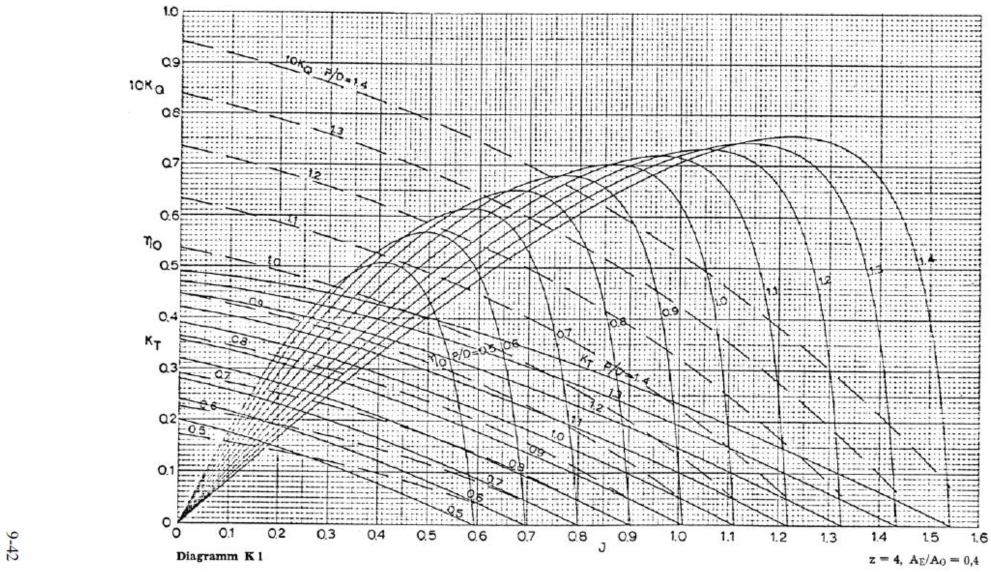
breaking strength

		Ρυμούλκια Σχοινί ἤ Σύρμα		Κάβοι		
Δείκτης Ἐξαρτισμοῦ	Ἀριθμός Ἐξαρτισμοῦ	Μῆκος m	Ἀντοχή Θραύσεως Kg	Ἀριθμός	Μῆκος Ἑκάστου m	Ἀντοχή Θραύσεως Kg
U6	150	180	10000	3	120	5500
U7	175	180	11400	3	120	6000
U8	205	180	13200	4	120	6500
U9	240	180	15300	4	120	7000
U10	280	180	17700	4	140	7500
U11	320	180	21100	4	140	8000
U12	360	180	22800	4	140	9000
U13	400	180	25500	4	140	10000
U14	450	180	28200	4	140	11000
U15	500	180	31200	4	160	12500
U16	550	180	34500	4	160	13500
U17	600	180	37800	4	160	15000
U18	660	180	41400	4	160	16000
U19	720	180	45000	4	170	17500
U20	780	180	48600	4	170	19000
U21	840	180	52800	4	170	20500
U22	910	180	57000	4	170	22000
U23	980	200	61500	4	180	23500
U24	1060	200	66000	4	180	25500
U25	1140	200	70500	4	180	27500
U26	1220	200	75300	4	180	29000
U27	1300	210	80100	4	180	31500
U28	1390	210	85200	4	180	33000
U29	1480	220	90600	5	180	33000
U30	1570	220	96000	5	180	34000
U31	1670	220	104400	5	190	36000
U32	1790	220	113100	5	190	38500
U33	1930	220	119100	5	190	41000
U34	2080	240	128400	5	200	43000
U35	2230	240	138300	5	200	46000
U36	2380	240	148200	5	200	49000
U37	2530	260	150000	6	200	49000
U38	2700	260	150000	6	200	50000
U39	2870	260	150000	6	200	51000
U40	3040	260	150000	6	200	53000

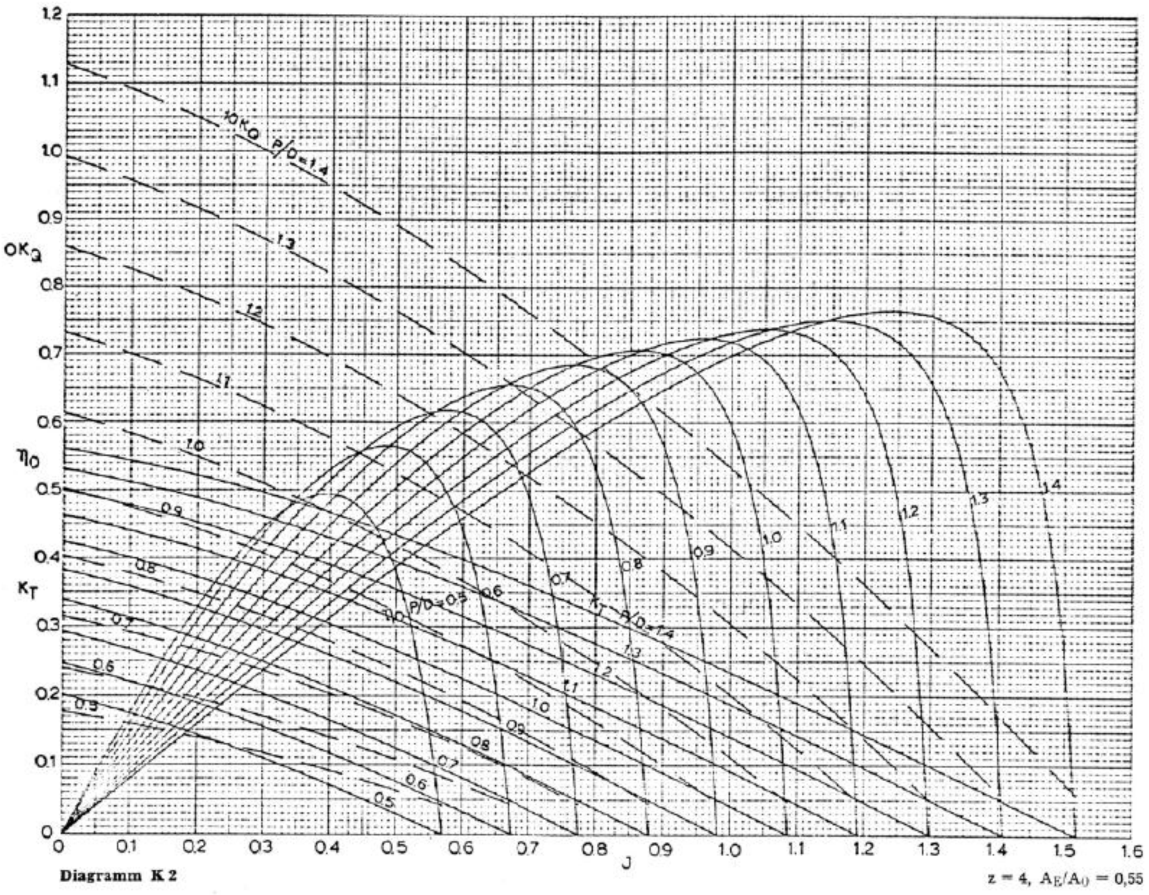
ΚΕΦΑΛΑΙΟ 28/9 Ἐξαρτισμός 1982

Picture 49. **Equipment Number 5/5.** Source: (A. Παπανικολάου et al., ΜΕΛΕΤΗ ΚΑΙ ΕΞΟΠΛΙΣΜΟΣ ΠΛΟΙΟΥ Ι (ΜΕΘΟΔΟΛΟΓΙΑ ΠΡΟΜΕΛΕΤΗΣ) ΣΥΛΛΟΓΗ ΒΟΗΘΗΜΑΤΩΝ, 2005)

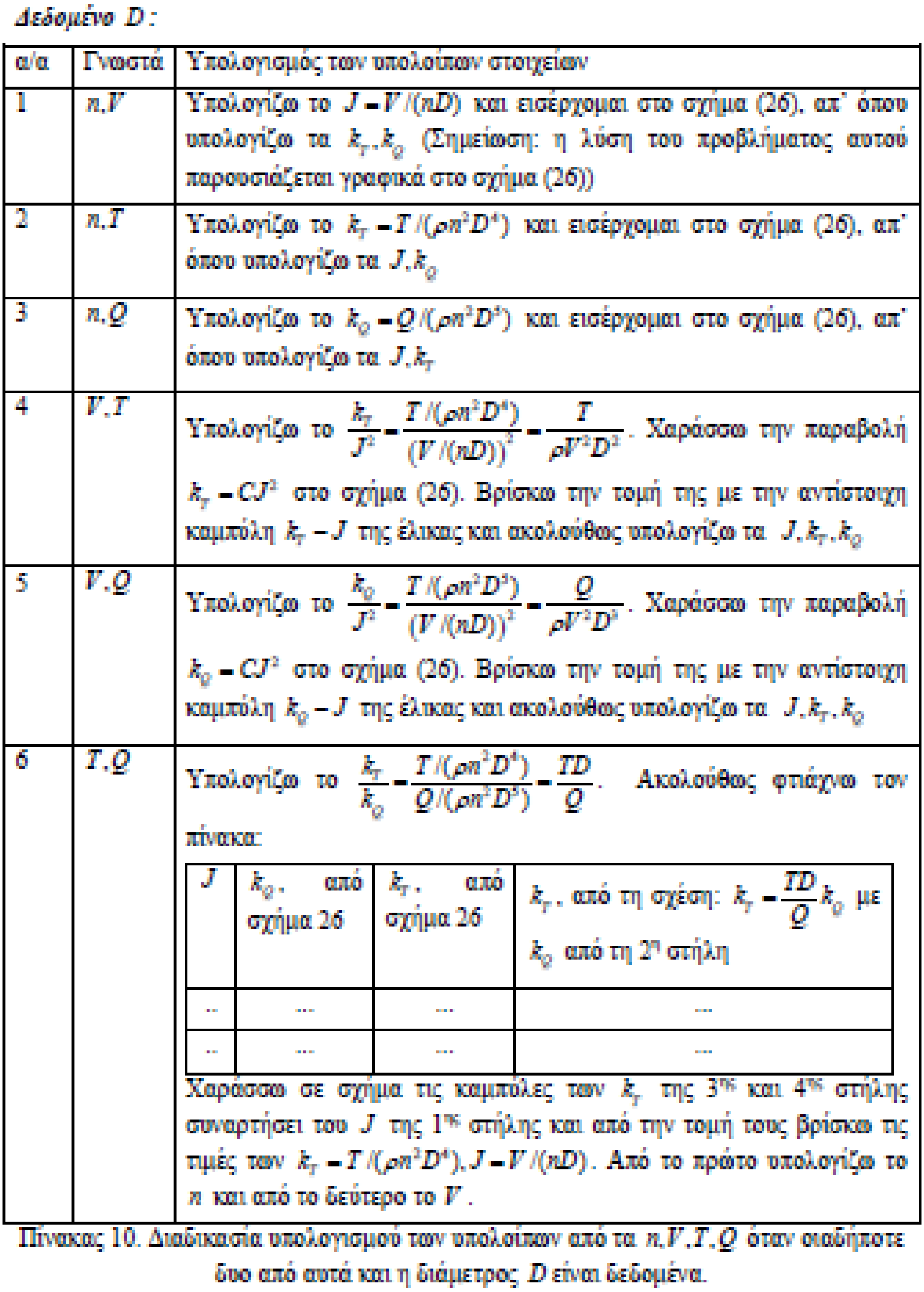
25. Appendix B (Resistance, Powering & Propulsion)



Picture 51. **Wagenigen B Series , z=4, A_E/A_0=0.4.** Source: (Γερασίμου Κ. Πολίτη, 2005)



Picture 52. **Wagenigen B Series , z=4, A_E/A_0=0.55.** Source: (Γερασίμου Κ. Πολίτη, 2005)

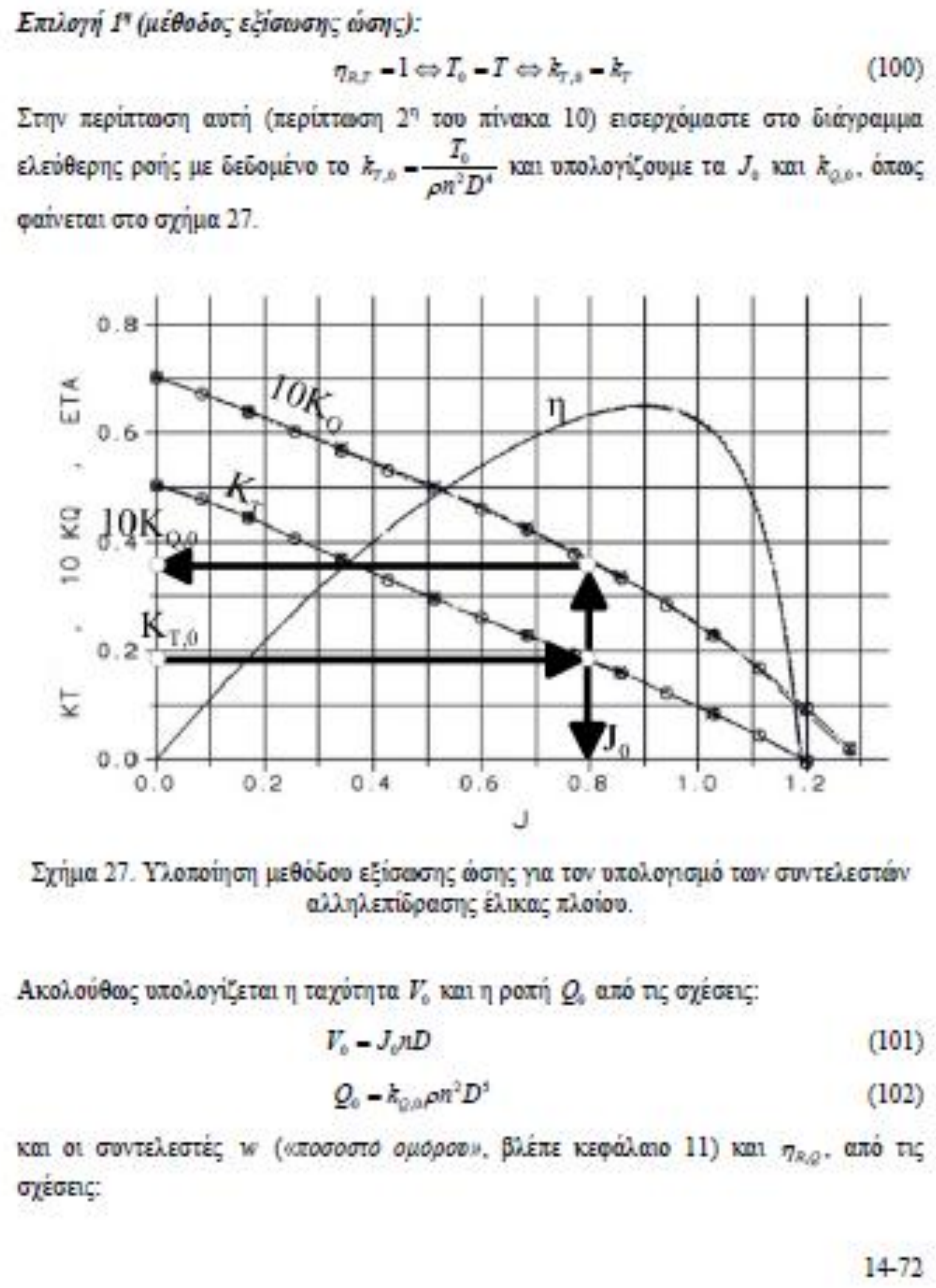


Δεδομένο D:

<table>
<tr><th>α/α</th><th>Γνωστά</th><th>Υπολογισμός των υπολοίπων στοιχείων</th></tr>
<tr><td>1</td><td>n,V</td><td>Υπολογίζω το $J = V/(nD)$ και εισέρχομαι στο σχήμα (26), απ' όπου υπολογίζω τα k_T, k_Q (Σημείωση: η λύση του προβλήματος αυτού παρουσιάζεται γραφικά στο σχήμα (26))</td></tr>
<tr><td>2</td><td>n,T</td><td>Υπολογίζω το $k_T = T/(\rho n^2 D^4)$ και εισέρχομαι στο σχήμα (26), απ' όπου υπολογίζω τα J, k_Q</td></tr>
<tr><td>3</td><td>n,Q</td><td>Υπολογίζω το $k_Q = Q/(\rho n^2 D^5)$ και εισέρχομαι στο σχήμα (26), απ' όπου υπολογίζω τα J, k_T</td></tr>
<tr><td>4</td><td>V,T</td><td>Υπολογίζω το $\frac{k_T}{J^2} = \frac{T/(\rho n^2 D^4)}{(V/(nD))^2} = \frac{T}{\rho V^2 D^2}$. Χαράσσω την παραβολή $k_T = CJ^2$ στο σχήμα (26). Βρίσκω την τομή της με την αντίστοιχη καμπύλη $k_T - J$ της έλικας και ακολούθως υπολογίζω τα J, k_T, k_Q</td></tr>
<tr><td>5</td><td>V,Q</td><td>Υπολογίζω το $\frac{k_Q}{J^2} = \frac{T/(\rho n^2 D^5)}{(V/(nD))^2} = \frac{Q}{\rho V^2 D^3}$. Χαράσσω την παραβολή $k_Q = CJ^2$ στο σχήμα (26). Βρίσκω την τομή της με την αντίστοιχη καμπύλη $k_Q - J$ της έλικας και ακολούθως υπολογίζω τα J, k_T, k_Q</td></tr>
<tr><td>6</td><td>T,Q</td><td>Υπολογίζω το $\frac{k_T}{k_Q} = \frac{T/(\rho n^2 D^4)}{Q/(\rho n^2 D^5)} = \frac{TD}{Q}$. Ακολούθως φτιάχνω τον πίνακα:
<table>
<tr><th>J</th><th>k_Q, από σχήμα 26</th><th>k_T, από σχήμα 26</th><th>k_T, από τη σχέση: $k_T = \frac{TD}{Q} k_Q$ με k_Q από τη 2^η στήλη</th></tr>
<tr><td>..</td><td>...</td><td>...</td><td>...</td></tr>
<tr><td>..</td><td>...</td><td>...</td><td>...</td></tr>
</table>
Χαράσσω σε σχήμα τις καμπύλες των k_T της 3^{ης} και 4^{ης} στήλης συναρτήσει του J της 1^{ης} στήλης και από την τομή τους βρίσκω τις τιμές των $k_T = T/(\rho n^2 D^4), J = V/(nD)$. Από το πρώτο υπολογίζω το n και από το δεύτερο το V.</td></tr>
</table>

Πίνακας 10. Διαδικασία υπολογισμού των υπολοίπων από τα n, V, T, Q όταν οιαδήποτε δυο από αυτά και η διάμετρος D είναι δεδομένα.

Picture 53. **Propeller Behavior Calculation Method 1/2.** Source: (Γερασίμου Κ. Πολίτη, 2005)



Επιλογή 1η (μέθοδος εξίσωσης ώσης):

$$\eta_{R,T} = 1 \Leftrightarrow T_0 = T \Leftrightarrow k_{T,0} = k_T \tag{100}$$

Στην περίπτωση αυτή (περίπτωση 2η του πίνακα 10) εισερχόμαστε στο διάγραμμα ελεύθερης ροής με δεδομένο το $k_{T,0} = \frac{T_0}{\rho n^2 D^4}$ και υπολογίζουμε τα J_0 και $k_{Q,0}$, όπως φαίνεται στο σχήμα 27.

Σχήμα 27. Υλοποίηση μεθόδου εξίσωσης ώσης για τον υπολογισμό των συντελεστών αλληλεπίδρασης έλικας πλοίου.

Ακολούθως υπολογίζεται η ταχύτητα V_0 και η ροπή Q_0 από τις σχέσεις:

$$V_0 = J_0 n D \tag{101}$$

$$Q_0 = k_{Q,0} \rho n^2 D^5 \tag{102}$$

και οι συντελεστές *w* («*ποσοστό ομόρου*», βλέπε κεφάλαιο 11) και $\eta_{R,Q}$, από τις σχέσεις:

14-72

Picture 54. **Propeller Behavior Calculation Method 2/2.** Source: (Γερασίμου Κ. Πολίτη, 2005)

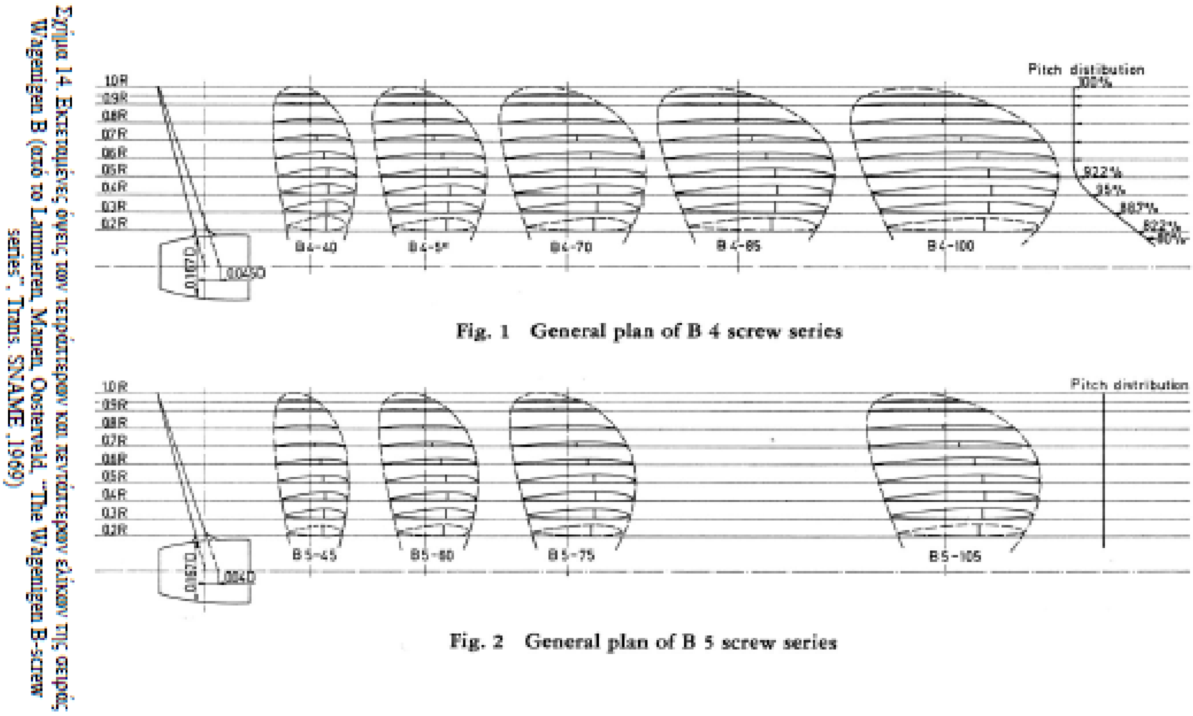
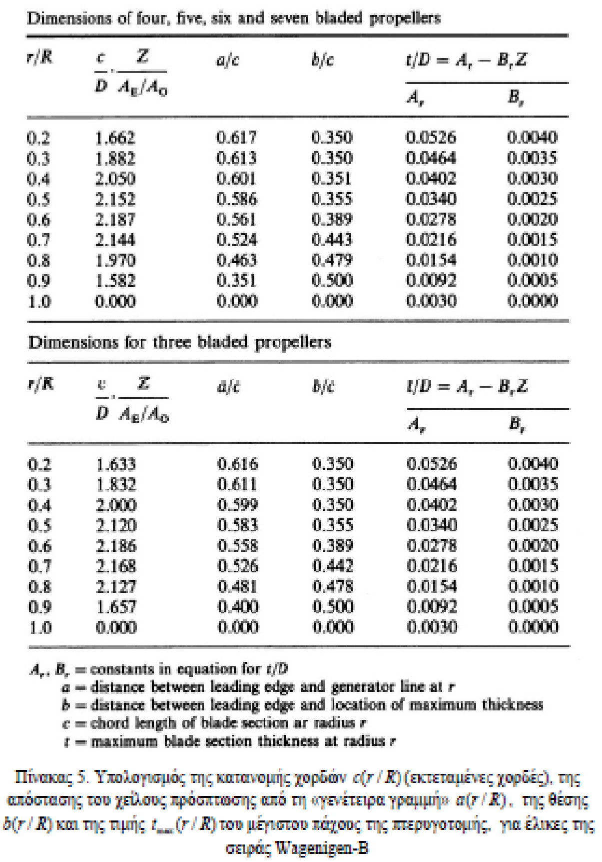

Σχήμα 14. Εκτεταμένες όψεις των τετράπτερων και πεντάπτερων ελίκων της σειράς Wageningen B (από το Lammeren, Manen, Oosterveld, "The Wageningen B-screw series", Trans. SNAME, 1969)

Fig. 1 General plan of B 4 screw series

Fig. 2 General plan of B 5 screw series

Picture 56. **Wagenigen B Series – Pitch Distribution.** **Source: (Γερασίμου Κ. Πολίτη, 2005)**



Dimensions of four, five, six and seven bladed propellers

r/R	$\frac{c}{D}\cdot\frac{Z}{A_E/A_0}$	a/c	b/c	$t/D = A_r - B_r Z$	
				A_r	B_r
0.2	1.662	0.617	0.350	0.0526	0.0040
0.3	1.882	0.613	0.350	0.0464	0.0035
0.4	2.050	0.601	0.351	0.0402	0.0030
0.5	2.152	0.586	0.355	0.0340	0.0025
0.6	2.187	0.561	0.389	0.0278	0.0020
0.7	2.144	0.524	0.443	0.0216	0.0015
0.8	1.970	0.463	0.479	0.0154	0.0010
0.9	1.582	0.351	0.500	0.0092	0.0005
1.0	0.000	0.000	0.000	0.0030	0.0000

Dimensions for three bladed propellers

r/R	$\frac{c}{D}\cdot\frac{Z}{A_E/A_0}$	a/c	b/c	$t/D = A_r - B_r Z$	
				A_r	B_r
0.2	1.633	0.616	0.350	0.0526	0.0040
0.3	1.832	0.611	0.350	0.0464	0.0035
0.4	2.000	0.599	0.350	0.0402	0.0030
0.5	2.120	0.583	0.355	0.0340	0.0025
0.6	2.186	0.558	0.389	0.0278	0.0020
0.7	2.168	0.526	0.442	0.0216	0.0015
0.8	2.127	0.481	0.478	0.0154	0.0010
0.9	1.657	0.400	0.500	0.0092	0.0005
1.0	0.000	0.000	0.000	0.0030	0.0000

A_r, B_r = constants in equation for t/D
a = distance between leading edge and generator line at r
b = distance between leading edge and location of maximum thickness
c = chord length of blade section ar radius r
t = maximum blade section thickness at radius r

Πίνακας 5. Υπολογισμός της κατανομής χορδών $c(r/R)$ (εκτεταμένες χορδές), της απόστασης του χείλους πρόσπτωσης από τη «γενέτειρα γραμμή» $a(r/R)$, της θέσης $b(r/R)$ και της τιμής $t_{max}(r/R)$ του μέγιστου πάχους της πτερυγοτομής, για έλικες της σειράς Wagenigen-B

Picture 57. Wagenigen B Series - Blade Thickness Distribution. Source: (Γερασίμου Κ. Πολίτη, 2005)