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Deliverable 2.1

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Deliverable data

Deliverable No	2.1
Deliverable Title	Sample Ships - Overview
Work Package no: title	WP2.1 Sample Ships

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Lead beneficiary	MW		
Responsible author	Henning Luhmann		
Co-authors	Anna-Lea Routi, Mike Cardinale, Rodolphe Bertin, Gijs Streppel, Juha Kujanpä		
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Peer reviewer 1	Rodolphe Bertin (CdA)		10.07.2019

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The research leading to these results has received funding from the European Union Horizon 2020 Program under grant agreement n° 814753.
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List of symbols and abbreviations

DoA Description of Action

EC European Commission

PMT Project Management Team

SG Steering Group

QA Quality Assurance

GT Gross Tonnage

NAPA Naval Architectural Package

MVZ Main Vertical Zone

FEM Finite Element Method

POB Persons On Board

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1 EXECUTIVE SUMMARY

This report gives an overview of the selected sample ships to be designed and further used in this project.

1.1 Problem definition

- To ensure realistic research for the response to flooding events it is necessary to have sample ships available, which may be used in other work packages of this project as well as made available to the public.
- The basic requirements for the sample ship are to reflect large passenger ships design according to the latest SOLAS amendments (SOLAS2020)

1.2 Technical approach and work plan

- Eight designs have been selected from a number of ships proposed by the designers.
- Special focus has been laid to reflect, with the selection of ships, the widest range of the existing fleet of cruise ships and RoPax ferries
- As there has been the request from WP3 to provide a sample ship including manoeuvring information and a FEM model of the steel structure, which is beyond the original scope of WP2.1 the data of a ship has been provided which has been used in previous EU funded research projects.

1.3 Results

- The selected designs have been created to reach a suitable degree of detail in order to provide reasonable continuation of the work.
- In particular the ships may form a valid basis for the cost benefit assessment of risk control options in WP7.
- None of the selected designs is a real existing ship, but project designs ready to start detailed engineering and construction. The layout and information allows all kind of investigations for damage stability, however detailed information about internal systems, like piping, ducting and cabling cannot be provided.

1.4 Conclusions and recommendation

- The selection of ships has been based on expert judgment and engineering approach.
- The work to be continued in this project is now based on realistic ship designs so that the results may be directly transferred into actual ship designs.

2 INTRODUCTION

2.1 Task/Sub-task text

A number of sample ships of large cruise vessels and RoPax ferries, will be provided by the FLARE participants to reflect typical designs of the current fleet. As the focus is laid on large ships, the following limits will be applied:

Gross tonnage > 10,000 GT

Length > 120m

No of MVZ > 2

It is anticipated that all ships comply with the future SOLAS requirements (SOLAS2020). In this respect, RoPax ships do not need to comply with Stockholm Agreement.

For this project the anticipated degree of detail in the information is based on realistic conceptual designs, conceptual GAP and NAPA model. No detailed information about the systems and components is needed, like the routing of pipes, ducts and cables. If for some work in the following work packages more detailed information is needed, suitable assumptions are to be made by the designers in the provision of such information.

The data of ships used as sample ships in this project is to be prepared to be published, so if existing ships are used a written confirmation by the owner/operator and designers is needed for such use.

The sample ships will be used in the other work packages and also as the basis for the impact of any risk control options.

For each ship a separate deliverable will be created containing a description of the ship, including a general arrangement drawing and the NAPA database.

3 STRATEGY TO SELECT SAMPLE SHIPS

The sample ships used in this project are not existing ships but realistic project designs which have never been materialized. The use of existing ships may cause difficulties with sharing the ship specific information due to intellectual property rights. However, as the project designs have been developed ready to be built they reflect the actual state of the art of these kinds of ships.

The quality of the work in this project depends very much on the sample ships selected as the basis. In this context it is important to understand the existing world fleet of cruise ships and RoPax ferries.

The following graphs show the distribution of ships shown as number of passengers versus the Gross Tonnage as documented in the ShipPax database [1]. As the information of persons on board is not available in public accessible databases the number of passengers has been used to illustrate the world fleet.

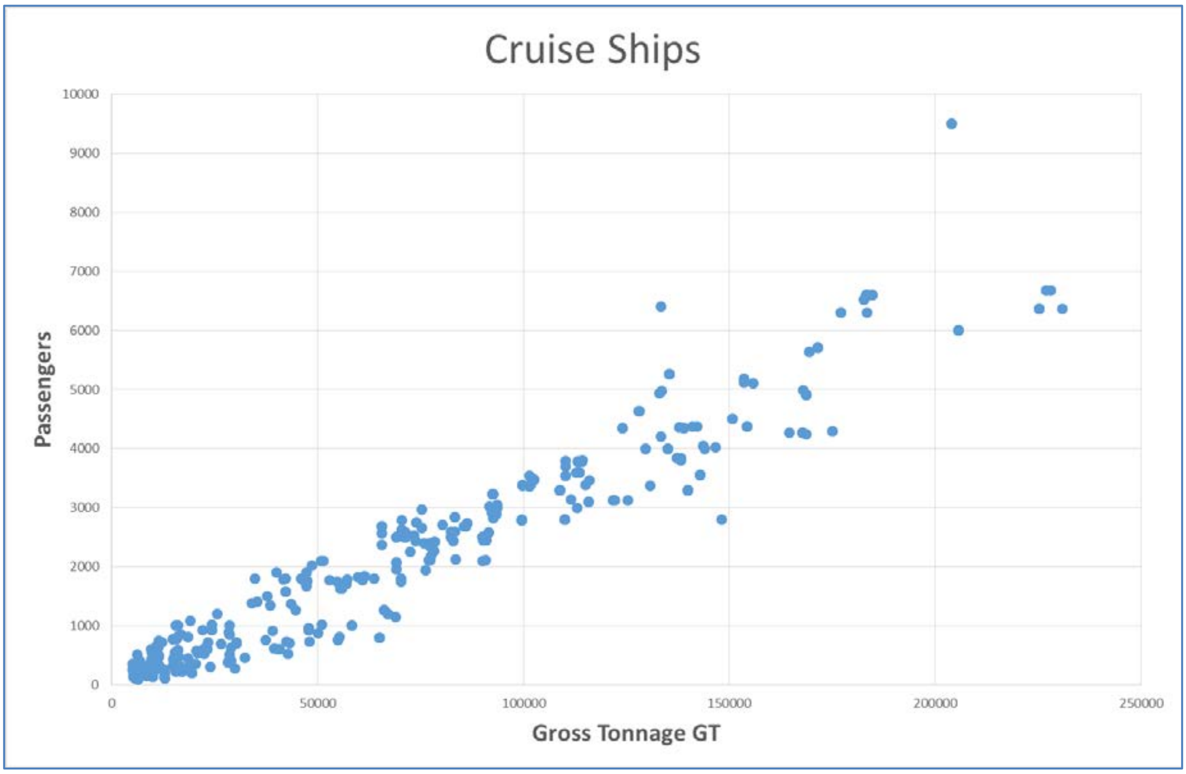

Figure 1 Cruise Ship World Fleet (Source: ShipPax Database)

The distribution of cruise ships is very linear, with increasing number of persons the size of the ship is growing.

To have a suitable sample of this fleet in the project it has been concluded to select 5 ships from approximately 10,000 GT to more than 230,000 GT.

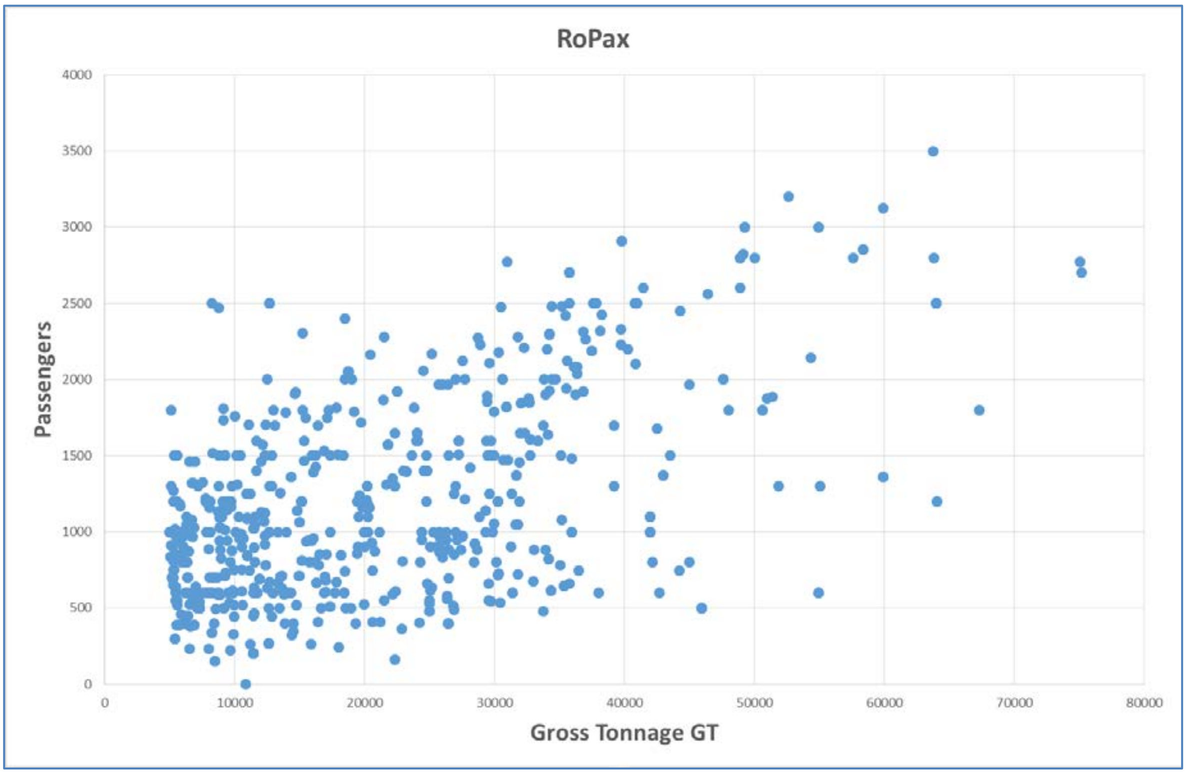

Figure 2 RoPax World Fleet (Source: ShipPax Database)

The distribution of RoPax ferries shows a much greater variety. The reason for this may be different objectives in the design and operation of RoPax ships. Some ships have the focus on cargo transport with a smaller passenger capacity; others are rather designed for a large number of passengers. Another reason may be the specific design of some RoPax ships for one special trade, which may induce design constraints and unusual design concepts.

As the focus in the FLARE project is on the development on measures to enhance safety after flooding these measures may be proven even with a smaller selection of ships.

Therefore only three RoPax ships have been selected between 28,000 GT and 70,000 GT, where the focus is laid on passenger transport.

As the anticipated work in some work packages requires additional information, like a complete finite element model for the assessment of crashworthiness or the effect of operational measures on existing ships information, four additional designs have been provided.

4 CONCLUSIONS AND RECOMMENDATIONS

4.1 Selected ships

The shipyards involved in this project made proposals for suitable designs of cruise ships and RoPax ferries and out of this set of possible designs the sample ships have been selected.

Sample ship no	Shipyard	Type	GT	POB	Comment
1	MT	Cruise	230,000	10,000	LNG, S2020
2	MW	Cruise	130,000	4,500	LNG, S2020
3	CdA	Cruise	95,900	~3,700	S2009, to be updated for S2020
4	CdA	Cruise	41,000	~1,300	S2009, to be updated for S2020
5	FC	Cruise	11,800	478	EMSA3 [2], S2009, to be updated for S2020
6	MT	RoPax	28,500	2,000	LNG, S2020
7	MW	RoPax	70,000	3,700	GOALDS [3] , S2009, to be updated for S2020
8	FC	RoPax	50,000	2,800	S2009+SA, LNG, to be updated for S2020

Table 1 overview of selected sample ships

All ships are design to comply with the latest SOLAS amendments (SOLAS2020) and due to their size with safe return to port requirements. Half of the ship sample is designed for LNG as primary fuel, while two designs (ship #5 and 7) have been used in earlier research projects. This may allow a transparent view on the development of damage stability requirements from SOLAS2009 via SOLAS2020 to any finding in this project.

The information for following additional designs will be provided on request:

Sample ship no	Shipyard	Type	GT	POB	Comment
5a	FC	Cruise	11,800	478	EMSA3, S2009
7a	MW	RoPax	70,000	3,700	GOALDS , S2009
9	MW	Cruise	63,000	2,400	FLOODSTAND [4], extreme Seas [5], S2009

Table 2 Overview of additional designs

With this selection of ships the fleet of cruise ships and RoPax ferries is well represented as shown in the following graphs. The red dots show the final selected designs, while the yellow dots show the available designs. The green dot shows the design #9.

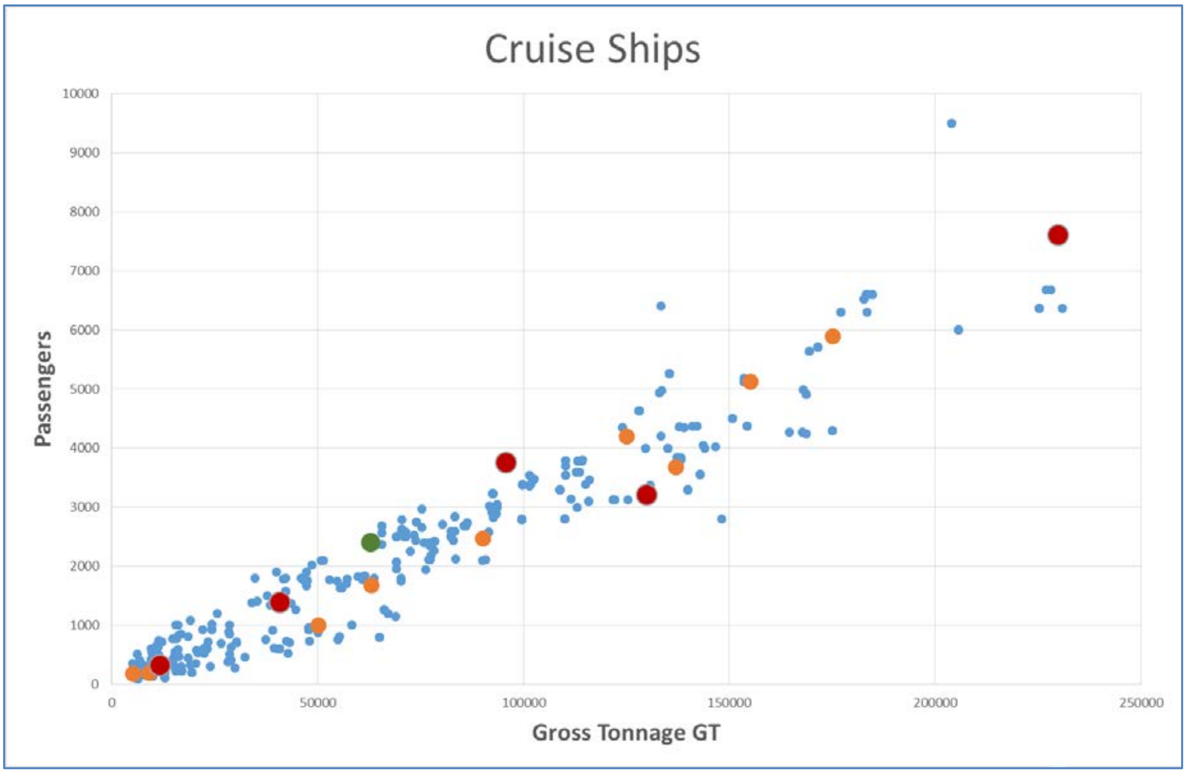

Figure 3 Sample cruise ships vs world fleet

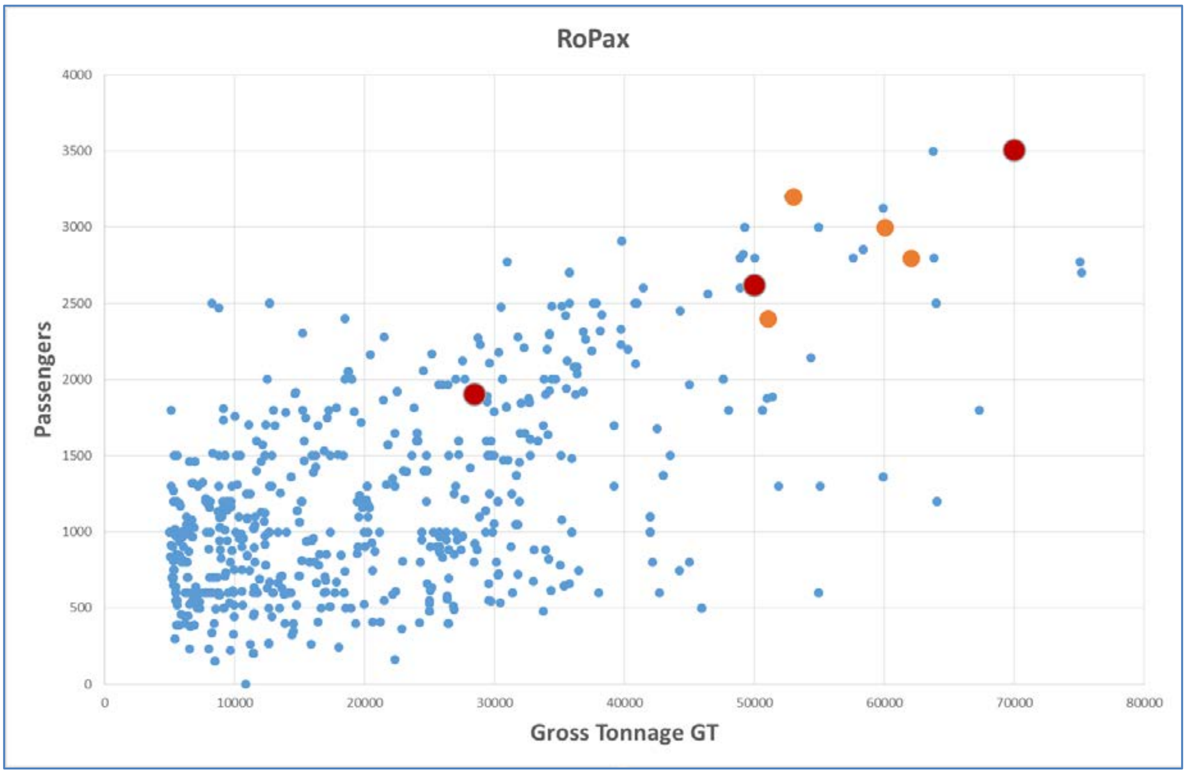

Figure 4 Selected RoPax designs vs world fleet

4.2 Conclusions

A suitable selection of ship designs has been made available for the use in this project. All designs show the current state of the art of its kind of ship and may offer a good possibility to prove the effectiveness of new measures to improve the safety of ships after flooding.

5 REFERENCES

[1] ShipPax database, 2019

[2] Odd Olufsen, *Risk Acceptance Criteria and Risk Based Damage Stability, Final Report, part 2: Formal Safety Assessment, EMSA/OP/10/2013*, Oslo 2015

[3] George Zaraphonitis, *GOALDS Deliverable 6.4 Evaluation of innovative designs,* Athens 2012

[4] Henning Luhmann, *FLOODSTAND deliverable D1.1b Concept Ship Design B,* Papenburg 2009

[5] Bettar el Moctar et al, *EXTREME SEAS deliverable D4.6-UDE, Report describing the implementation of additional nonlinear contribution in existing time domain seakeeping code and calculation examples,* Duisburg 2012

6 ANNEXES

The detailed descriptions of the sample ships are shown in the annexes 1-8. The description of the additional sample ship #9 can be found in [4].

The descriptions are also available as independent document for each ship.

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Deliverable 2.1.1

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Duration: 36 months - Project Start: 01/06/2019 - Project End: 31/05/2022

Deliverable data

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Deliverable Title	Sample Ship no 1		
Work Package no: title	WP2.1 Sample Ships		

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Responsible author	Anna-Lea Routi (MT)		
Co-authors	Olli Salmela (MT), Jussi Blomberg (MT)		
Date of delivery	25-09-2019		
Approved	**Name (partner)**		**Date 25-09-2019**
Peer reviewer 1	Henning Luhmann (MW)		
Peer reviewer 2			

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Version	**Date**	**Description**
V01	**23.09.2019**	Initial version
V02	**25.09.2019**	Contents ready

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1 EXECUTIVE SUMMARY

This report describes sample ship no 1, a large cruise vessel.

1.1 Problem definition

- To ensure realistic research for the response to flooding events it is necessary to have sample ships available, which may be used in other work packages of this project as well as made public available.
- The basic requirements for the sample ship are to reflect large passenger ships design according to the latest SOLAS amendments (SOLAS2020)

1.2 Technical approach and work plan

- A design has been chosen which fulfils the standards of SOLAS 2020.
- To be further future compliant the design is primarily fuelled by liquefied natural gas (LNG).

1.3 Results

- The selected design has been created to reach suitable degree of detail to provide reasonable continuation of the work.
- In particular the ship may form a valid basis for the cost benefit assessment of risk control options in WP7.
- This design is at a pre-contractual stage but ready to for starting detailed engineering and construction. The layout and information allows all kind of investigations for damage stability, however detailed information about internal systems, like piping, ducting and cabling cannot be provided.

1.4 Conclusions and recommendation

- The information provided may form on part of the basic data so that the work can be continued in this project in other work packages.

2 INTRODUCTION

2.1 Task/Sub-task text

A number of sample ships of large cruise vessels and RoPax ferries, will be provided by the FLARE participants to reflect typical designs of the current fleet. As the focus is laid on large ships, the following limits will be applied:

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The data of ships used as sample ships in this project is to be prepared to be published, so if existing ships are used a written confirmation by the owner/operator and designers is needed for such use.

The sample ships will be used in the other work packages and also as the basis for the impact of any risk control options.

For each ship a separate deliverable will be created containing a description of the ship, including a general arrangement drawing and the NAPA database.

3 BUSINESS MODEL

As the basis for the design of this ship a business model has been defined to define the basic parameters which need to be fulfilled. These parameters and the business model will be kept unchanged throughout the design process and also during further design studies during a later stage of this project.

The ship is a large modern cruise vessel with podded propulsion and liquefied natural gas (LNG) as prime fuel (MGO capacity is sufficient as back-up fuel in case no LNG is available).

The ship is designed as a cruise vessel for world-wide operation with a large number of cabins and suitable public rooms, like restaurants, shopping areas, a conference centre, lounges, a spa area and large outside (sun) decks and pool areas. Lanai decks on both sides of the ship are available.

Following main parameters are to be kept to maintain the business model of this vessel:

1. Size of the vessel approx. 230,000 GT with 39 GT / lower berth.
2. Approx. 2,960 passenger cabins with approx. 59% balcony ratio.
3. Approx. 1,180 crew cabins with approx. 2,200 crew berth
4. Total number of persons on board 10,000
5. Public rooms:
    a. Lido restaurant 2,800 m²
    b. Main restaurants 4,000 m²
    c. 10 special restaurants 500 – 600 m² each
    d. Theatre 2,200 m²
    e. Lounges 1,100 and 1,600 m²
    f. Several bars 300 - 500 m²
    g. Spa & Gym 2,000 m²
    h. Retail area 1,500 m²
    i. Casino 2,800 m²
    j. Lanai decks 5,500 m²
    k. Kids & teens 500 m²
    l. Pool & sun deck 13,200 m²
6. Crew messes and recreation areas
7. Provision rooms, storage rooms and workshops according to ship size
8. Restrictions of main dimensions
    a. Length between perpendiculars < 350m
    b. Maximum draught ≤ 9.2m
9. Tank capacities
    a. Liquefied natural gas 4,300 m³
    b. Marine gas Oil 2,400 m³
    c. Potable Water 6,000 m³
10. Deadweight at design draught 13,000 t
    a. 2,000 t liquefied natural gas
    b. 420 t gas oil
    c. 3,300 t potable water
    d. 1000 t treated waste water

e. 900 t grey water
f. 600 t heeling water
g. 200 t lubricating oil
h. 300 t special tanks
i. 250 t technical water
j. 130 t urea solution
k. 1000 t pool water
l. 200 t sundrie items
m. 1,700 t stores and provision
n. 1,000 t crew and passengers

11. Service speed 21.0 knots at 85% propulsion power
12. Operational profile: 7 day eastern Caribbean cruise on LNG only

	Time [h]	Speed [kn]
Low Speed	13.0	9.0
Medium Speed	60.0	18.0
High Speed	50.0	21.0
Port	45.0	0.0

Table 1 Operational profile 7 day eastern Caribbean cruise

4 General Description of the Ship

The ship is a large modern cruise vessel with liquefied natural gas as prime fuel. Capacities are optimized for a 7 day eastern Caribbean cruise with a large number of balcony cabins and suitable public rooms, like restaurants, shopping areas, conference centre, lounges and a spa area. The design is completed by big pool and sun deck areas, making the vessel suitable for worldwide operation.

The propulsion concept is based on triple screw podded propulsion and six dual fuel main engines driving generators. These generators provide the necessary electrical energy for propulsion and the hotel services. The anticipated service speed is with 21.0 kn nowadays relatively high, however the actual service speed may vary with the specific service.

Main dimensions

Length over all	Approx. 373 m
Length between perpendiculars	346.50 m
Subdivision length	366.00 m
Breadth	48.00 m
Design draught	8.80 m
Subdivision draught	9.10 m
Height of bulkhead deck	12.40 m
Number of passengers, max.	7,800
Number of crew	2,200
Max. persons on board	10,000
Gross tonnage	230,000
Deadweight	13,000 t
No of cabins	2,960

Table 2 Main dimensions

4.1 Regulations

The design complies with all relevant IMO rules and regulations applicable for ships with contract after 1 January 2020, which includes following codes.

1. SOLAS1974 as amended, including probabilistic damage stability and "Safe Return to Port" (SOLAS2020)
2. Intact Stability Code (IS Code 2008)
3. Load line Convention
4. MARPOL, including fuel oil tank protection
5. International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code)
6. Marine Labour Convention 2006

4.2 General Arrangement

The following figures show the General Arrangement plan

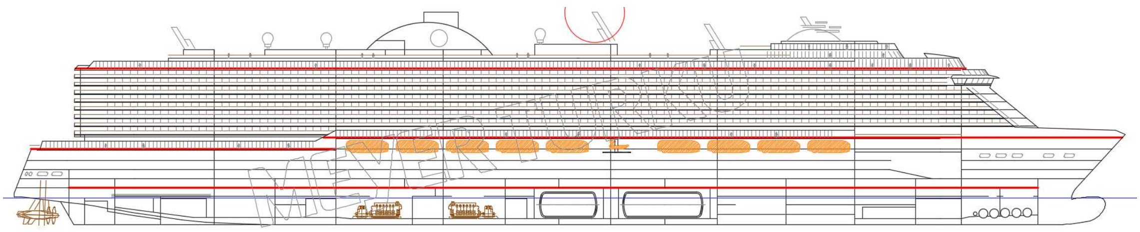


Figure 1 Ship profile

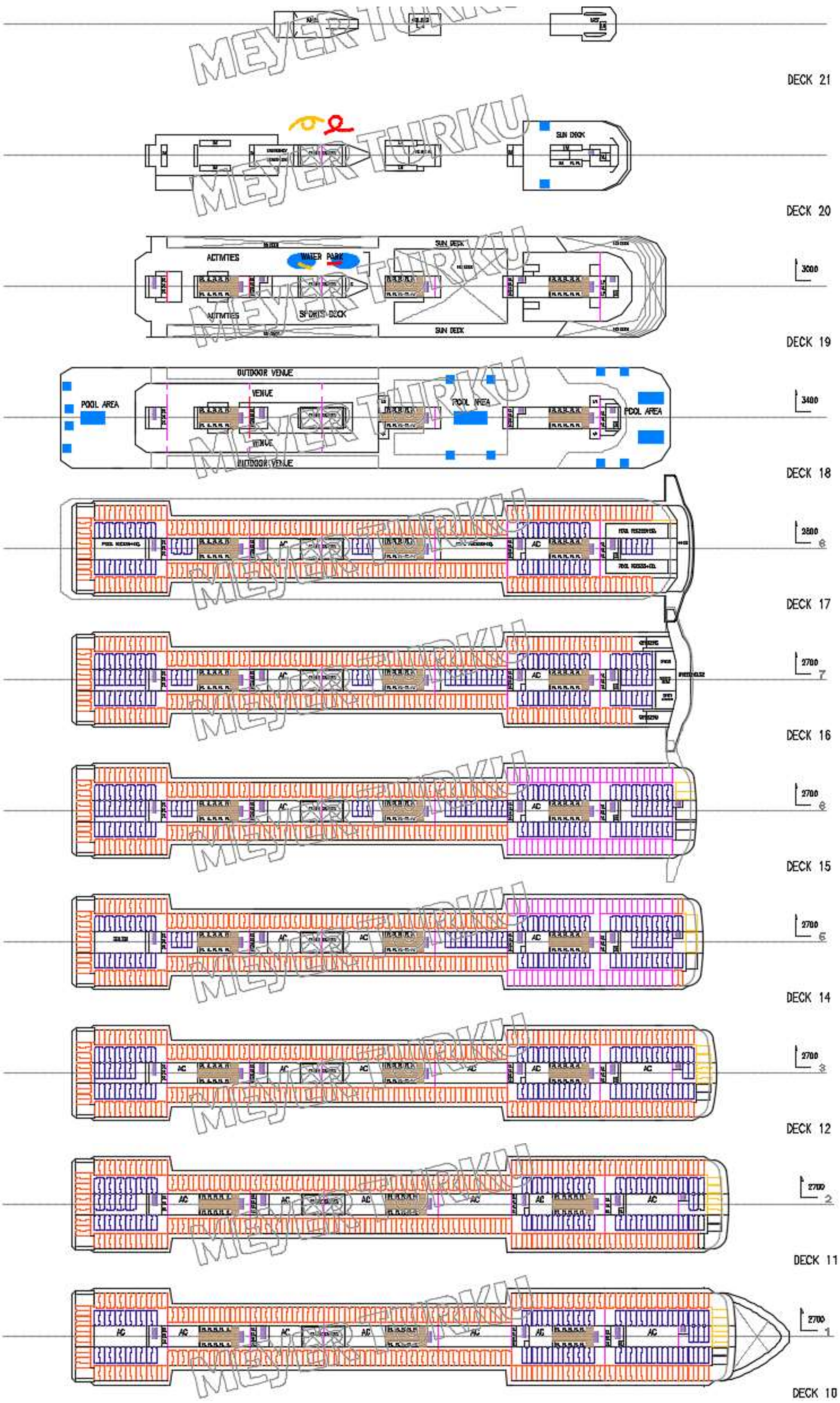


Figure 2 GAP Decks 10 – 21

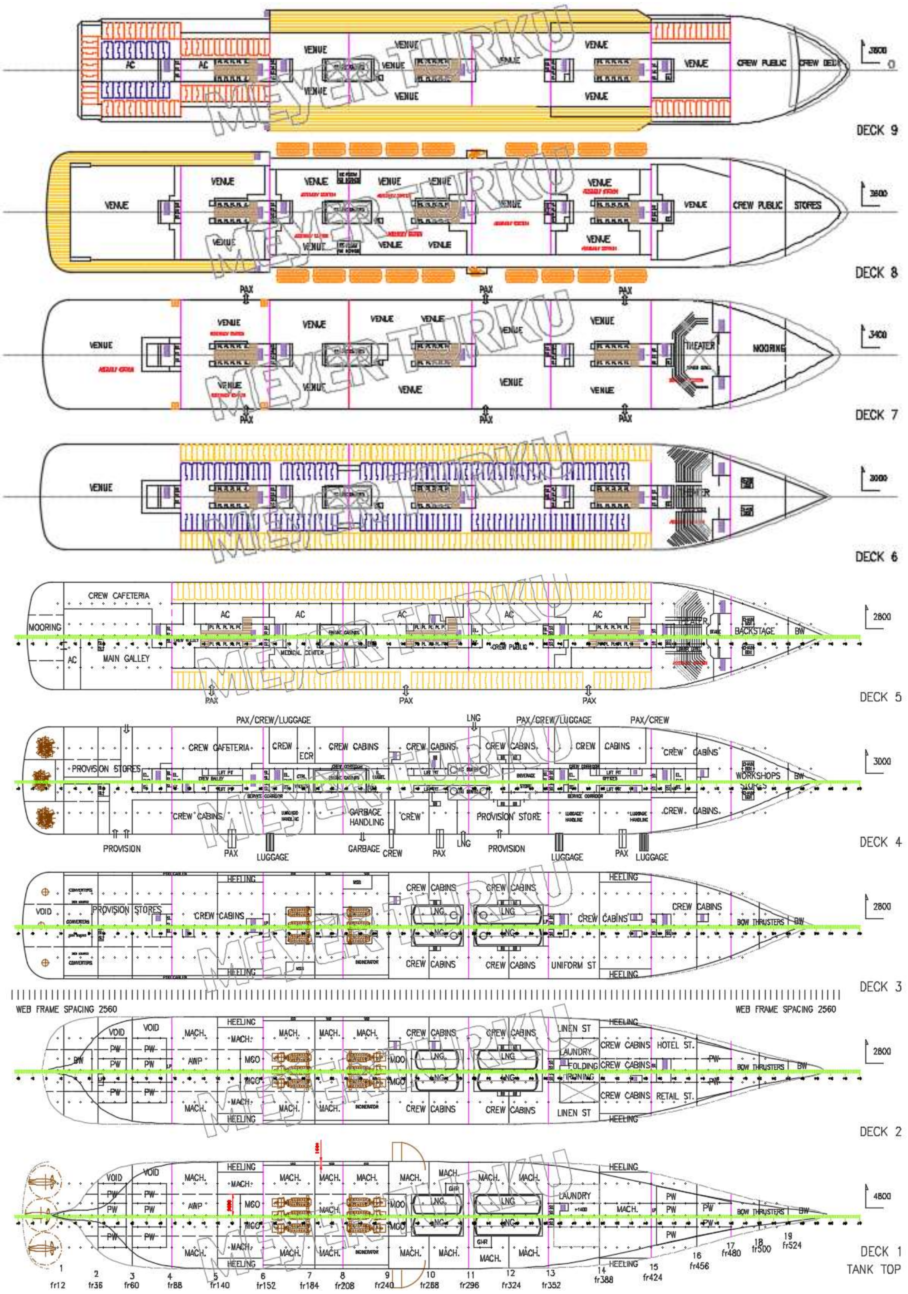


Figure 3 GAP Decks 1 - 9

4.3 Hullform

The ship has a modern hull form with a three-pod propulsion. The bow is of conventional type. The aft hull has a slender skeg and a negative transom.

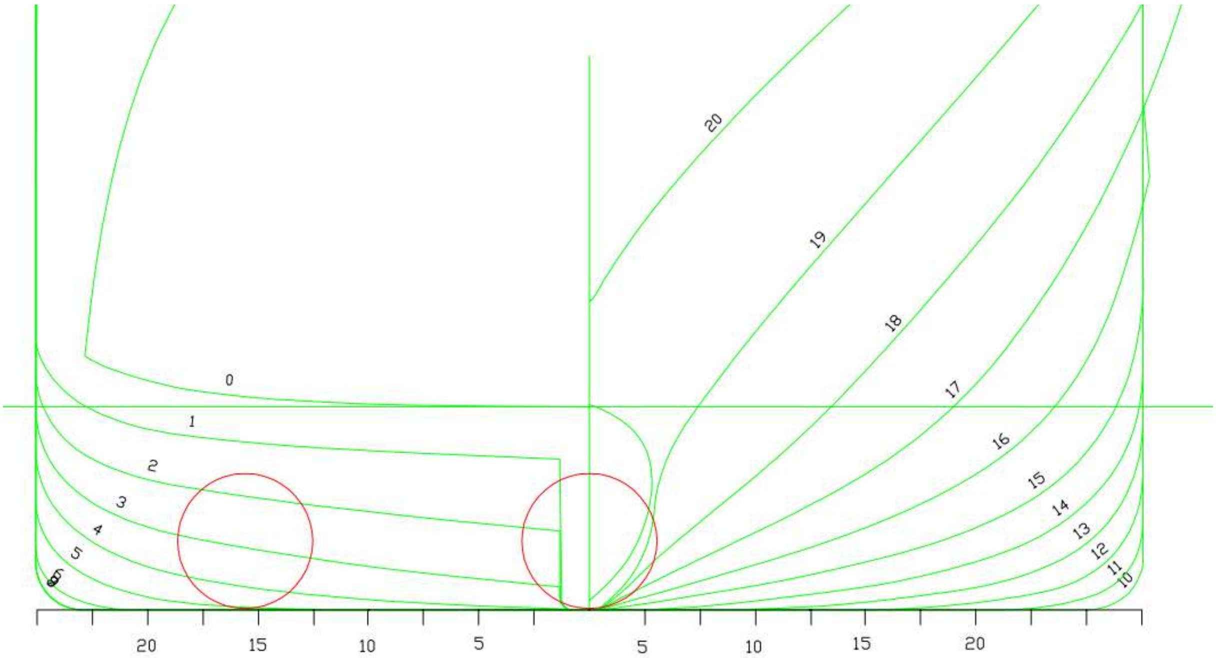


Figure 4 Bodyplan

4.4 Engine configuration

The engine configuration is based on 6 medium sized dual fuel engines, with total installed power 82 MW. There are 3 engines in the aft main engine room and 3 engines in the forward engine room. All engines are driving a generator set.

4.5 Tankplan

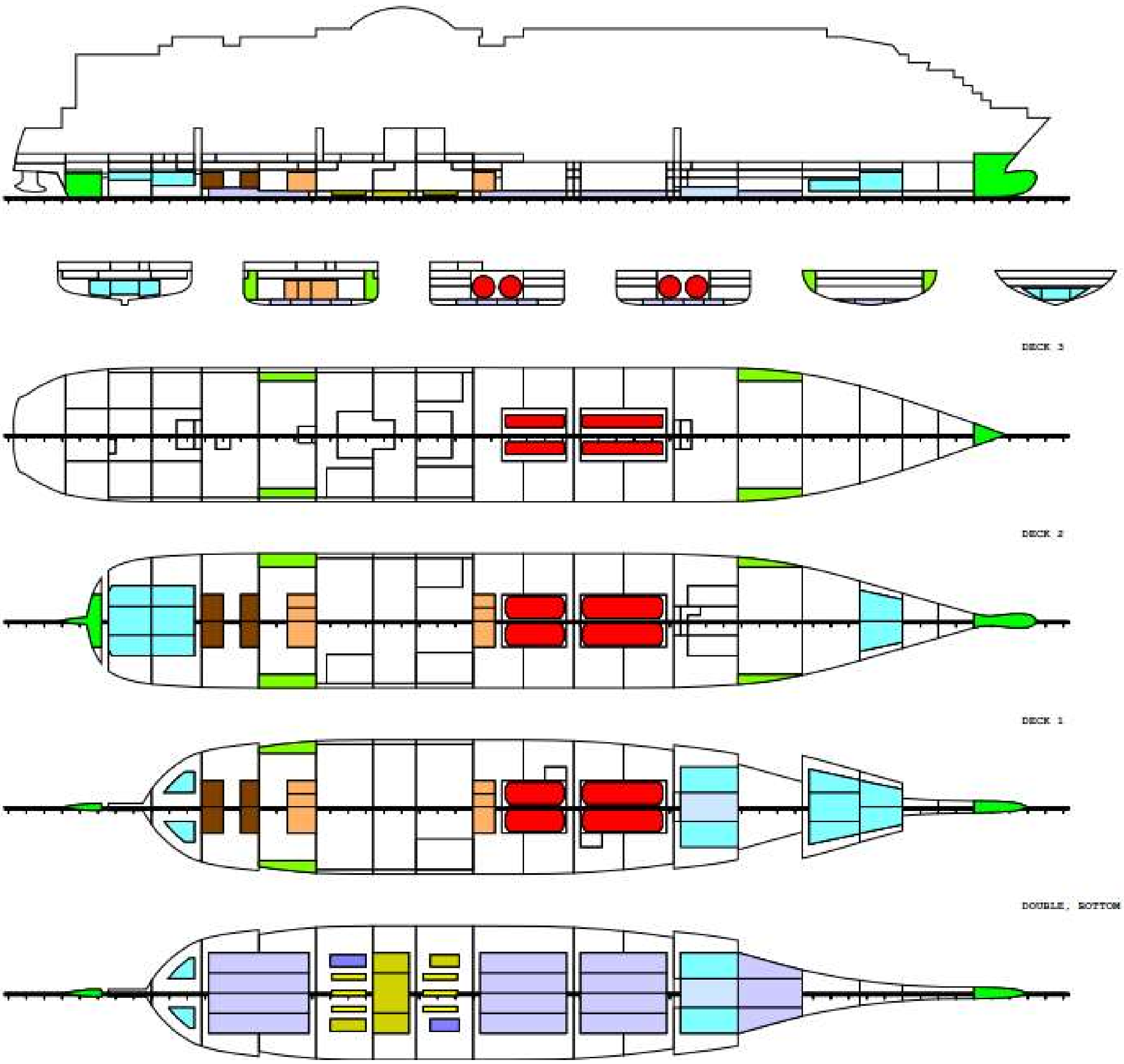


Figure 5 Tankplan

The following capacities are achieved for the various purposes:

NAME	VNET	WEIGHT	LCG	VCG
POTABLE WATER	5697.5 m3	5697.5 t	153.50 m	5.98 m
LAUNDRY CLEAN WATER	1039.4 m3	1039.4 t	237.60 m	1.97 m
HEELING WATER	2752.0 m3	2752.0 t	151.10 m	7.88 m
BALLAST WATER	1633.7 m3	1674.6 t	249.80 m	7.82 m
TECHNICAL WATER	913.5 m3	913.5 t	124.20 m	1.00 m
LIQUIFIED NATURAL GAS	4574.5 m3	2150.0 t	193.80 m	6.50 m
GAS OIL	2245.1 m3	1930.8 t	120.10 m	5.40 m
LUBRICATING OIL	350.0 m3	320.0 t	146.70 m	5.00 m
AWP WATER	1453.8 m3	1453.8 t	66.30 m	6.00 m
TREATED + GREY WATER	6448.3 m3	6448.3 t	153.80 m	1.20 m

Table 3 Tank capacities

4.6 Subdivision

The watertight subdivision follows the needs from the functionality of the spaces, e.g. the size of the LNG tanks as well as the size of the main engine rooms.

Due to redundancy requirements as defined in SOLAS II/2 the engine rooms are quite large and cause special attention for the damage stability. Additionally the engine rooms are separated by an extra compartment and protected by a double hull up to the bulkhead deck (deck 4)

The heeling water tanks are located outside the LNG tank areas, for minimising the heel after damage as far as possible. LNG tanks are fully within B/5. No additional damage analysis for LNG tanks according to IGF code is thus necessary.

There are partial bulkheads on the bulkhead deck to extend the watertight compartmentation. Partial bulkheads will be built mainly above the watertight transversal bulkheads located below the bulkhead deck. Two exemptions are located in provision area in aft and above Aft Main Engine Room, where partial watertight bulkheads are missing. Bulkhead deck in these areas is assumed watertight within the worst positive residual range.

Damage hull is extending three decks above the bulkhead deck (decks 4, 5 and 6). Main fire bulkheads are partially watertight up to deck7. Deck 6 between main fire bulkheads on both sides is watertight within the worst positive residual range.

There is a continuous double bottom with a height of at least 2m.

Figure 6 shows the watertight subdivision and the damage zones used in the SOLAS2020 calculation of the attained index.

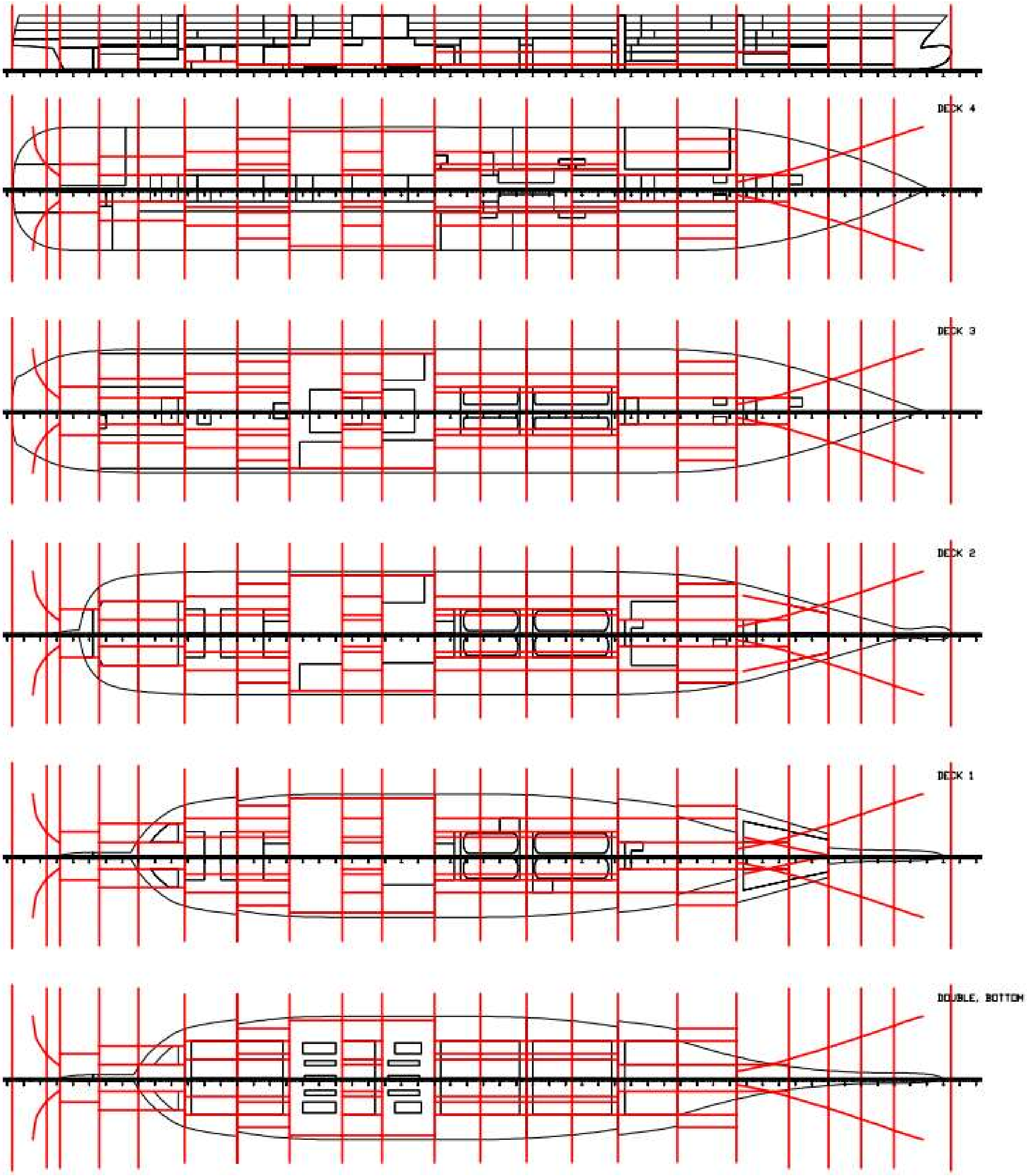


Figure 6 Subdivision used for calculations

5 Hydrodynamics

5.1 Speed power performance

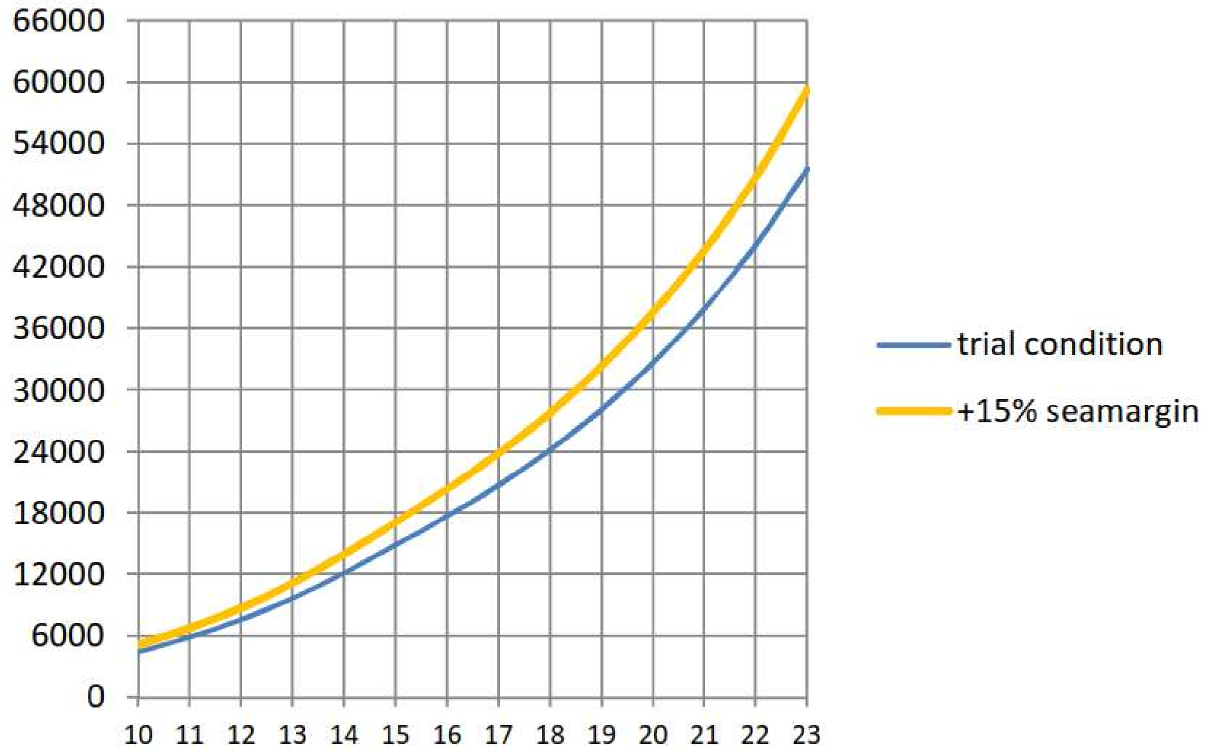


Figure 7 Speed power (kW) performance with the function of ship's speed (knots)

5.2 Manoeuvrability

The ship is equipped with 5 bow thrusters of 4,500 kW each and 3 pods with a total of 55 MW to maintain the required wind speed of 40 kn in the worst direction. For manoeuvring the maximum output of the pods is limited to approx. 10 MW each.

Under the wind speed given above the ship will be able to keep its position without the help of tugs.

6 INTACT STABILITY

6.1 Loading conditions

The table below shows the loading conditions designed for further examination of the sample ship:

NAME	TEXT	DW	FW	BW	GW+TWW	LNG	GO
L2	Design deadweight	13,000 t	3300 t	0 t	1900 t	2000 t	420 t
L3	100% Bunkers, Stores Max Draft	17,453 t	5935 t	0 t	1386 t	2065 t	1890 t
L4	30% Bunkers , Stores	10,445 t	2021 t	300 t	1260 t	630 t	568 t
L5	10% Bunkers , Stores	7434 t	670 t	300 t	782 t	200 t	204 t
L6	10% LNG + 100% MGO, otherwise like L2	12,880 t	3300 t	0 t	1400 t	200 t	1,700 t
L7	10% LNG + MGO, 100% PW, 55% GW+TWW	17,454 t	5837 t	0 t	4336 t	200 t	204 t
L8	20% LNG+MGO, 100 % PW, 20% GW+TWW	15,909 t	5837 t	700 t	1690 t	400 t	404 t
L9	100% LNG+MGO, 20% PW, 55% GW+TWW	16,169 t	1340 t	0 t	3953 t	2107 t	1892 t

NAME	TEXT	Draught	trim/- by stern	GM
L2	Design deadweight	8.80 m	-0.01 m	5.59 m
L3	100% Bunkers,Stores, Max draft	9.10 m	0.01 m	5.89 m
L4	30% Bunkers , Stores	8.62 m	-0.03 m	5.53 m
L5	10% Bunkers , Stores	8.42 m	-0.01 m	5.31 m

L6	10% LNG + 100% MGO, otherwise like L2	8.79 m	0.02 m	5.64 m
L7	10% LNG + 100% MGO, 100%PW, 55% GW+TWW	9.10 m	-0.06 m	6.13 m
L8	20% LNG+MGO, 100 % PW, 20% GW+TWW	9.00 m	0.00 m	5.84 m
L9	100% LNG+MGO, 20% PW, 50% GW+TWW	9.01 m	-0.14 m	6.04 m

Table 4: Loading condition details

6.2 GM Limiting curve

The following diagram shows the summary of the GM requirements together with the actual loading conditions.

There are various limits shown which all need to be complied with, in particular there is the limit of the intact stability criteria as defined by the IS code 2008, and limits for compliance with the damage stability requirements.

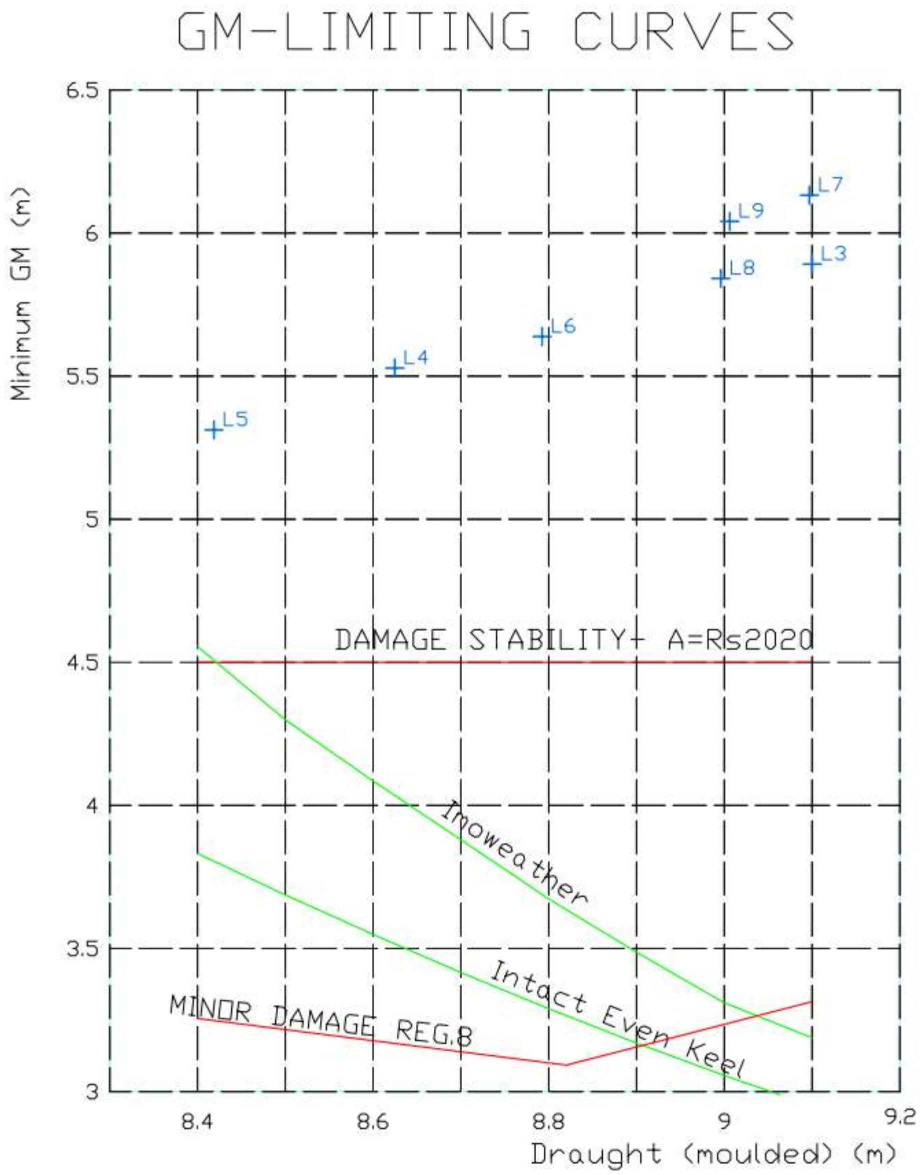


Figure 8 GM limiting curve

7 Results of damage stability calculation

7.1 Attained index vs R

The following tables show the result of the damage stability calculations according SOLAS II-1.

ATTAINED AND REQUIRED SUBDIVISION INDEX

```
Subdivision length             365.981 m
Breadth at the load line        48.000 m
Number of persons N1           7800
Number of persons N2           2200

Required subdivision index R = 0.91730 according to SOLAS 2020

Required subdivision index R = 0.89152 according to SOLAS 2009

Attained subdivision index A = 0.92401
```

INITDAMTAB		T m	GM m	A/R	A	A*WCOEF	WCOEF
DL	DAMP	8.400	4.500	1.04	0.92246	0.09225	0.100
DL	DAMS	8.400	4.500	1.05	0.93575	0.09358	0.100
DP	DAMP	8.820	4.500	1.03	0.92146	0.18429	0.200
DP	DAMS	8.820	4.500	1.05	0.93553	0.18711	0.200
DS	DAMP	9.100	4.500	1.02	0.90983	0.18197	0.200
DS	DAMS	9.100	4.500	1.04	0.92411	0.18482	0.200

Table 5: Attained index for each initial condition

DAMAGES	W*P*V*S	W*P*V
1-ZONE DAMAGES	0.36622	0.36622
2-ZONE DAMAGES	0.42202	0.42148
3-ZONE DAMAGES	0.11946	0.11649
4-ZONE DAMAGES	0.02072	0.01981
A-INDEX TOTAL	0.92841	0.92401

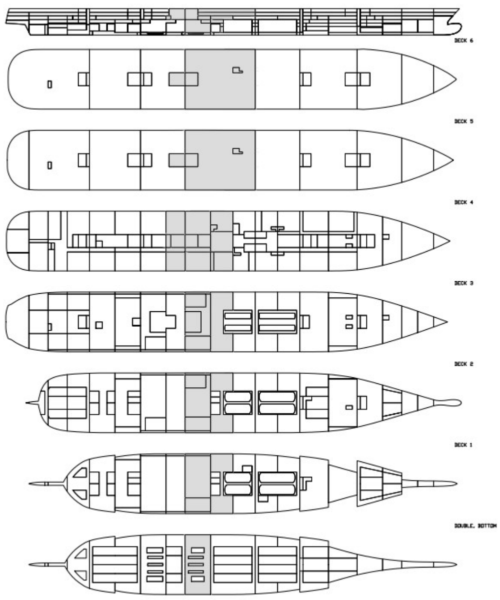
Table 6: Index according to number of zones.

7.2 Reg 8 results

Table 7 GM limits for s>0.9 acc. Reg 8.3

The corresponding GM limiting curves is shown in figure 8.

T	MINGM	MAXKG	DCRI	DAM
8.40	3.25546	26.99015	S-REG8	MP10-11.1.0-1
8.82	3.09240	26.37780	S-REG8	MP10-11.1.0-1
9.10	3.31406	25.70180	S-REG8	MP15-16.1.0



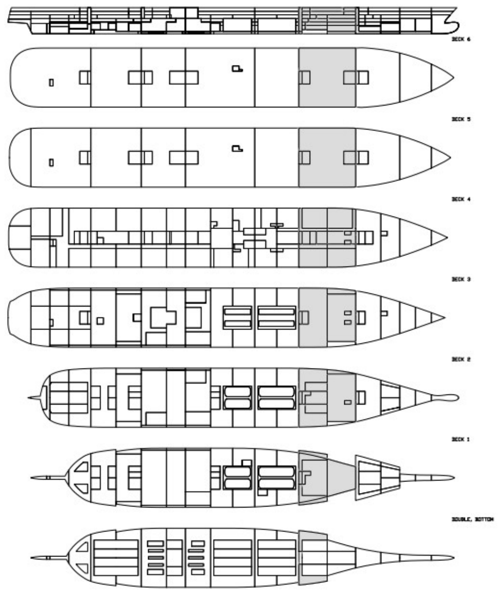


Figure 9 Worst Case MP10-11.1.0-1 **Worst Case MP15-16.1.0**

7.3 Results non-zonal approach

In addition to the standard damage stability results the attained index following the non-zonal approach [1] has been calculated for collision, bottom grounding and side grounding/contact.

As the basis the SOLAS parameters for draughts, permeability and s-factor have been used. For each of the three categories of flooding events 50,000 breaches have been created.

Initial condition	Draught	Attained Index Collision	Attained Index Bottom grounding	Attained Index Side grounding/contact
DL	8.400	0.95802	0.92708	0.89358
DP	8.820	0.95066	0.92298	0.88862
DS	9.100	0.94575	0.91934	0.88209

Table 8 Attained index acc. non-zonal approach

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The information shown in this document and the associated files define a state-of-the-art large cruise vessel using latest knowledge for fulfilling the highest (safety and environmental) standards for passenger vessels.

REFERENCES

[1] Gabriele Bulian et al, *Considering collision, bottom grounding and side grounding/contact in a common non-zonal framework*, Proceedings of the 17th International Ship Stability Workshop, Helsinki 2019

ADDITIONAL INFORMATION

Following information is available as separated files:

- General Arrangement Drawing (pdf and dwg format)
- Napa data base, including hull form and internal geometry, loading conditions and damage stability data [NAPA db)

Acronym: FLARE
Project full title: Flooding Accident REsponse
Grant agreement No. 814753
Coordinator: BALance Technology Consulting GmbH

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Duration: 36 months - Project Start: 01/06/2019 - Project End: 31/05/2022

Deliverable data

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Co-authors			
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Peer reviewer 1	Anna-Lea routi (MT)		
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The research leading to these results has received funding from the European Union Horizon 2020 Program under grant agreement n° 814753.
This report reflects only the author's view. INEA is not responsible for any use that may be made of the information it contains.

CONTENTS

List of symbols and abbreviations

SOLAS	International convention for the Safety of Life at Sea
NAPA	Naval Architectural Package
GT	Gross Tonnage
MVZ	Main Vertical Zone
GM	Metacentric height in meters
DCRI	Damage criterion
R-Index	Required damage stability index acc. SOLAS reg. 7
A-Index	Attained damage stability index acc. SOLAS reg. 7
VNET	Net volume in cubic meters
LCG	Longitudinal center of gravity in meters
VCG	Vertical center of gravity in meters

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1 EXECUTIVE SUMMARY

This report describes sample ship no 2, a large cruise vessel.

1.1 Problem definition

- To ensure realistic research for the response to flooding events it is necessary to have sample ships available, which may be used in other work packages of this project as well as made public available.
- The basic requirements for the sample ship are to reflect large passenger ships design according to the latest SOLAS amendments (SOLAS2020)

1.2 Technical approach and work plan

- A design has been chosen which fulfils the standards of SOLAS 2020.
- To be further future compliant the design is primarily fuelled by liquefied natural gas (LNG).

1.3 Results

- The selected design has been created to reach suitable degree of detail to provide reasonable continuation of the work.
- In particular the ship may form a valid basis for the cost benefit assessment of risk control options in WP7.
- This design is at a pre-contractual stage but ready to start detailed engineering and construction. The layout and information allows all kind of investigations for damage stability, however detailed information about internal systems, like piping, ducting and cabling cannot be provided.

1.4 Conclusions and recommendation

- The information provided may form on part of the basic data so that the work can be continued in this project in other work packages.

2 INTRODUCTION

2.1 Task/Sub-task text

A number of sample ships of large cruise vessels and RoPax ferries, will be provided by the FLARE participants to reflect typical designs of the current fleet. As the focus is laid on large ships, the following limits will be applied:

Gross tonnage > 10,000 GT

Length > 120m

No of MVZ >2

It is anticipated that all ships comply with the future SOLAS requirements (SOLAS2020). In this respect, RoPax ships do not need to comply with Stockholm Agreement.

For this project the anticipated degree of detail in the information is based on realistic conceptual designs, conceptual GAP and NAPA model. No detailed information about the systems and components is needed, like the routing of pipes, ducts and cables. If for some work in the following work packages more detailed information is needed, suitable assumptions are to be made by the designers in the provision of such information.

The data of ships used as sample ships in this project is to be prepared to be published, so if existing ships are used a written confirmation by the owner/operator and designers is needed for such use.

The sample ships will be used in the other work packages and also as the basis for the impact of any risk control options.

For each ship a separate deliverable will be created containing a description of the ship, including a general arrangement drawing and the NAPA database.

3 BUSINESS MODEL

As the basis for the design of this ship a business model has been defined to define the basic parameters which need to be fulfilled. These parameters and the business model will be kept unchanged throughout the design process and also during further design studies during a later stage of this project.

The ship is a large modern cruise vessel with podded propulsion and liquefied natural gas (LNG) as prime fuel (MGO capacity is sufficient as back-up fuel in case no LNG is available).

The ship is designed as a cruise vessel for world-wide operation with a large number of cabins and suitable public rooms, like restaurants, shopping areas, conference centre, lounges, a spa area and large outside (sun) decks and pool areas. In the centre of the vessel a big atrium is available.

Following main parameters are to be kept to maintain the business model of this vessel:

1. Size of the vessel approx. 130,000 GT with > 40 GT / lower berth.
2. Approx. 1620 passenger cabins with approx. 88% balcony ratio.
3. Approx. 740 crew cabins with approx. 1300 crew berth
4. Total number of persons on board 4940
5. Public rooms:
    a. Lido restaurant 1,800 m²
    b. 8 special restaurants 500 – 600 m² each
    c. 1 special restaurant < 100 m²
    d. Theatre 1,400 m²
    e. Cinema 70 m²
    f. Lounge 700 m²
    g. Bar 1200 m²
    h. Spa & Gym 1,750 m²
    i. Retail area 1,000 m²
    j. Casino 700 m²
    k. Atrium 4,000 m²
    l. Kids & teens 375 m²
    m. Pool & sun deck 10,000 m²
6. Crew mess and recreation areas
7. Provision rooms, storage rooms and workshops according to ship size
8. Restrictions of main dimensions
    a. Length between perpendiculars < 300m
    b. Maximum draught ≤ 8.50m
9. Tank capacities
    a. Liquefied natural gas 2,800 m³
    b. Marine gas Oil 1,200 m³
    c. Potable Water 3,300 m³
10. Deadweight at design draught 10,200 t
    a. 1,200 t liquefied natural gas
    b. 1,000 t gas oil
    c. 2,700 t potable water

d. 405 t treated waste water
e. 650 t grey water
f. 1,000 t heeling water
g. 200 t lubricating oil
h. 250 t special tanks
i. 200 t technical water
j. 150 t urea solution
k. 250 t pool water
l. 130 t sundrie items
m. 1,420 t stores and provision
n. 645 t crew and passengers

11. Service speed 22.0 knots at 85% propulsion power
12. Operational profile: 7 day eastern Caribbean cruise on LNG only

	Time [h]	Speed [kn]
Low Speed	13.0	9.0
Medium Speed	60.0	18.0
High Speed	50.0	21.0
Port	45.0	0.0

Table 1 Operational profile 7 day eastern Caribbean cruise

4 GENERAL DESCRIPTION OF THE SHIP

The ship is a large modern cruise vessel with liquefied natural gas as prime fuel. Capacities are optimized for a 7 day eastern Caribbean cruise with a large number of balcony cabins and suitable public rooms, like restaurants, shopping areas, conference centre, lounges and a spa area. The design is completed by big pool and sun deck areas, making the vessel suitable for worldwide operation.

The propulsion concept is based on twin screw podded propulsion and 5 dual fuel main engines driving generators. These generators provide the necessary electrical energy for propulsion and the hotel services. The anticipated service speed is with 22.0kn nowadays relatively high, however the actual service speed may vary with the specific service.

Main dimensions

Length over all	Approx. 308 m
Length between perpendiculars	299.40 m
Subdivision length	307.711 m
Breadth	39.80 m
Subdivision draught	8.50 m
Height of bulkhead deck	11.80 m
Number of passengers (double occupancy) Number of passengers (max.)	3,238 3,640
Number of crew	1,300
Max. persons on board	4,940
Gross tonnage	130,000
Deadweight	10,200 t
No of cabins	1,619

Table 2 Main dimensions

4.1 Regulations

The design complies with all relevant IMO rules and regulations applicable for ships with contract after 1 January 2020, which includes following codes.

1. SOLAS1974 as amended, including probabilistic damage stability and "Safe Return to Port" (SOLAS2020)
2. Intact Stability Code (IS Code 2008)
3. Load line Convention
4. MARPOL, including fuel oil tank protection
5. International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code)
6. Marine Labour Convention 2006

4.2 General Arrangement

The following figures show the General Arrangement plan

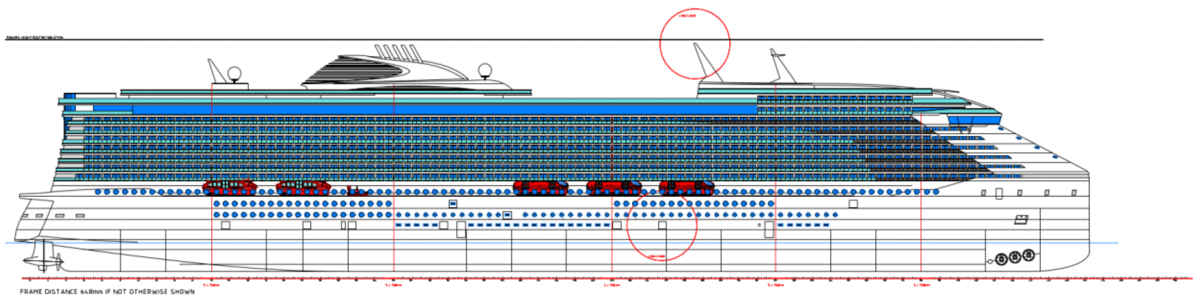

Figure 1 Ship profile

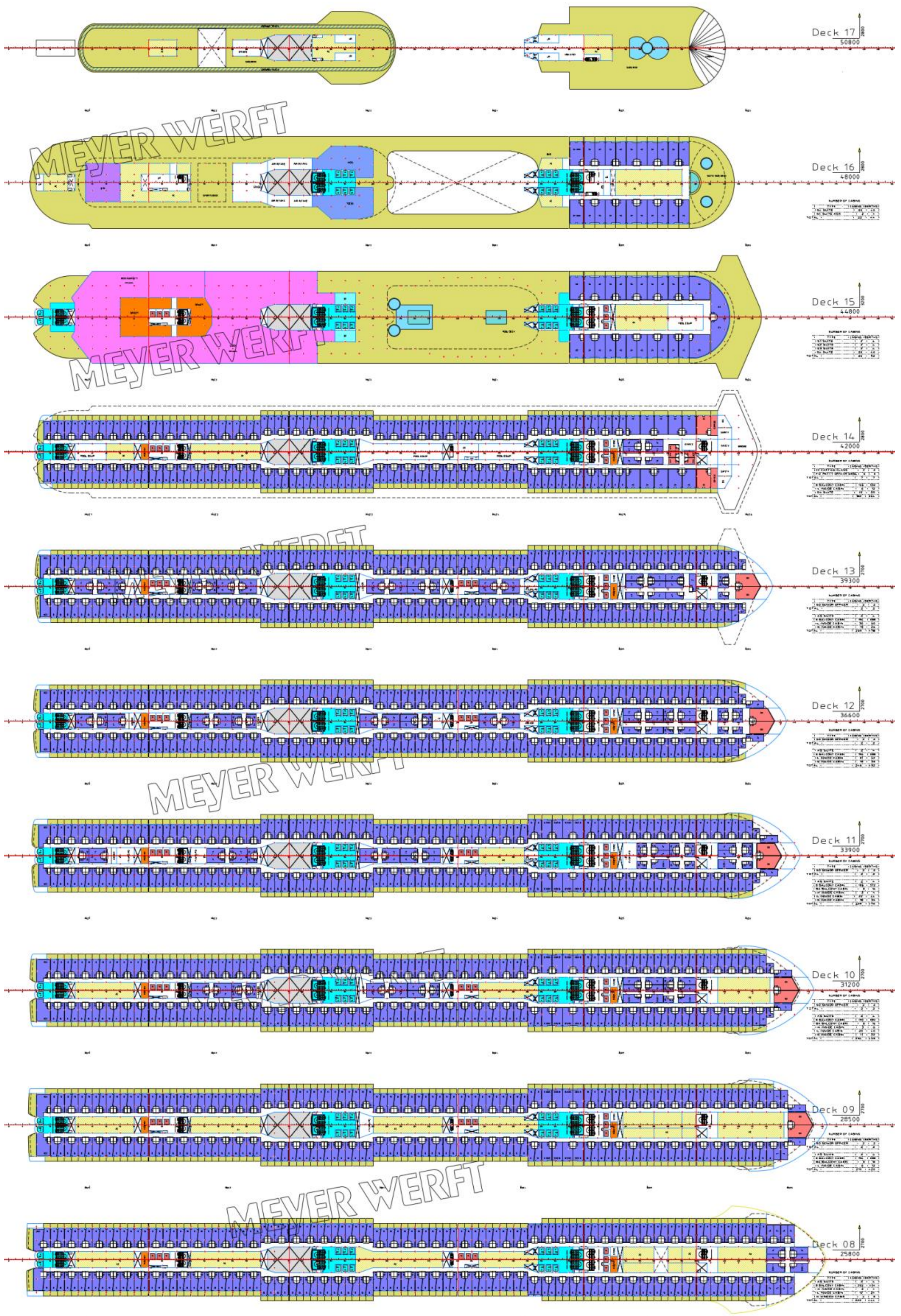
MEYER WERFT
Deck 17
50800
Deck 16
48000
Deck 15
44800
Deck 14
42000
Deck 13
39300
Deck 12
36600
Deck 11
33900
Deck 10
31200
Deck 09
28500
Deck 08
25800

Figure 2 GAP Decks 8 - 17

Figure 3 GAP Decks 1 - 7

4.3 Hull form

The ship has a modern hull form of a podded propelled twin screw vessel with a straight bow giving the ship a slender fore body. The aft body is equipped with a slender skeg and transom stern.

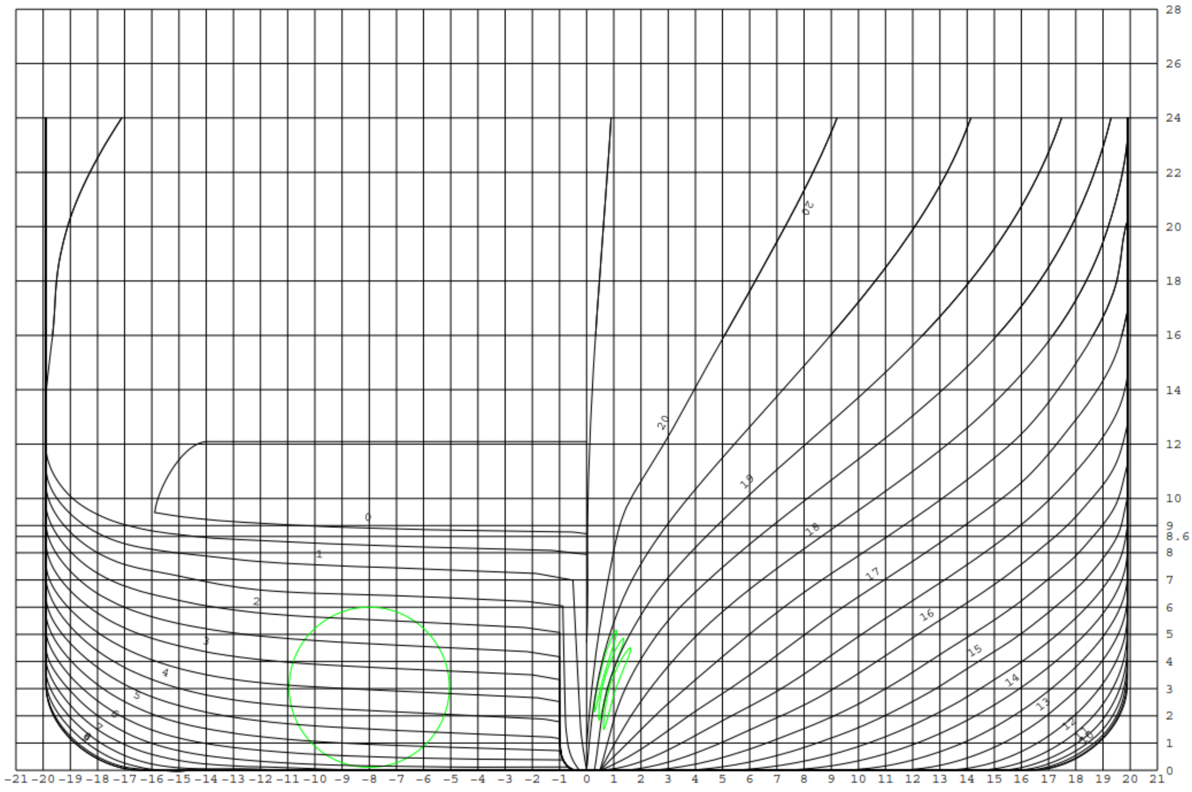

Figure 4 Bodyplan

4.4 Engine configuration

The engine configuration is based on 5 medium sized dual fuel engines. Two bigger ones (approx. 13,800 kW) in the aft main engine room and three smaller ones (approx. 9,150 kW) in the forward main engine room. All engines are driving a generator set.

4.5 Tankplan

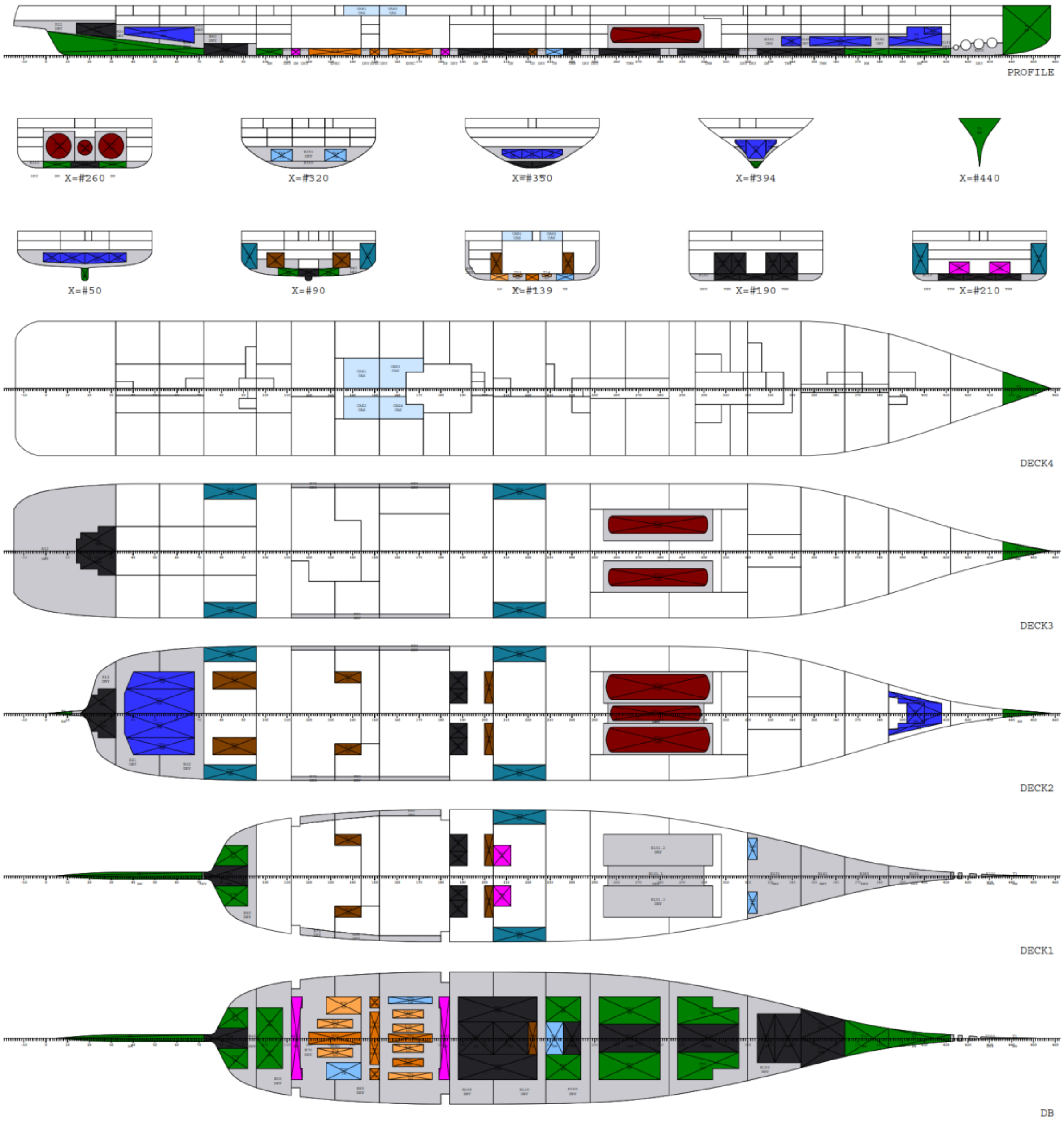

Figure 5 Tankplan

The following capacities are achieved for the various purposes:

NAME	VNET	WEIGHT	LCG	VCG	MOM
POTABLE WATER (PW)	3328.0 m3	3328.0 t	141.16 m	5.68 m	4637 mt
HEELING WATER (HW)	2213.9 m3	2213.9 t	103.64 m	6.95 m	503 mt
BALLAST WATER (BW)	2858.5 m3	2929.9 t	164.80 m	3.20 m	7020 mt
TECHNICAL WATER (TW)	373.9 m3	373.9 t	147.28 m	1.91 m	625 mt
LIQUIFIED NATURAL GAS (LNG)	2884.9 m3	1306.8 t	181.57 m	6.43 m	992 mt
GAS OIL (GO)	1225.1 m3	1078.0 t	87.06 m	5.44 m	767 mt
LUBRICATING OIL (LO)	247.4 m3	222.7 t	96.21 m	1,24 m	168 mt
SPECIAL TANKS (SPEC)	335.4 m3	335.4 t	97.01 m	1,00 m	327 mt
GREY WATER (GW)	1125.7 m3	1125.7 t	137.39 m	3.20 m	2997 mt
TREATED GREY WATER (TWW)	2483.6 m3	2483.6 t	134.48 m	2.42 m	7377 mt

Table 3 Tank capacities

4.6 Subdivision

The watertight subdivision follows the needs from the functionality of the spaces, e.g. the size of the LNG tanks as well as the size of the main engine rooms.

Due to redundancy requirements as defined in SOLAS II/2 the engine rooms are quite large and cause special attention for the damage stability. Additionally the engine rooms are separated by an extra compartment and protected by a double hull up to the bulkhead deck (deck 4)

The voids spaces around the LNG tanks are designed in such a way that they are fully redundant. Instantaneous symmetrical flooding is therefore not possible. The heeling water tanks are located outside the LNG tank space, to minimize heel after damage as far as possible. LNG tanks are fully within B/5. No additional damage analysis for LNG tanks according to IGF code is thus necessary.

The bulkhead deck is equipped with partial bulkheads to extend the watertight compartmentation. Any additional progressive flooding above the bulkhead is prevented by watertight racking bulkheads.

The ship is provided with a continuous double bottom with a height of at least 2m.

The figure below shows the watertight subdivision and the damage zones used in the SOLAS2020 calculation of the attained index.

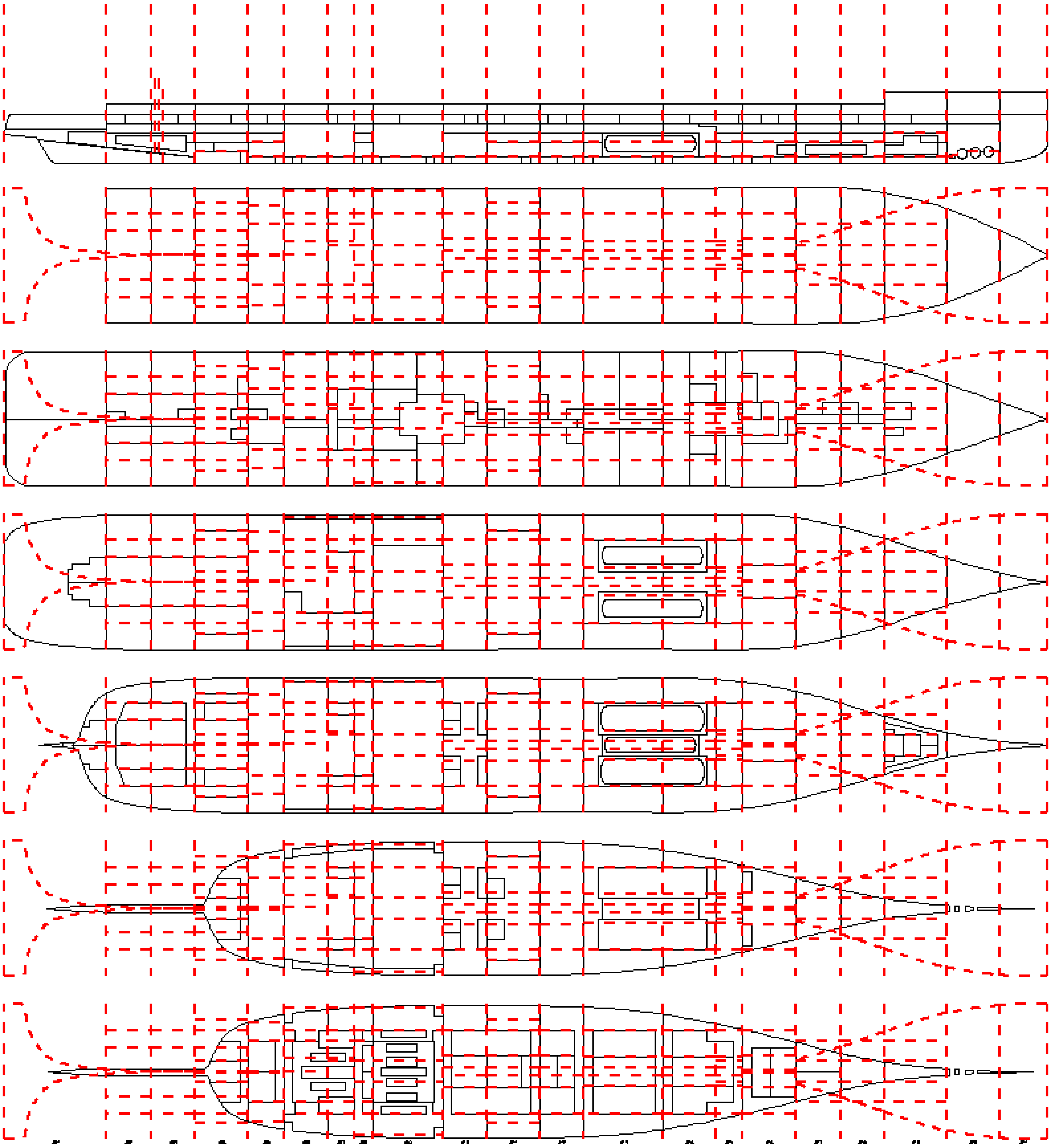

Figure 6 Subdivision used for calculations

5 HYDRODYNAMICS

5.1 Speed power performance

Figure 7 Speed power performance

5.2 Manoeuvrability

The ship is equipped with 3 bow thrusters of 3,000 kW each and two pods with a total of 39 MW to maintain the required wind speed of 27kn in the worst direction. For manoeuvring the maximum output of the pods is limited to approx. 10 MW each.

Under the wind speed given above the ship will be able to keep its position without the help of tugs.

6 INTACT STABILITY

6.1 Loading conditions

The table below shows the loading conditions designed for further examination of the sample ship:

NAME	TEXT	DW	PW	BW	GW	TWW	LNG	GO
LD20	100% consumables, max draught	13,490 t	3,309 t	637 t	839 t	1,986 t	1,242 t	1,025 t
LD25	10% consumables	6,420 t	333 t	385 t	582 t	434 t	131 t	157 t
LD30	Design deadweight	10,200 t	2,700 t	0 t	650 t	405 t	1,200 t	1,000 t
LD31	10% fuel, 100% PW, 100% GW	12,269 t	3,309 t	895 t	907 t	2,472 t	131 t	104 t
LD33	20% fuel, 100% PW, 20% GW	9,673 t	3,309 t	454 t	493 t	497 t	261 t	207 t
LD35	100% fuel, 20% PW, 100% GW	10,642 t	666 t	287 t	907 t	2,472 t	1,242 t	1,025 t

NAME	TEXT	DRAUGHT	TRIM	GM
LD20	100% consumables, max draught	8.49 m	0.00 m	4.63 m
LD25	10% consumables	7.80 m	0.09 m	3.78 m
LD30	Design deadweight	8.17 m	0.04 m	4.13 m
LD31	10% fuel, 100% PW, 100% GW	8.38 m	0.00 m	4.46 m
LD33	20% fuel, 100% PW, 20% GW	8.13 m	0.00 m	4.05 m
LD35	100% fuel, 20% PW, 100% GW	8.22 m	0.00 m	4.28 m

Table 4: Loading condition details

6.2 GM Limiting curve

The following diagram shows the summary of the GM requirements together with the actual loading conditions.

There are various limits shown which all need to be complied with, in particular there is the limit of the intact stability criteria as defined by the IS code 2008, and limits for compliance with the damage stability requirements.

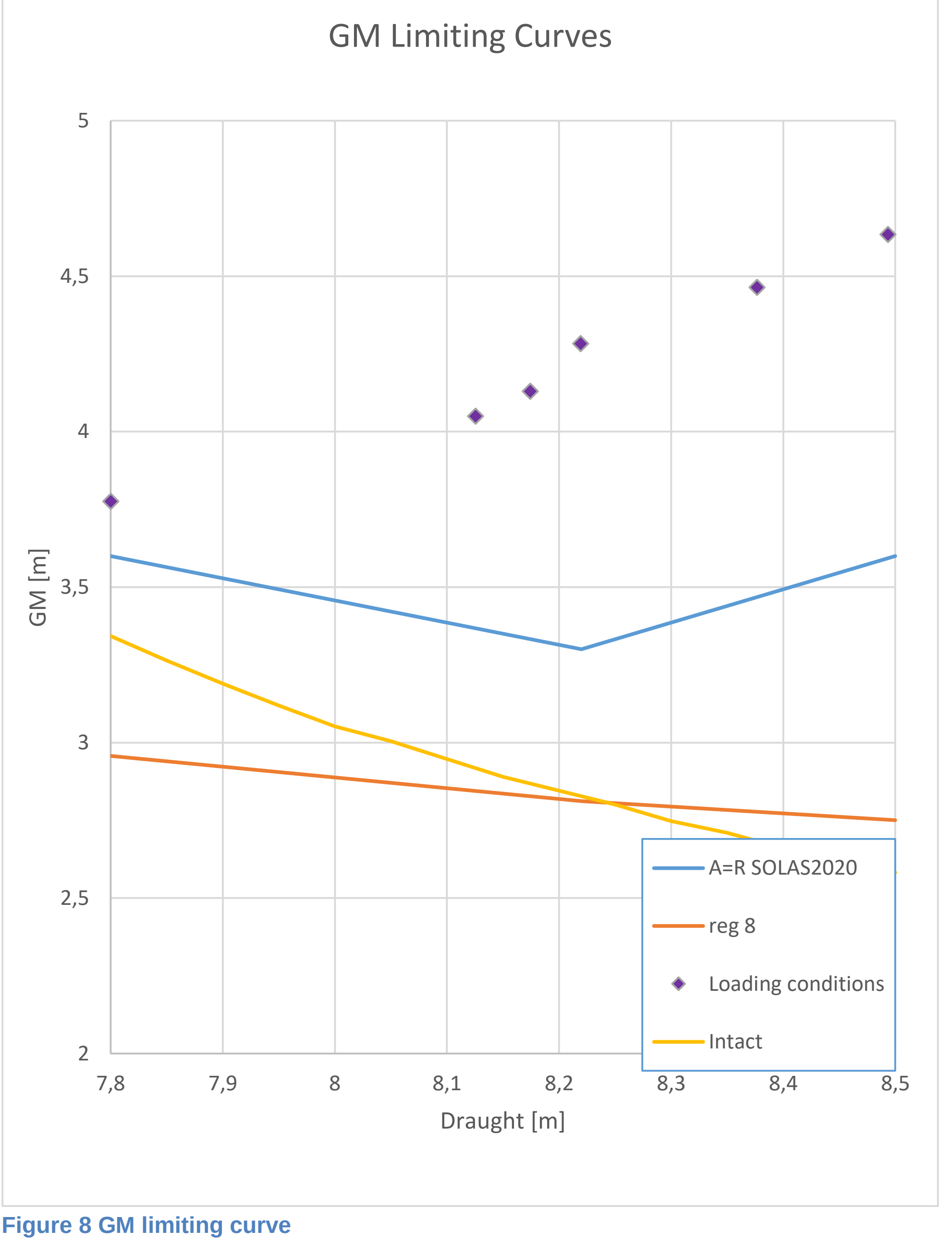

Figure 8 GM limiting curve

7 RESULTS OF DAMAGE STABILITY CALCULATION

7.1 Attained index vs R

The following tables show the result of the damage stability calculations according SOLAS II-1.

ATTAINED AND REQUIRED SUBDIVISION INDEX

```
Subdivision length            307.711 m
Breadth at the load line       39.800 m
Number of persons N1          3708
Number of persons N2          1232

Required subdivision index R = 0.893498 according to SOLAS 2020

Required subdivision index R = 0.83852 according to SOLAS 2009

Attained subdivision index A = 0.90668
```

INITDAMTAB		T m	GM m	A/R	A	A*WCOEF	WCOEF
DL	DAMP	7.800	3.602	1.10	0.92569	0.09257	0.100
DL	DAMS	7.800	3.602	1.10	0.92007	0.09201	0.100
DP	DAMP	8.220	3.304	1.08	0.90403	0.18081	0.200
DP	DAMS	8.220	3.304	1.07	0.89461	0.17892	0.200
DS	DAMP	8.500	3.609	1.09	0.91421	0.18284	0.200
DS	DAMS	8.500	3.609	1.07	0.89768	0.17954	0.200

Table 5: Attained index for each initial condition

DAMAGES	W*P*V*S	W*P*V
1-ZONE DAMAGES	0.34243	0.34245
2-ZONE DAMAGES	0.35401	0.36499
3-ZONE DAMAGES	0.16242	0.18390
4-ZONE DAMAGES	0.03855	0.07129
5-ZONE DAMAGES	0.00928	0.01862
A-INDEX TOTAL	0.90668	0.98126

Table 6: Index according to number of zones.

7.2 Reg 8 results

T	MINGM	MAXKG	DCRI	DAM
7.80 m	2.95718 m	21.4078 m	S-REG8	R8P13-14.1.0-1
8.22 m	2.81201 m	21.0042 m	S-REG8	R8P13-14.1.0-1
8.50 m	2.75004 m	20.7641 m	S-REG8	R8P13-14.1.0-1

Table 7: GM limits for s>0.9 acc. Reg 8.3

The corresponding GM limiting curves are shown in figure 8.

7.3 Results non-zonal approach

In addition to the standard damage stability results the attained index following the non-zonal approach [1] has been calculated for collision, bottom grounding and side grounding/contact.

As the basis the SOLAS parameters for draughts, permeability and s-factor have been used. For each of the three categories of flooding events 50,000 breaches have been created.

Initial condition	Draught	Attained Index Collision	Attained Index Bottom grounding	Attained Index Side grounding/contact
DL	7.800 m	0.95736	0.95447	0.91650
DP	8.220 m	0.93160	0.94799	0.89993
DS	8.500 m	0.94018	0.94601	0.90650

Table 8 Attained index acc. non-zonal approach

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The information shown in this document and the associated files define a state-of-the-art large cruise vessel using latest knowledge for fulfilling the highest (safety and environmental) standards for passenger vessels.

9 REFERENCES

[1] Gabriele Bulian et al, *Considering collision, bottom grounding and side grounding/contact in a common non-zonal framework*, Proceedings of the 17th International Ship Stability Workshop, Helsinki 2019

10 ADDITIONAL INFORMATION

Following information is available as separated files:

- General Arrangment Drawing (pdf and dwg format)
- Napa data base, including hull form and internal geometry, loading conditions and damage stability data (NAPA db)

Acronym: FLARE
Project full title: Flooding Accident REsponse
Grant agreement No. 814753
Coordinator: BALance Technology Consulting GmbH

Deliverable 2.1.3

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Deliverable data

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Work Package no: title	WP2.1 Sample Ships		

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Responsible author	Rodolphe Bertin		
Co-authors			
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Peer reviewer 1	Mike Cardinale		
Peer reviewer 2			

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This report reflects only the author's view. INEA is not responsible for any use that may be made of the information it contains.

CONTENTS

List of symbols and abbreviations

DoA	Description of Action
EC	European Commission
PMT	Project Management Team
SG	Steering Group
QA	Quality Assurance
GT	Gross Tonnage
NAPA	Naval Architectural Package
MVZ	Main Vertical Zone
FEM	Finite Element Method
POB	Persons On Board
RPM	Rotation per minute

1 EXECUTIVE SUMMARY

This report describes the sample ship no 3, a large Cruise Ship.

1.1 Problem definition

- To ensure realistic research for the response to flooding events it is necessary to have sample ships available, which may be used in other work packages of this project as well as made public available.
- The basic requirements for the sample ship are to reflect large passenger ships design according to the latest SOLAS amendments (SOLAS2020)

1.2 Technical approach and work plan

- A real existing design has been chosen which has not been used before in similar research project and has not been built.
- The calculation has been performed and it has been possible to reach the SOLAS2020 standard without major modification of the design.
- The addition of a scrubber system to reach the latest requirements of MARPOL Annex VI Regulation 14 would be feasible but has not been included in the scope of this project, as the impact in case of flooding is not considered significant.

1.3 Results

- The selected design has been created to reach suitable degree of detail to provide reasonable continuation of the work.
- In particular the ship may form a valid basis for the cost benefit assessment of risk control options in WP7.
- This design is at a pre-contractual stage but ready to start detailed engineering and construction. The layout and information allows all kind of investigations for damage stability, however detailed information about internal systems, like piping, ducting and cabling cannot be provided.

1.4 Conclusions and recommendation

- The information shown in this document and the associated files define a state-of-the-art for large cruise vessels intended for 7 to 10 days cruises operation in European waters or Worldwide operation in warm and temperate waters.
- The information provided is a part of the basic data required so that the work can be continued in this project in other work packages.

2 INTRODUCTION

2.1 Task/Sub-task text

A number of sample ships of large cruise vessels and RoPax ferries, will be provided by the FLARE participants to reflect typical designs of the current fleet. As the focus is laid on large ships, the following limits will be applied:

Gross tonnage > 10,000 GT

Length > 120m

No of MVZ >2

It is anticipated that all ships comply with the future SOLAS requirements (SOLAS2020). In this respect, RoPax ships do not need to comply with Stockholm Agreement.

For this project the anticipated degree of detail in the information is based on realistic conceptual designs, conceptual GAP and NAPA model. No detailed information about the systems and components is needed, like the routing of pipes, ducts and cables. If for some work in the following work packages more detailed information is needed, suitable assumptions are to be made by the designers in the provision of such information.

The data of ships used as sample ships in this project is to be prepared to be published, so if existing ships are used a written confirmation by the owner/operator and designers is needed for such use.

The sample ships will be used in the other work packages and also as the basis for the impact of any risk control options.

For each ship a separate deliverable will be created containing a description of the ship, including a general arrangement drawing and the NAPA database.

3 BUSINESS MODEL

As the basis for the design of this ship a business model has been defined to define the basic parameters which need to be fulfilled. These parameters and the business model will be kept unchanged throughout the design process and also during further design studies in a later stage of this project.

The vessel is designed to accommodate on long international voyage 3750 persons, 2750 passengers and 1000 crew members.

The vessel is primarily designed to operate on 7 to 10 days cruises in European waters and has possibility for South America and Caribbean and World wide operation in warm and temperate waters.

The vessel is designed for operation in ports with large tidal range.

The vessel is of adequate overall size (height, hull beam, draught) to pass – non regular transit-through future Panama locks.

Following main parameters are to be kept to maintain the business model of this vessel:

1. Pax accomodation:

1270 pax cabins with 2540 lower beds and 250 sofa beds for a total of 2790 beds

2. Crew accomodation:

624 crew cabins for a total of 1000 berths

Crew common spaces	Gross Area (sqm)
Coffee House	75
Bar & Disco	180
Crew Gym	120
Internet café / Library	75
Crew retail	15
Training Centre	60
Crew mess	440+180

3. Public rooms:

See the GA for more details. Areas allocated to each main function shall be kept unchanged to keep the business model:

Function indoor	Gross Area (sqm)
activity	4972
bar	3556
Circulation	5636
dining	7817
entertainment	2083
guest service	1859
retail	1822

Function outdoor	Gross Area (sqm)
bar	515
dining	30
outside space	8827

4. Tank capacities

	VOL (m3)
Grey Water	1000
Heavy Fuel Oil	1800
Heeling Tank	1150
Laundry Fresh Water	260
Laundry Grey Water	95
Lubricating Oil	270
Low Sulfure Heavy Fuel Oil	390
Marine Gas Oil	580
Miscellaneous	660
Potable Water	2700
Technical Fresh Water	270
Treated Water/Water Ballast	1080
Water Ballast	3100
Water Treatment	1350

5. Deadweight total 8500t at design draught

Passengers with belongings	300	t
Crew with belongings	100	t
Provisions & hotel stores	400	t
Hotel Stores	180	t
Technical stores	50	t
Potable fresh water	2400	t
Laundry water	250	t
Technical fresh water	50	t
Water mist	45	t
Fuel oil	2160	t
Marine gas oil	300	t
Lub-oil	120	t
Swimming pools	200	t
Heeling tanks	400	t
Grey and black water	760	t
Treated water	760	t
Miscellaneous	25	t

6. Service speed:
   In trial conditions the speed is to be at least 22.25 knots, with electric propulsion motors at 100% MCR.

7. Design criteria:
   - HFO for 6000 miles at 18 knots with 15% sea margin on power and normal electrical load of abt 7000 kW.
   - MGO or HFO, depending on damage case, for return to port.
   - Fresh water (potable and laundry) for 3 days at 250 l/d/pers
   - Treated water storage for two days : one day in dedicated tank, one day in combined ballast tanks)

8. Operational profile: as an average 360 days per year in service, whereof 40% in port and 60% in navigation.

4 General Description of the Ship

This sample ship is a large cruise ship designed to fit brand's philosophy, bring innovations, and deliver ground-breaking tailored vacation experience.

The vessel is designed with six main fire zones.

The public rooms are mainly distributed on decks 5,6,7 and 14,15,16. An Atrium is arranged midship, from deck 3 to 16.

The bulkhead deck is deck 4 in general and may be raised locally at the forward and aft ends as required to meet the stability requirements. Semi watertight bulkheads are arranged above bulkhead deck as required. Arrangement should allow normal operation with watertight doors below bulkhead deck continuously closed at sea.

For compliance with intact stability criteria the superstructure are considered watertight up to deck 7 (three tiers above bulkhead deck).

The assembly stations are on deck 7 on outside deck and inside rooms.

The vessel is powered by a diesel electric power plant driving two shaft lines with rudders. It is equipped with two aft thrusters and three bow thrusters. The total diesel power installed is 50 400 kW about.

Main dimensions:

Length over all	About 300m
Length between perpendiculars	270.00 m
Subdivision length	296.74 m
Breadth	35.20 m
Subdivision draught	8.20 m
Height of bulkhead deck	11.00 m
Number of passengers	2750
Number of crew	1000
Gross tonnage	95 900
Deadweight	8500 t
No of pax cabins	1270

4.1 Regulations

The design complies with all relevant IMO rules and regulations applicable for ships with contract after 1 January 2020, which includes following codes.

1. SOLAS1974 as amended, including probabilistic damage stability and "Safe Return to Port" (SOLAS2020)
2. Intact Stability Code (IS Code 2008)
3. Load line Convention
4. MARPOL, including fuel oil tank protection (scrubber system to be added in order to fulfil the last update of Annex VI Regulation 14)
5. Marine Labour Convention 2006

4.2 General Arrangement

The following figures show the General Arrangement plan

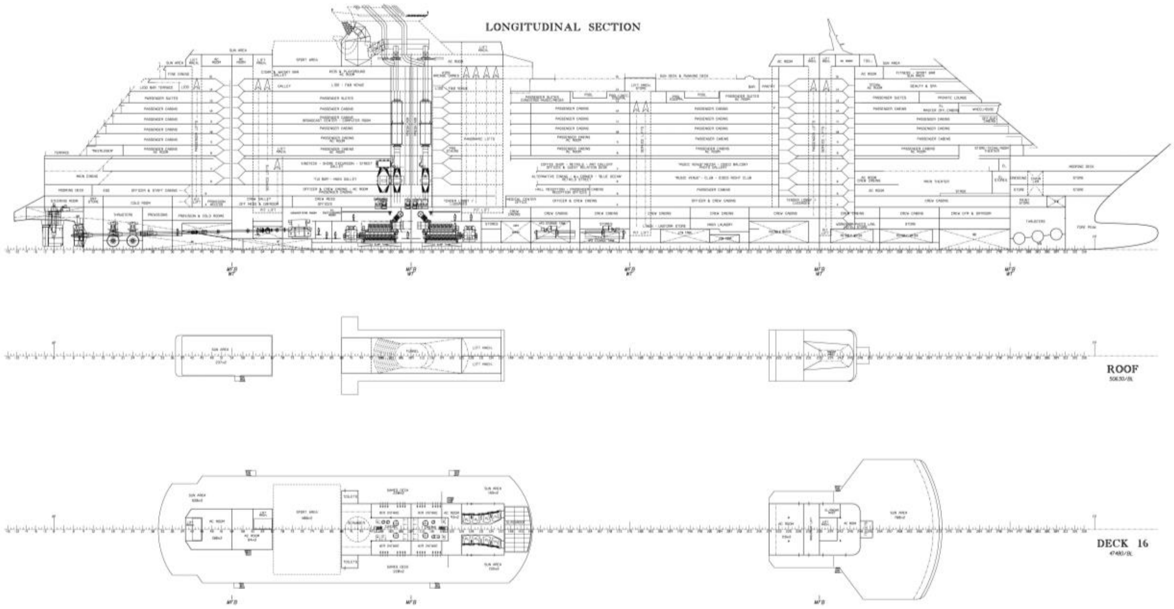

Figure 1 Deck 16 –Roof – Longitudinal view

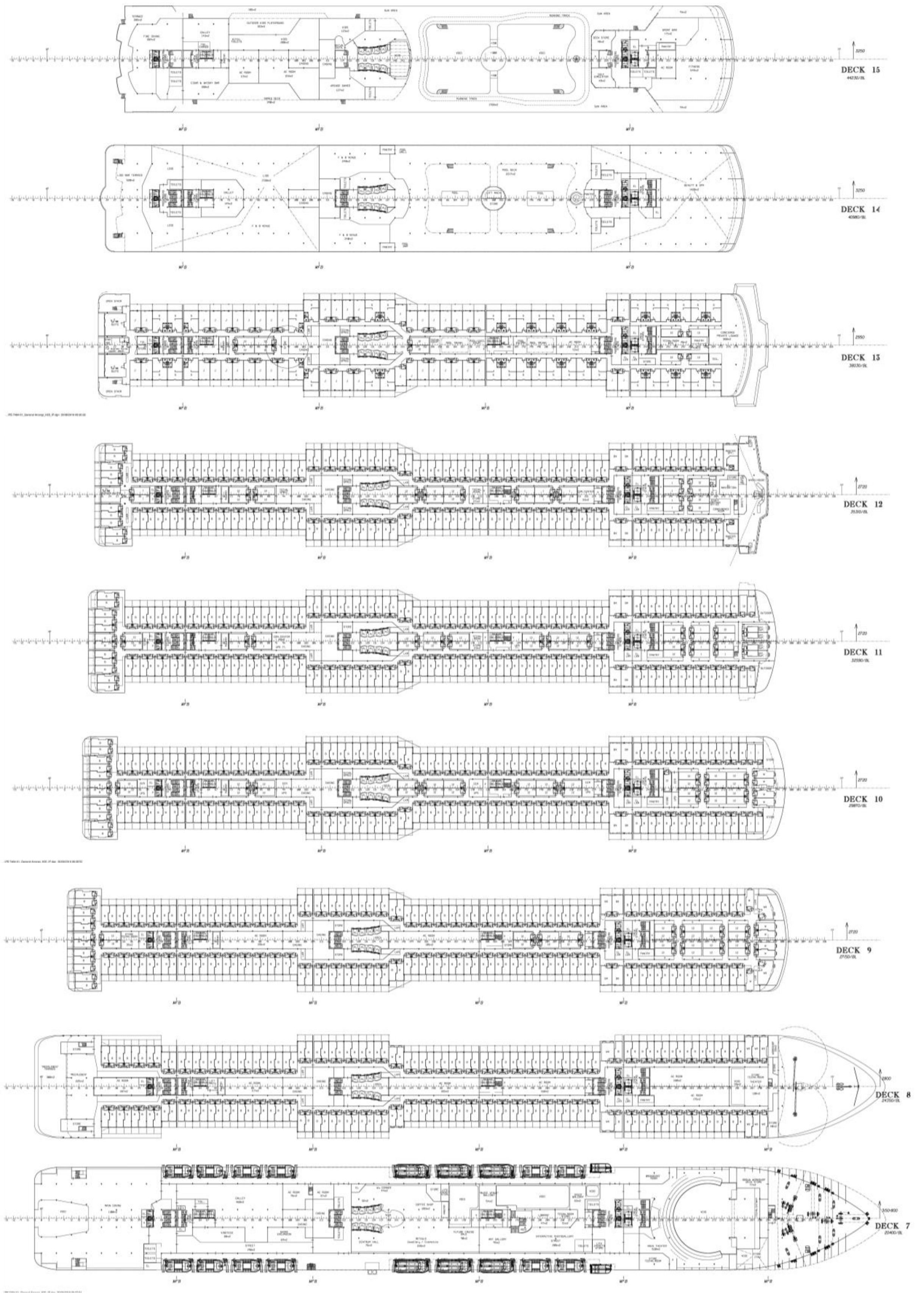

Figure 1 Deck 07 to 15

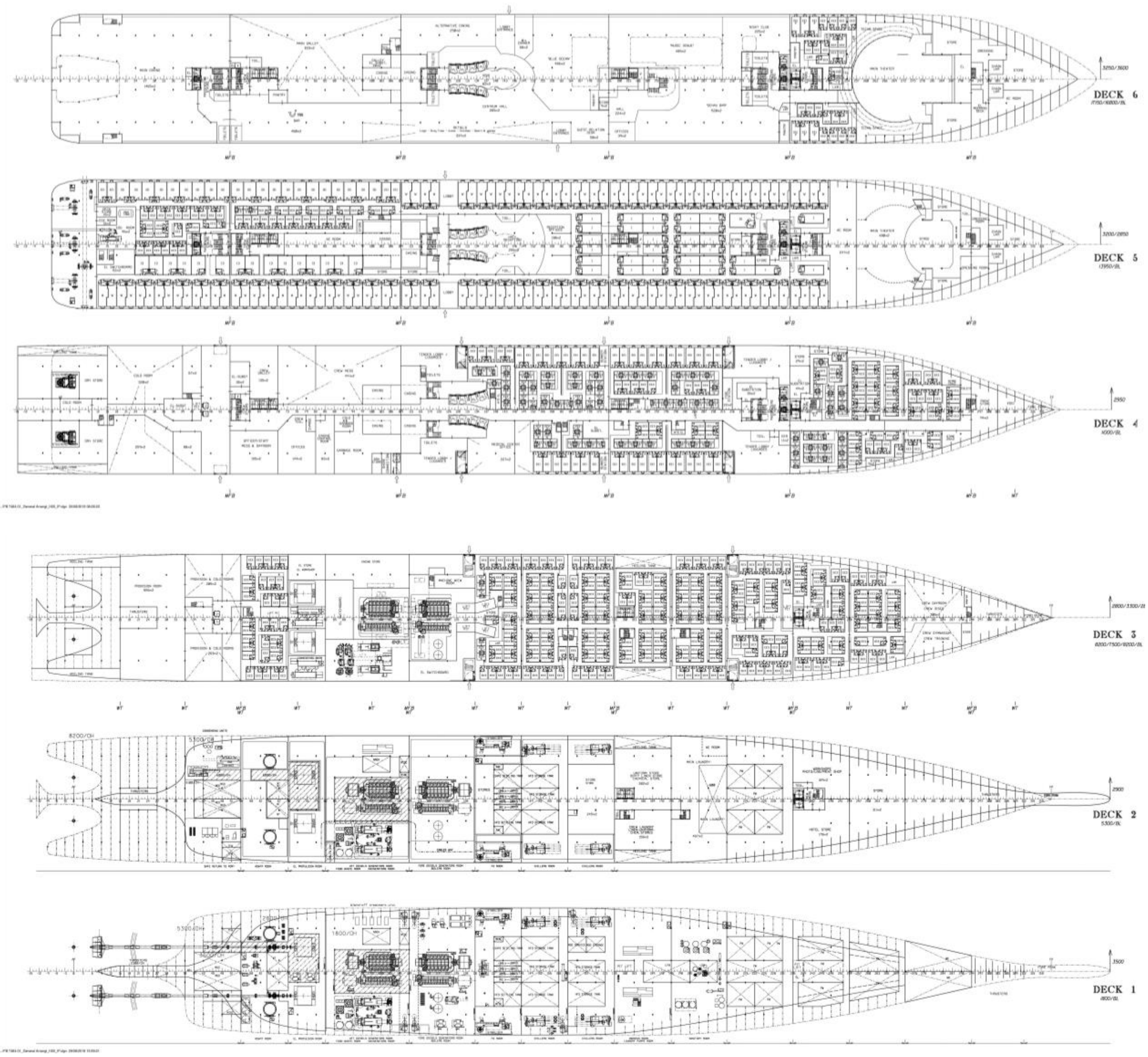

Figure 3 deck 01 to 06

4.3 Hullform

The ship has a conventional modern hull form of a twin screw vessel with bulbous bow and slender skeg and transom stern and a tunnel shaped aft body.

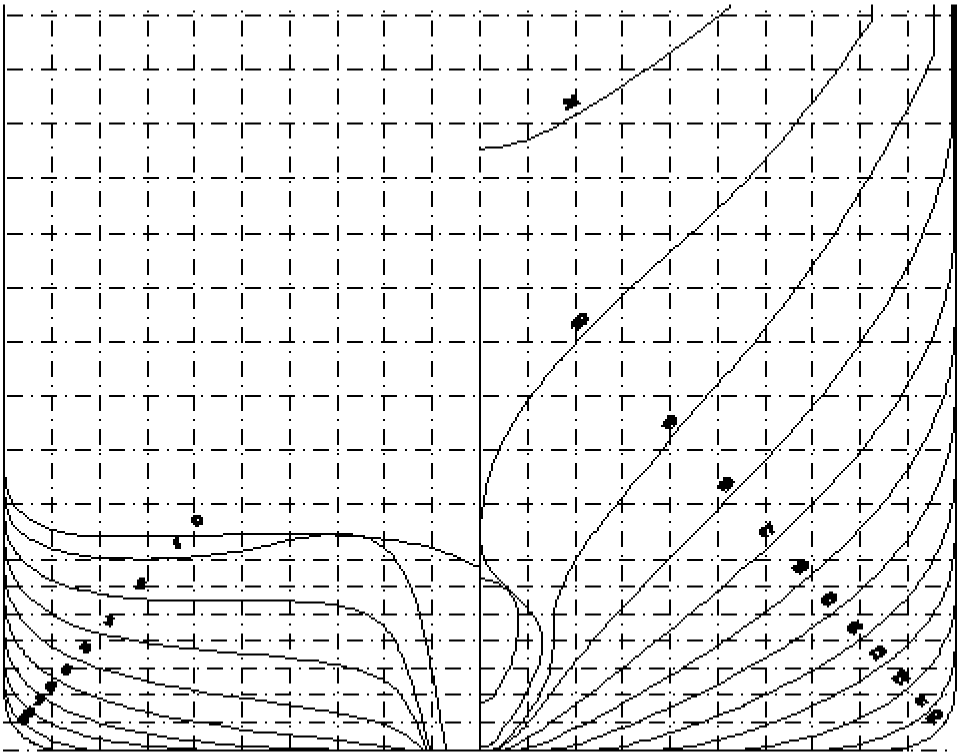

Figure 4 Bodyplan

4.4 Engine configuration

The vessel is propelled by a diesel electric propulsion plant, consisting of four (4) resiliently mounted medium speed main diesel engines, each driving a brushless alternator, producing electrical energy for propulsion and hotel service.
The propulsion system consists of two inboard electric motors at variable speed, each driving a shaft line and pump propeller.

4.5 Tankplan

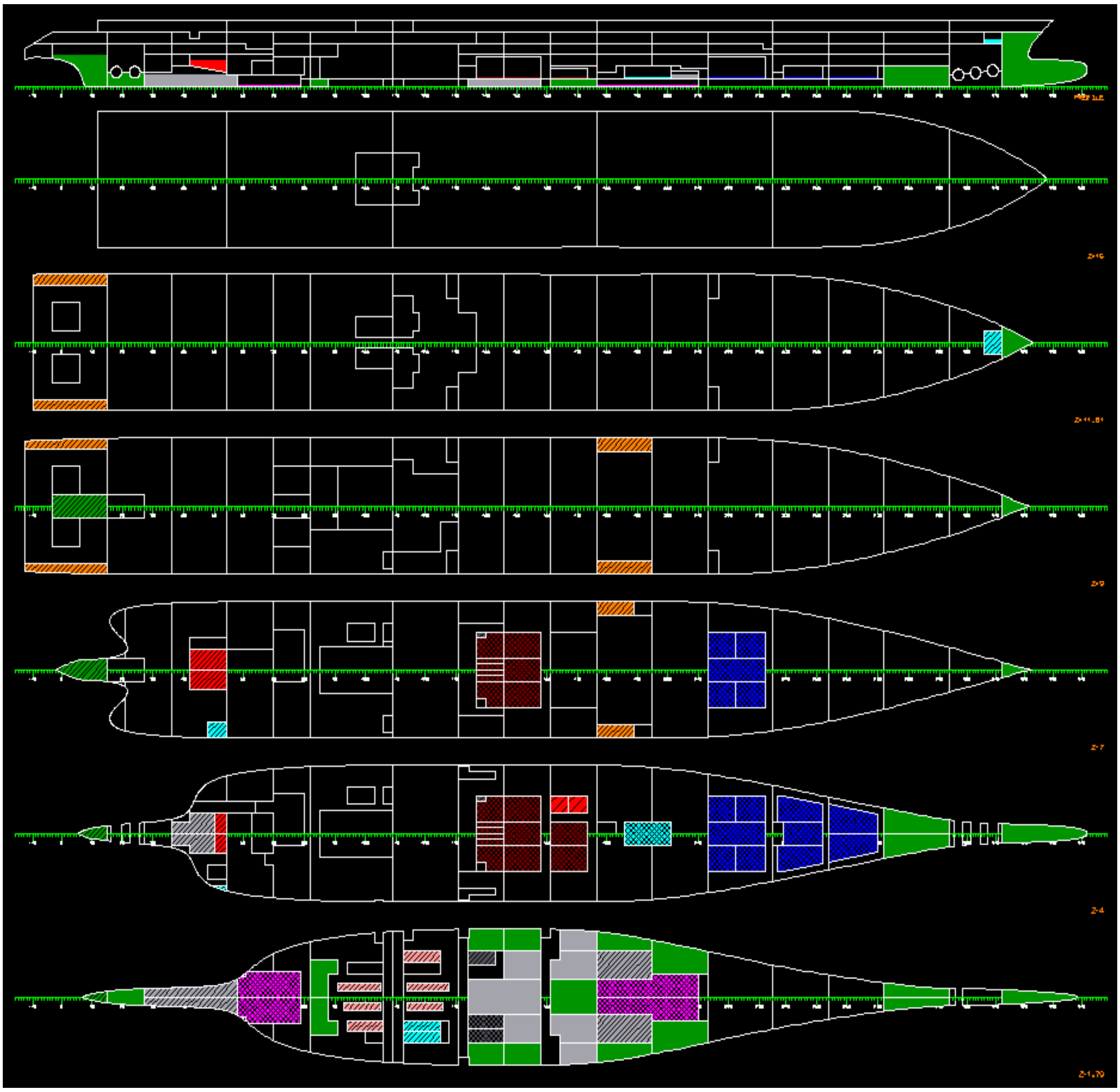

Figure 5 Tankplan

The following capacities are achieved for the various purposes:

NAME	VOLM	VNET
	m3	m3
Grey Water	1049.3	1033.6
Heavy Fuel Oil	1858.6	1830.7
Heeling Tank	1164.6	1147.2
Laundry Fresh Water	268.8	264.8
Laundry Grey Water	96.8	95.3
Lubricating Oil	276	271.8
Low Sulfure Heavy Fuel Oil	393.3	387.4
Marine Gas Oil	580.5	571.8
Miscellaneous	663.8	653.9
Potable Water	2755.3	2714
Technical Fresh Water	270.1	266
Treated Water/Water Ballast	1082.7	1066.5
Water Ballast	3182.8	3135
Water Treatment	1365.1	1344.6

Table 1 Tank capacities

4.6 Subdivision

The watertight subdivision is typical for that ship type. The ship has n.19 watertight compartments but n.24 zones have been defined for the generation of the damage cases. This approach permits to gain index in areas with complex watertight arrangements such as PEM and Main Engine rooms.

The two Propulsion Electric Motors (PEM) are located in the same compartment but one of them is encapsulated to comply with the SRTP requirements.

The ship is provided with a continuous double bottom with a height of more than B/20.

The figure below shows the watertight subdivision and the damage zones used in the SOLAS2020 calculation of the attained index.

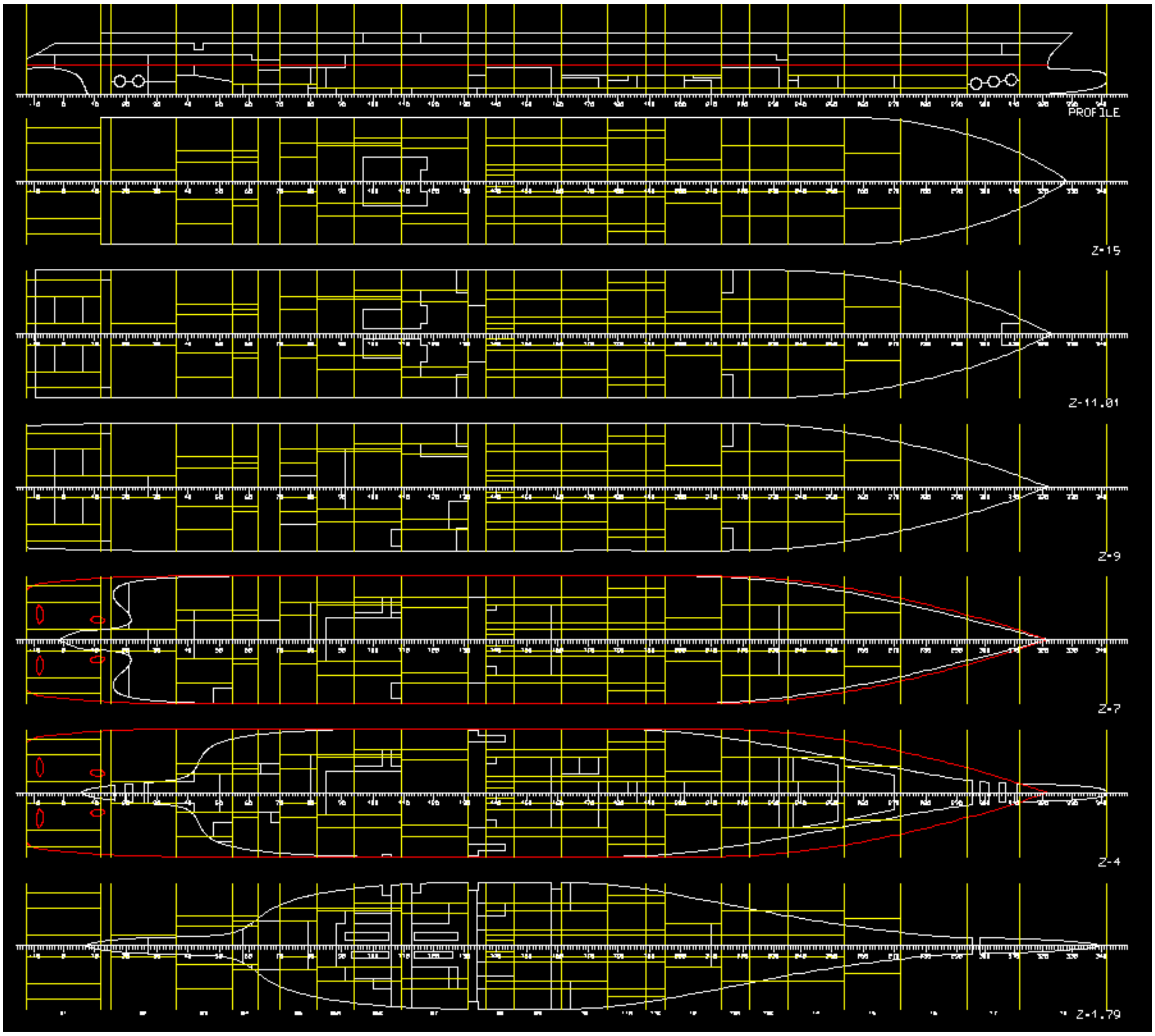

Figure 6: Subdivision used for calculations

5 Hydrodynamics

5.1 Speed power performance

Performance prediction:

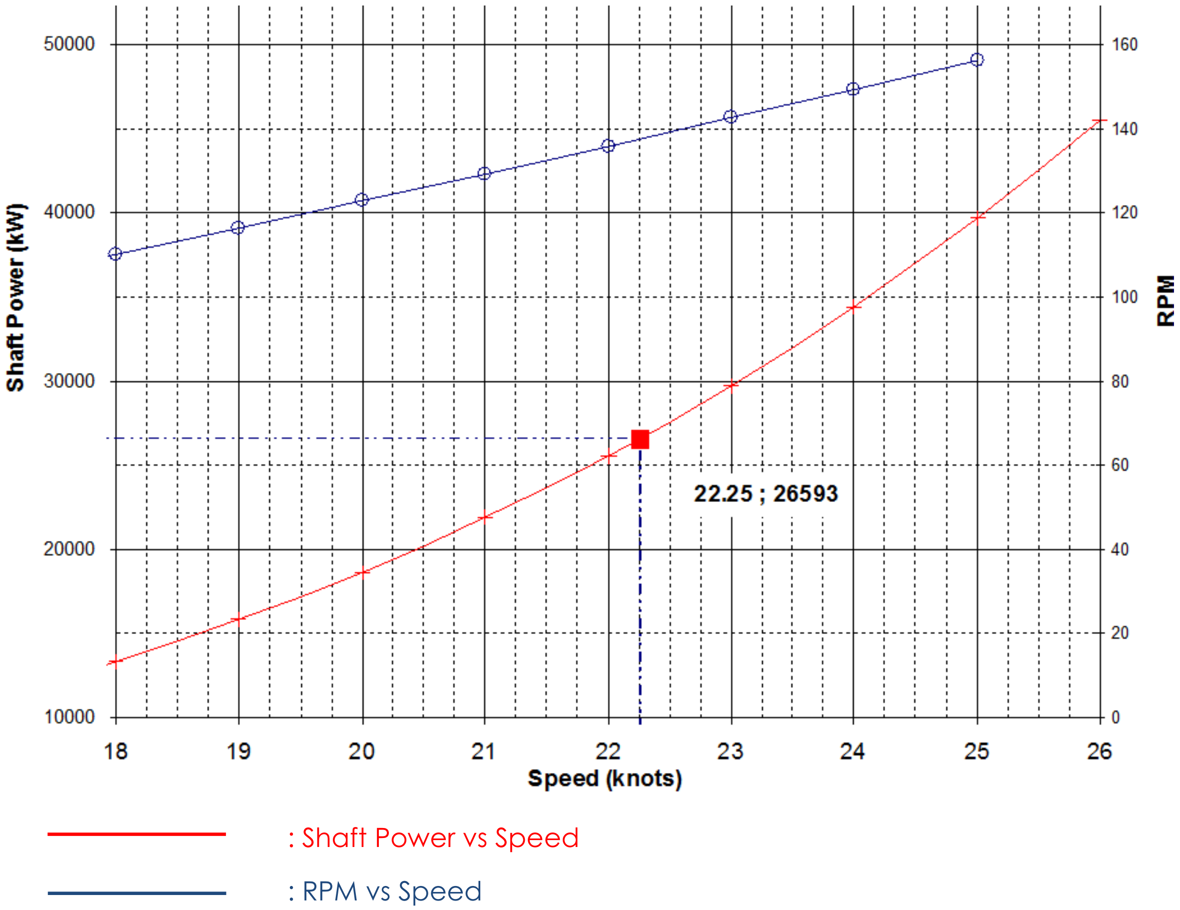

Figure 7: Speed power performance

5.2 Manoeuvrability

The ship is equipped with 3 bow thrusters and two stern thrusters and high lift rudders to sustain the required wind speed in the worst direction.

6 Intact stability

6.1 Loading conditions

The table below shows the loading conditions designed for further examination of the sample ship:

CASE	DESCRIPTION
DESIGN	Design
LC100	100% consumables
LC10	10% consumables
LC10A	10% consumables SWP empty

CASE		DESIGN	LC100	LC10	LC10A
Heavy Fuel Oil	t	1740.3	1740.3	179.4	179.4
Low Sulfur Heavy Fuel Ot		368.3	368.3	38.0	38.0
Marine Gas-Oil	t	342.0	498.8	342.0	342.0
Lub Oil	t	110.4	245.1	110.4	110.4
Grey Water	t	650.0	1033.6	650.0	650.0
Laundry Grey Water	t	50.0	95.3	50.0	50.0
Treated Water/Water Balt		760.0	853.2	1066.5	1066.5
Water Treatment	t	60.0	672.3	60.0	60.0
Potable Water	t	2400.0	2658.5	271.4	271.4
Laundry Fresh Water	t	250.0	264.8	26.5	26.5
Technical Fresh Water	t	95.0	186.4	95.0	95.0
Heeling tank	t	400.0	573.6	400.0	400.0
Water ballast	t	0.0	430.0	2914.7	2914.7
Miscellaneous tank	t	25.0	256.4	25.0	25.0
DEADWEIGHT	t	8481.0	11186.4	7098.8	6898.9
LIGHTWEIGHT	t	41502.2	41502.2	41502.2	41502.2
TOTAL DISPLACEMENT	t	49983.2	52688.6	48601.0	48401.1
MEAN DRAFT (Below keel)	(M)	7.902	8.222	7.746	7.720
TRIM (Positive by bow)	(M)	-0.139	-0.008	0.000	-0.040
TRANSV. METAC. HEIGHT	(M)	20.160	20.124	20.005	20.034
GM (Solid)	(M)	3.169	3.802	2.892	3.017
FS correction	(M)	-0.246	-0.199	-0.178	-0.168
GM (Fluid)	(M)	2.923	3.603	2.714	2.850

Table 2: Loading condition details

6.2 GM Limiting curve

The following diagram shows the summary of the GM requirements together with the actual loading conditions.

Several limits are shown which all need to be complied with, in particular:

- limit of the intact stability criteria as defined by the IS code 2008
- limits for compliance with the damage stability requirements.

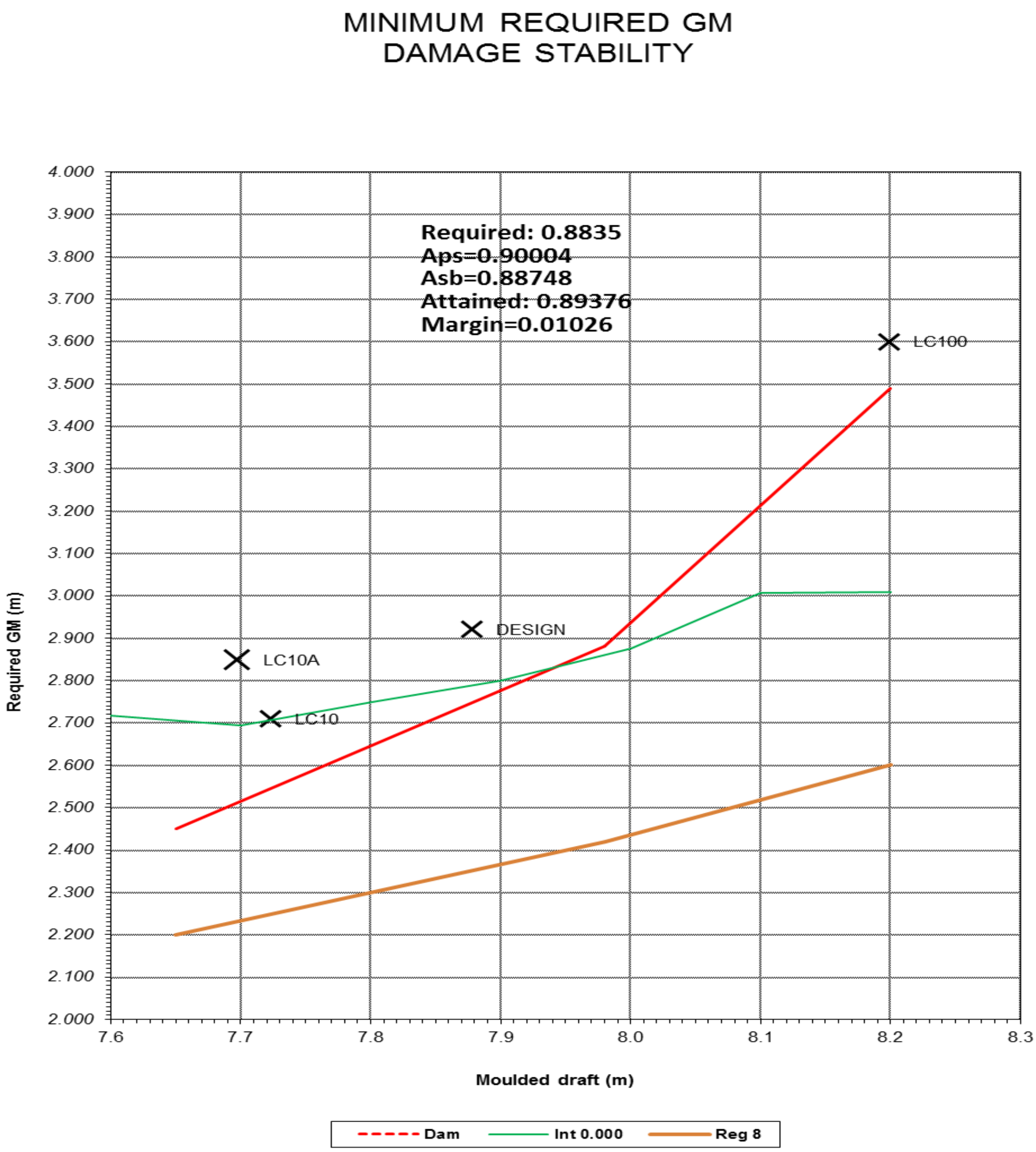

Figure 8: GM Limiting curve

7 Results of damage stability calculation

7.1 Attained index vs R

The following tables show the result of the damage stability calculations according SOLAS II-1.

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length 296.741 m
Breadth at the load line 35.000 m
Breadth at the bulkhead deck 35.000 m

Portside:
Required subdivision index R = 0.88353
Attained subdivision index A = 0.90004

INIT	DAMTAB	T	TR	GM SUBD		PSI/R	PSI	WCOEF	ASI
		m	m	m		%			
DL	SDSPS	8.200	0.000	3.490	DEFSUBD	112.4	0.91732	0.400	0.36693
PL	SDSPS	7.980	0.000	2.880	DEFSUBD	109.6	0.89499	0.400	0.35799
LL	SDSPS	7.650	0.000	2.450	DEFSUBD	107.3	0.87559	0.200	0.17512
TOTAL									0.90004

Starboard:
Required subdivision index R = 0.88353
Attained subdivision index A = 0.88748

INIT	DAMTAB	T	TR	GM SUBD		PSI/R	PSI	WCOEF	ASI
		m	m	m		%			
DL	SDSSB	8.200	0.000	3.490	DEFSUBD	110.4	0.90120	0.400	0.36048
PL	SDSSB	7.980	0.000	2.880	DEFSUBD	108.5	0.88548	0.400	0.35419
LL	SDSSB	7.650	0.000	2.450	DEFSUBD	105.8	0.86403	0.200	0.17281
TOTAL									0.88748

Table 3: Attained index for each initial condition

Portside:

DAMAGES	MAX.INDEX	ATT.INDEX
1-ZONE DAMAGES	0.31277	0.31277
2-ZONE DAMAGES	0.37555	0.37555
3-ZONE DAMAGES	0.19472	0.17186
4-ZONE DAMAGES	0.08218	0.03650
5-ZONE DAMAGES	0.02626	0.00336
A-INDEX TOTAL	0.99148	0.90004

Starboard:

DAMAGES	MAX.INDEX	ATT.INDEX
1-ZONE DAMAGES	0.31277	0.31277
2-ZONE DAMAGES	0.37555	0.37555
3-ZONE DAMAGES	0.19472	0.16638
4-ZONE DAMAGES	0.08218	0.03142
5-ZONE DAMAGES	0.02626	0.00134
A-INDEX TOTAL	0.99148	0.88748

Table 4: Index according to number of zones.

7.2 Reg 8 results

Portside:

ZONE	NZONE	CASE	SFAC
13B/14	2	DL/DMINP19-20.1.0-2	0.93920
13B/14	2	PL/DMINP19-20.1.0-2	0.95411
07/07A/08	3	DL/DMINP10-12.1.0	0.97989
07/07A	2	DL/DMINP10-11.1.0	0.97989
08/09	2	DL/DMINP12-13.1.0	0.98648
08/09	2	PL/DMINP12-13.1.0	0.98995
07/07A	2	PL/DMINP10-11.1.0	0.99727
07/07A/08	3	PL/DMINP10-12.1.0	0.99727
02	1	DL/DMINP3.1.0	1.00000

Starboard:

ZONE	NZONE	CASE	SFAC
14/15	2	DL/DMINS20-21.1.0	0.93635
08/09	2	DL/DMINS12-13.1.0	0.94918
08/09	2	PL/DMINS12-13.1.0	0.95360
04A/05	2	DL/DMINS6-7.1.0	0.96260
04/04A/05	3	DL/DMINS5-7.1.0	0.96260
03/04	2	DL/DMINS4-5.1.0	0.96385
03/04/04A	3	DL/DMINS4-6.1.0	0.96385
07A/08/09	3	DL/DMINS11-13.1.0	0.96574
07A/08/09	3	PL/DMINS11-13.1.0	0.96971
14/15	2	PL/DMINS20-21.1.0	0.97043
06B/07	2	DL/DMINS9-10.1.0	0.97205
08/09	2	LL/DMINS12-13.1.0	0.97924
07/07A/08	3	DL/DMINS10-12.1.0	0.98121
07/07A	2	DL/DMINS10-11.1.0	0.98121
06B/07	2	PL/DMINS9-10.1.0	0.98254
04/04A/05	3	PL/DMINS5-7.1.0	0.98284
04A/05	2	PL/DMINS6-7.1.0	0.98284
03/04/04A	3	PL/DMINS4-6.1.0	0.99315
03/04	2	PL/DMINS4-5.1.0	0.99315
07A/08/09	3	LL/DMINS11-13.1.0	0.99342
07/07A/08	3	PL/DMINS10-12.1.0	0.99778
07/07A	2	PL/DMINS10-11.1.0	0.99778
06B	1	DL/DMINS9.1.0	1.00000

Table 5: GM limits for s>0.9 acc. Reg 8.3

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The information shown in this document and the associated files define a state-of-the-art for large cruise vessels intended for 7 to 10 days cruises operation in European waters or Worldwide operation in warm and temperate waters.

The information provided is a part of the basic data required so that the work can be continued in this project in other work packages.

9 REFERENCES

[1] George Zaraphonitis, *GOALDS Deliverable 6.4 Evaluation of innovative designs,* Athens 2012

[2] Henning Luhmann, *Task 6: Damage Stability Calculations of GOALDS RoPax Designs, EMSA/OP/10/2013*, Oslo 2015

[3] Gabriele Bulian et al, *Considering collision, bottom grounding and side grounding/contact in a common non-zonal framework*, Proceedings of the 17th International Ship Stability Workshop, Helsinki 2019

10 ADDITIONAL INFORMATION

Following information is available as separated files:

- General Arrangment Drawing (pdf and dwg format)
- Napa data base, including hull form and internal geometry, loading conditions and damage stability data [NAPA db)

Acronym:	FLARE
Project full title:	Flooding Accident REsponse
Grant agreement No.	814753
Coordinator:	BALance Technology Consulting GmbH

FLARE
FLOODING ACCIDENT RESPONSE

Deliverable 2.1.4

The project has received funding from the European's Horizon 2020 research and innovation programme (Contract No.: 814753)

Duration: 36 months - Project Start: 01/06/2019 - Project End: 31/05/2022

Deliverable data

Deliverable No	2.1.4		
Deliverable Title	Sample Ship n°4		
Work Package no: title	WP2.1 Sample Ships		

Dissemination level	Public	**Deliverable type**	Report
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Co-authors			
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Peer reviewer 1	Antonio E.Todde		26-09-2019
Peer reviewer 2			

Document history

Version	**Date**	**Description**
V00	**30.8.2019**	Initial version
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V02	**26.9.2019**	Clean version

The research leading to these results has received funding from the European Union Horizon 2020 Program under grant agreement n° 814753.
This report reflects only the author's view. INEA is not responsible for any use that may be made of the information it contains.

CONTENTS

List of symbols and abbreviations

DoA	Description of Action
EC	European Commission
PMT	Project Management Team
SG	Steering Group
QA	Quality Assurance
GT	Gross Tonnage
NAPA	Naval Architectural Package
MVZ	Main Vertical Zone
FEM	Finte Element Method
POB	Persons On Board

1 EXECUTIVE SUMMARY

This report describes sample ship no 4, a medium size passenger vessel.

1.1 Problem definition

- To ensure realistic research for the response to flooding events it is necessary to have sample ships available, which may be used in other work packages of this project as well as made public available.
- The basic requirements for the sample ship are to reflect large passenger ships design according to the latest SOLAS amendments (SOLAS2020)

1.2 Technical approach and work plan

- A real existing design has been chosen which has not been used before in similar research project and has not been built.
- The original design has been upgraded by modifications of the general arrangement with impact on the weight and CoG to reach the SOLAS2020 standard.
- At the time of the offer, it had been agreed that the vessel would be delivered with scrubbers. However the detailed integration studies had not been performed. It is not considered part of the scope of this project as the impact of this system in case of flooding is not considered significant.

1.3 Results

- The selected design has been created to reach suitable degree of detail to provide reasonable continuation of the work.
- In particular the ship may form a valid basis for the cost benefit assessment of risk control options in WP7.
- This design is at a pre-contractual stage but ready to start detailed engineering and construction. The layout and information allows all kind of investigations for damage stability, however detailed information about internal systems, like piping, ducting and cabling cannot be provided.

1.4 Conclusions and recommendation

- The information shown in this document and the associated files define a state-of-the-art for medium cruise vessels intended for worldwide operation in warm and temperate waters and it will transit regularly in Panama, Suez and Kiel canal.
- The information provided is a part of the basic data required so that the work can be continued in this project in other work packages.

2 INTRODUCTION

2.1 Task/Sub-task text

A number of sample ships of large cruise vessels and RoPax ferries, will be provided by the FLARE participants to reflect typical designs of the current fleet. As the focus is laid on large ships, the following limits will be applied:

Gross tonnage > 10,000 GT

Length > 120m

No of MVZ >2

It is anticipated that all ships comply with the future SOLAS requirements (SOLAS2020). In this respect, RoPax ships do not need to comply with Stockholm Agreement.

For this project the anticipated degree of detail in the information is based on realistic conceptual designs, conceptual GAP and NAPA model. No detailed information about the systems and components is needed, like the routing of pipes, ducts and cables. If for some work in the following work packages more detailed information is needed, suitable assumptions are to be made by the designers in the provision of such information.

The data of ships used as sample ships in this project is to be prepared to be published, so if existing ships are used a written confirmation by the owner/operator and designers is needed for such use.

The sample ships will be used in the other work packages and also as the basis for the impact of any risk control options.

For each ship a separate deliverable will be created containing a description of the ship, including a general arrangement drawing and the NAPA database.

3 BUSINESS MODEL

As the basis for the design of this ship a business model has been defined to define the basic parameters which need to be fulfilled. These parameters and the business model will be kept unchanged throughout the design process and also during further design studies during a later stage of this project.

The ship is a medium modern passenger vessel designed for international voyages. This vessel is designed for 942 passengers and 444 crew members. The ship will operate worldwide in warm and temperate waters and it will transit regularly in Panama, Suez and Kiel canal.

The ship is designed as a passenger cruise ship with a large number of cabins and suitable public rooms, like restaurants, shopping areas, conference centre, lounges and a spa area.

Following main parameters are to be kept to maintain the business model of this vessel:

1. Pax accomodation:
   424 pax cabins
   The ship is fitted with 200 additional beds by mean of convertible sofas

2. Crew accomodation
   240 officers and crew cabins

3. Public rooms on lower decks
   - Supper club 400 m²
   - Indoor restaurant 600 m²
   - 2 speciality restaurants 650 m²
   - Jazz Club 150 m²
   - Spa / Thalasso area 550 m²
   - 2 cinemas (200 seats) 250 m²
   - Theater (160 seats)
   - Explorer Lounge 700 m²
   - Sun deck
   - Cafés and bars
   - Shopping street
   - Reception
   - Casino

4. Crew mess and recreation areas deck 3
   - Mess and day room 201 m²
   - Recreation 82 m²
   - Officer Mess 87 m²
   - Officer recreation 43 m²

5. Tank capacities
   - HFO (incl. settling and service) 850 m3
   - Marine Gas-Oil (incl. service) 505 m3
   - Lubricating oil 42 m3
   - Potable water 844 m3
   - Laundry fresh water 150 m3
   - Technical fresh water 150 m3
   - Heeling tanks 300 m3
   - Grey water holding 320 m3
   - Water treatment 500m3
   - Sea water ballast (as needed for stability) abt. 1500m3
   - Treated water 300 m3
   - Bilge water 90 m3
   - Miscellaneous (inc. oil sludge) 150 m3

6. Deadweight total 3100 t, to be distributed approximately as follows

Passengers & luggage	111 t
Crew& luggage	55.5 t
Provisions	222 t
Hotel & shop stores	115 t
Engines stores	100 t
Miscellaneous items and owners supplies	200 t
Swimming pools and whirlpools	175 t
HFO	750 t
Marine Gas Oil	250 t
Lube-oil	40 t
Potable water	300 t
Laundry fresh water	100 t
Technical fresh water	40 t
Heeling tanks	150 t
Grey water	100 t
Water treatment	50 t
Treated water	200 t
Miscellaneous	81.5 t
Oil sludge	10 t
Bio Sludge	10 t
Bilge water	40 t

7. Service speed
   The trial speed is 20.0 knots with an average shaft power corresponding to 100 % of nominal propulsion motors output power and with 4.2 megawatts hotel load

8. Design criteria

- Fuel oil : The total bunker capacity (HFO, LSHFO, GO, storage and service tanks) is designed for a minimum range of 6000 nautical miles continuous sailing at a speed of 18 knots with 15% sea margin on propulsion power and an auxiliary electric load of 4200 kW.

- Potable water : The potable fresh water capacity is designed for an autonomy of 3 days with a specific consumption of 250 l/day/person and a number of persons on board corresponding to the ship passenger cabins (lower beds) filling.

- Grey water and treated water: Grey water and black water storage tanks are designed for an autonomy of 1 day. The treated water storage tanks are designed for an autonomy of 3 days either in dedicated tanks or in ballast/treated water tanks.

- Heeling tanks: Heeling tanks to compensate a steady lateral wind of 15 m/s (BN 7 abt) when loaded at the design deadweight.

  - Safe return to port: Autonomy for SRTP is from Nemo point to 1500 nm closest land at BF4 using MDO/MGO/HFO.

9. Operational profile: as an average 360 days per year in service, whereof 40% in port and 60% in navigation.

4 General Description of the Ship

The vessel is a medium passenger cruise vessel designed for long international voyages. The vessel is designed to operate worldwide in warm and temperate waters (no icing) with regular transit in Panama, Suez and Kiel canal.

The ship is designed as passenger ship with a large number of cabins and suitable public rooms, like restaurants, shopping areas, conference centre, lounges and a spa area.

The passengers embark the vessel on deck 4 on Starboard or Portside.

Secondary access is provided on deck 3 (from tenders).

An atrium is formed from deck 4 up to deck 10.

There are two main vertical passenger circulations with staircases and lifts and two passenger panoramic lifts in the atrium.

Service is done through separate staircases and lifts.

Passengers spaces are located on deck 3,4,5,7,8,9,10 and outdoor deck 11.

Tendering facilities are on deck 3 with one tendering area on each side. The vessel is carrying four tender boats. Assembly stations are located deck 5 on inside deck to the maximum extend and outside rooms if necessary.

Crew spaces are mainly located below passenger decks. Crew public rooms are on deck 3 aft ship.

Bulkhead deck is deck 3.

The vessel is a shafted twin screw diesel electric driven passenger cruise ship. The main machinery consists of four diesel engines each coupled to AC generator.

Main dimensions

Length over all	230 m
Length between perpendiculars	199 m
Subdivision length	227.97 m
Breadth	27 m
Subdivision draught	6.10 m
Height of bulkhead deck	11.35 m
Number of passengers	942
Number of crew	444
Gross tonnage	41000
Deadweight	3100 t
No of cabins (pax)	424

4.1 Regulations

The design complies with all relevant IMO rules and regulations applicable for ships with contract after 1 January 2020, which includes following codes.

1. SOLAS1974 as amended, including probabilistic damage stability and "Safe Return to Port" (SOLAS2020), Short international voyage
2. Intact Stability Code (IS Code 2008)
3. Load line Convention
4. MARPOL, including fuel oil tank protection
5. Marine Labour Convention 2006

4.2 General Arrangement

The following figures show the General Arrangement plan

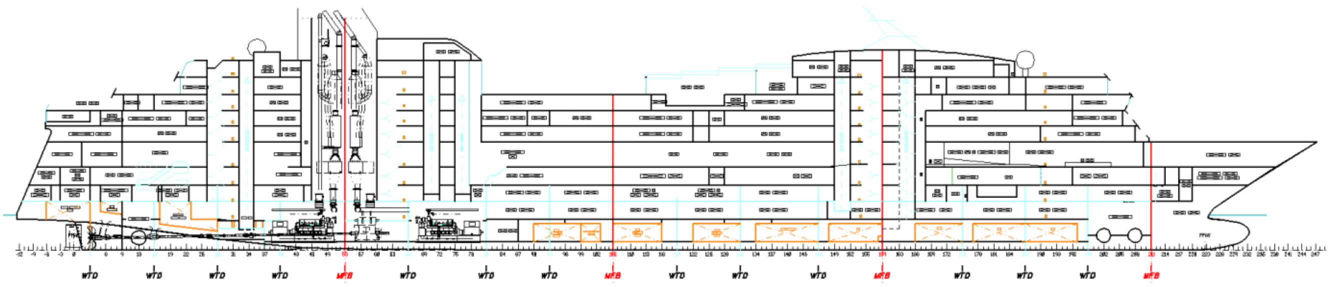

Figure 1 Profile view

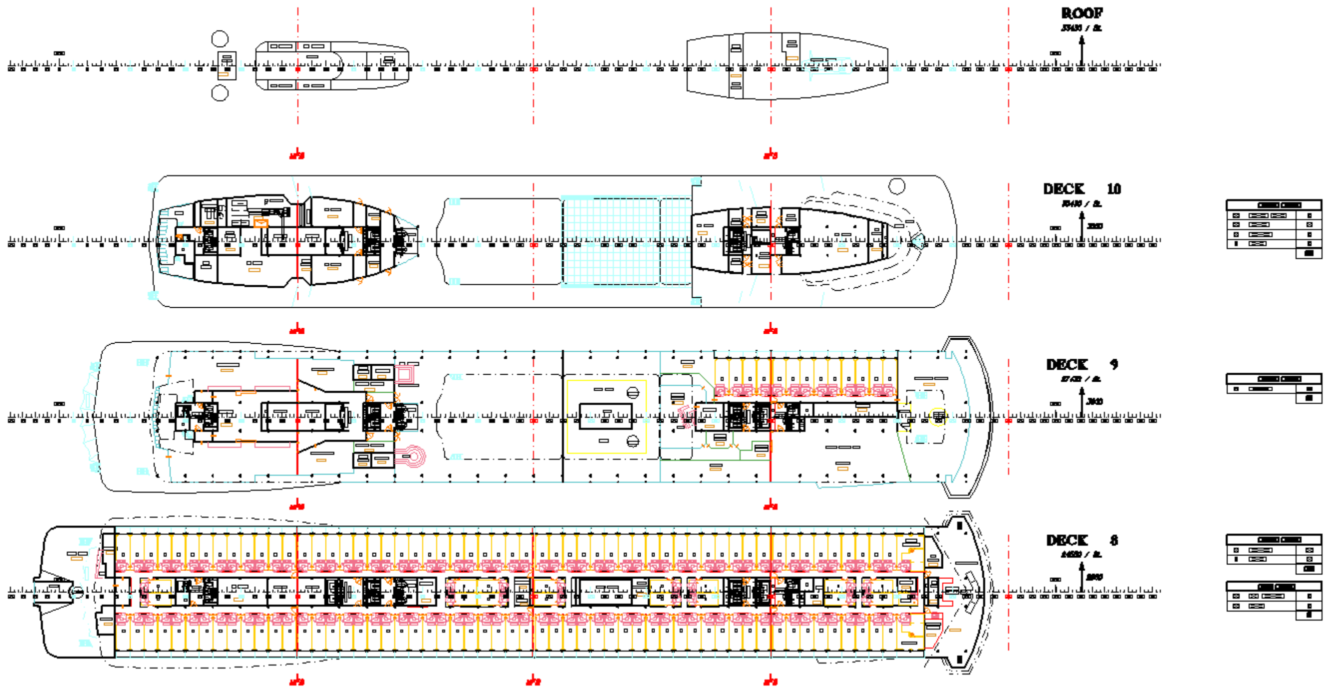

Figure 2 Deck 8 to Roof

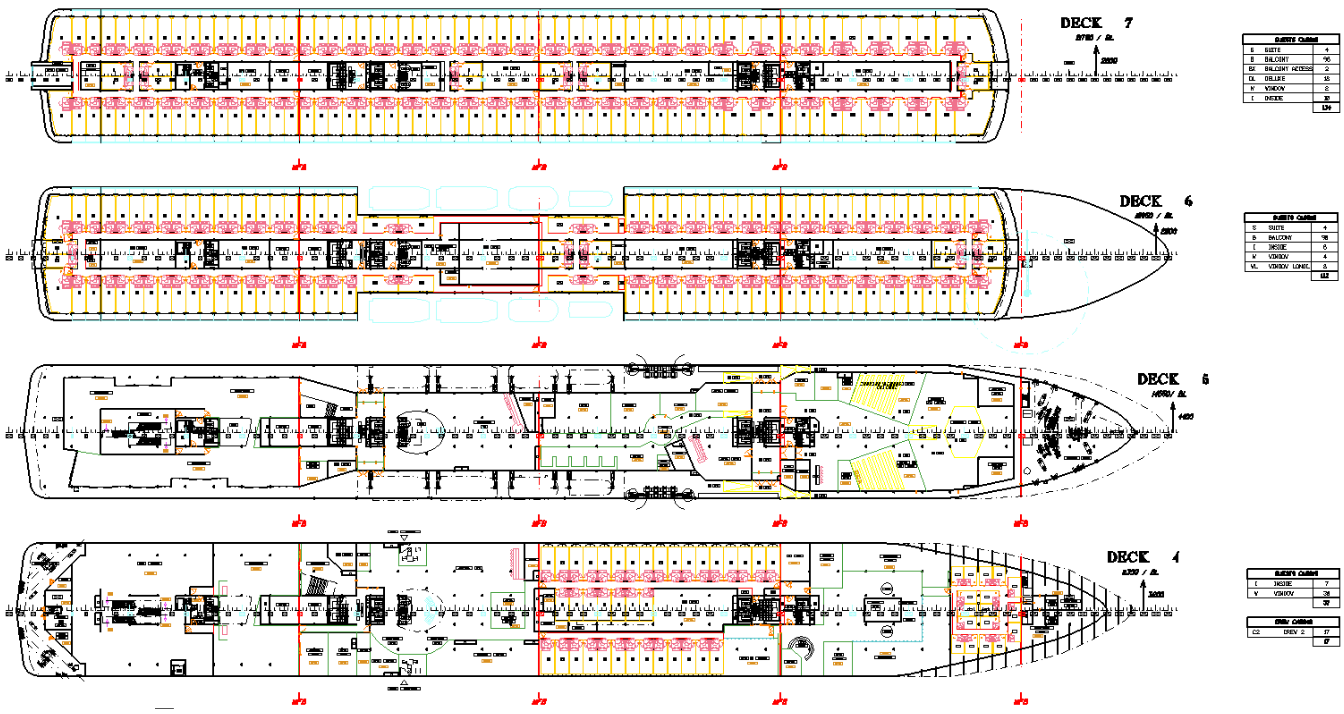

Figure 3 Decks 04 to 07

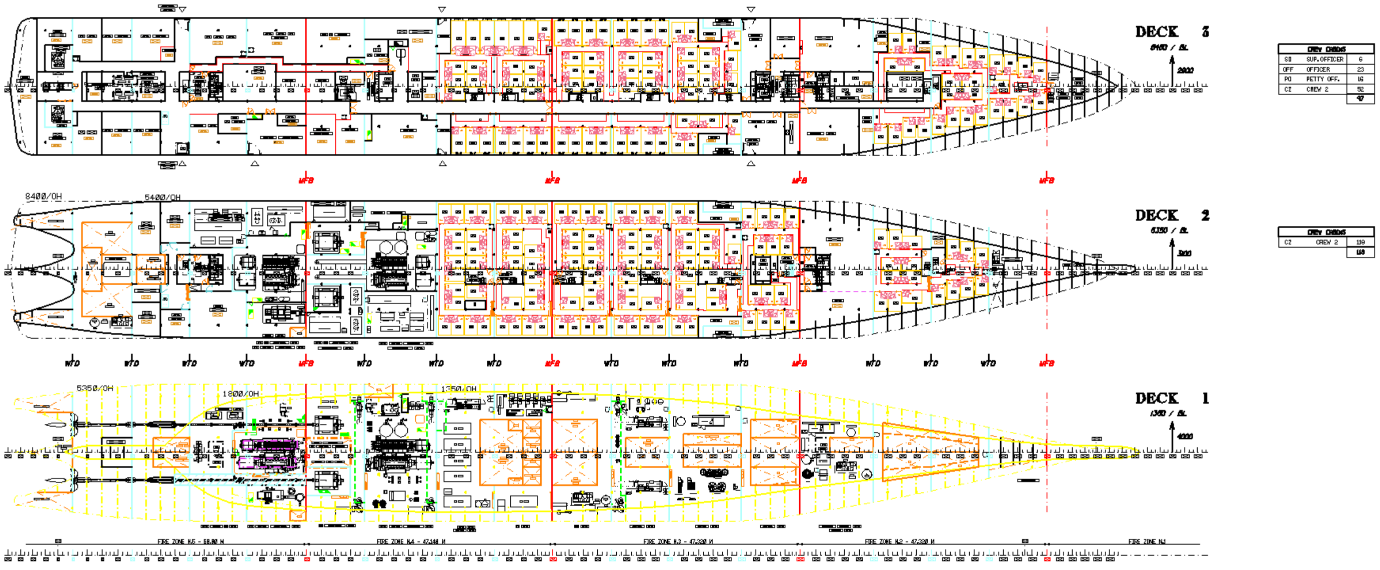

Figure 4 Decks 01 to 03

4.3 Hullform

The ship has a conventional modern hull form of a twin screw vessel with bulbous bow and slender skeg and transom stern.

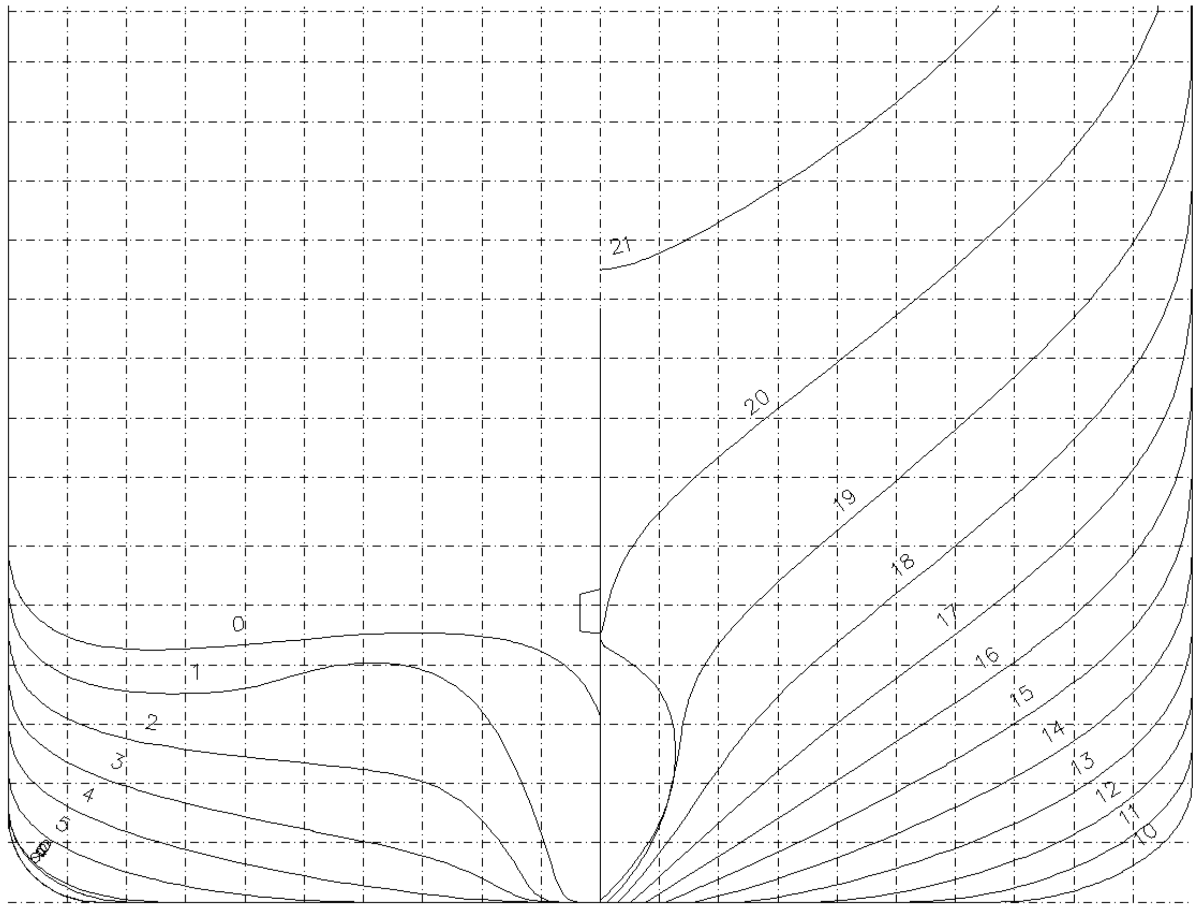

Figure 5 Bodyplan

4.4 Engine configuration

The vessel is propelled by a diesel electric propulsion plant, consisting of four (4) resiliently mounted medium speed main diesel engines, each driving a brushless alternator, producing electrical energy for propulsion and hotel service.

The vessel is a shafted twin screw diesel electric driven passenger cruise ship.

The propulsion system consists of two inboard electric motors at variable speed, each driving a shaft line and pump propeller.

4.5 Tankplan

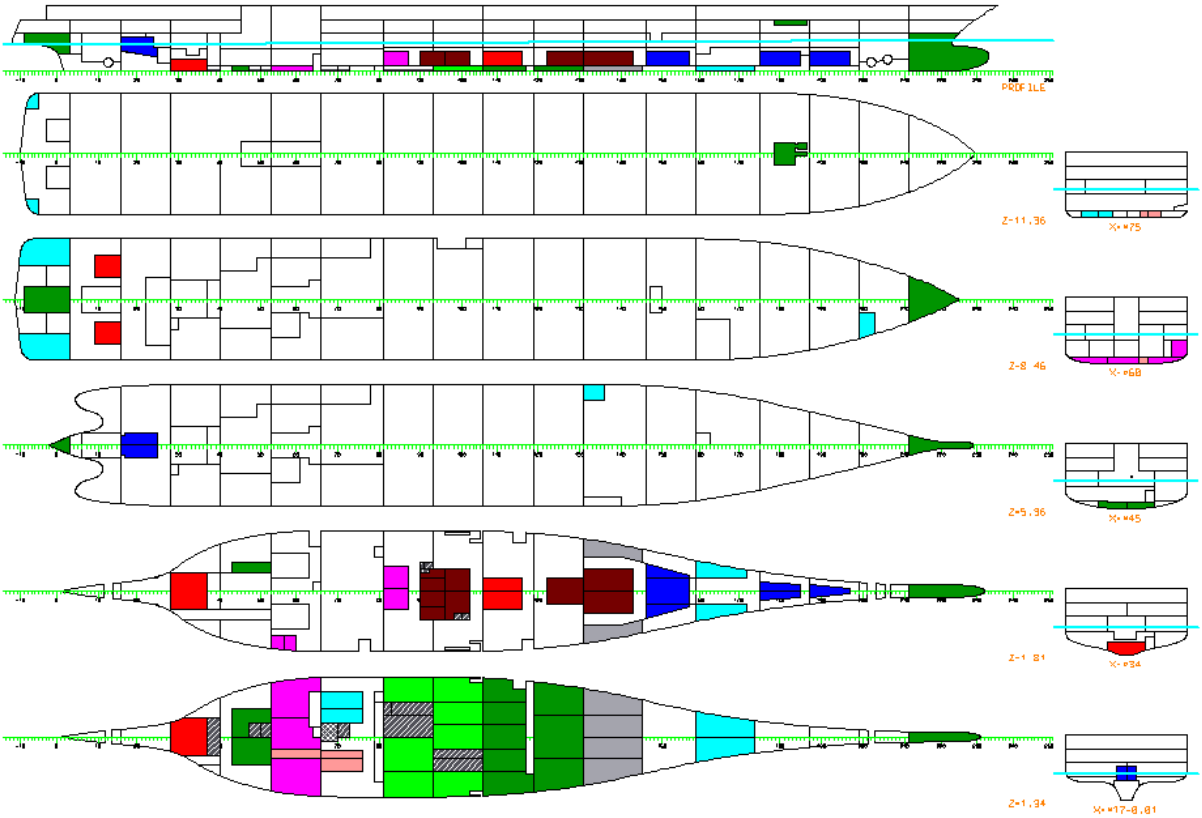

Figure 6 Tankplan

NAME	VNET	WEIGHT
	m3	T
HFO (incl. service and settling)	856.6	822.7
Marine Gas-Oil (incl. service)	536.0	467.5
Lubricating oil	91.1	82.1
Potable water	854.6	854.6
Laundry fresh water	158.4	158.4
Technical fresh water	174.4	174.4
Heeling tanks	354.1	354.1
Grey water	323.3	323.3
Water treatment (incl. Bio sludge)	520	520
Sea water ballast	1253.9	1223.3
Treated water/ Water ballast	588.1	588.1
Bilge Water	90.3	90.3
Miscellaneous	212.5	212.5

Table 1 Tank capacities

4.6 Subdivision

The ship has n.18 watertight compartments but n.21 zones have been defined for the generation of the damage cases. This approach permits to gain index in areas with complex watertight arrangements such as PEM and Main Engine rooms.

No double hull has been provided to protect the main engines but the fore and aft engine rooms are separated by an intermediate watertight compartment, which means that damages of lesser extent do not lead to the loss of both engine rooms.

The two Propulsion Electric Motors (PEM) are located in the same compartment but one of them is encapsulated to comply with the SRTP requirements.

The ship is provided with a continuous double bottom with a height of more than B/20.

The figure below shows the watertight subdivision and the damage zones used in the SOLAS2020 calculation of the attained index.

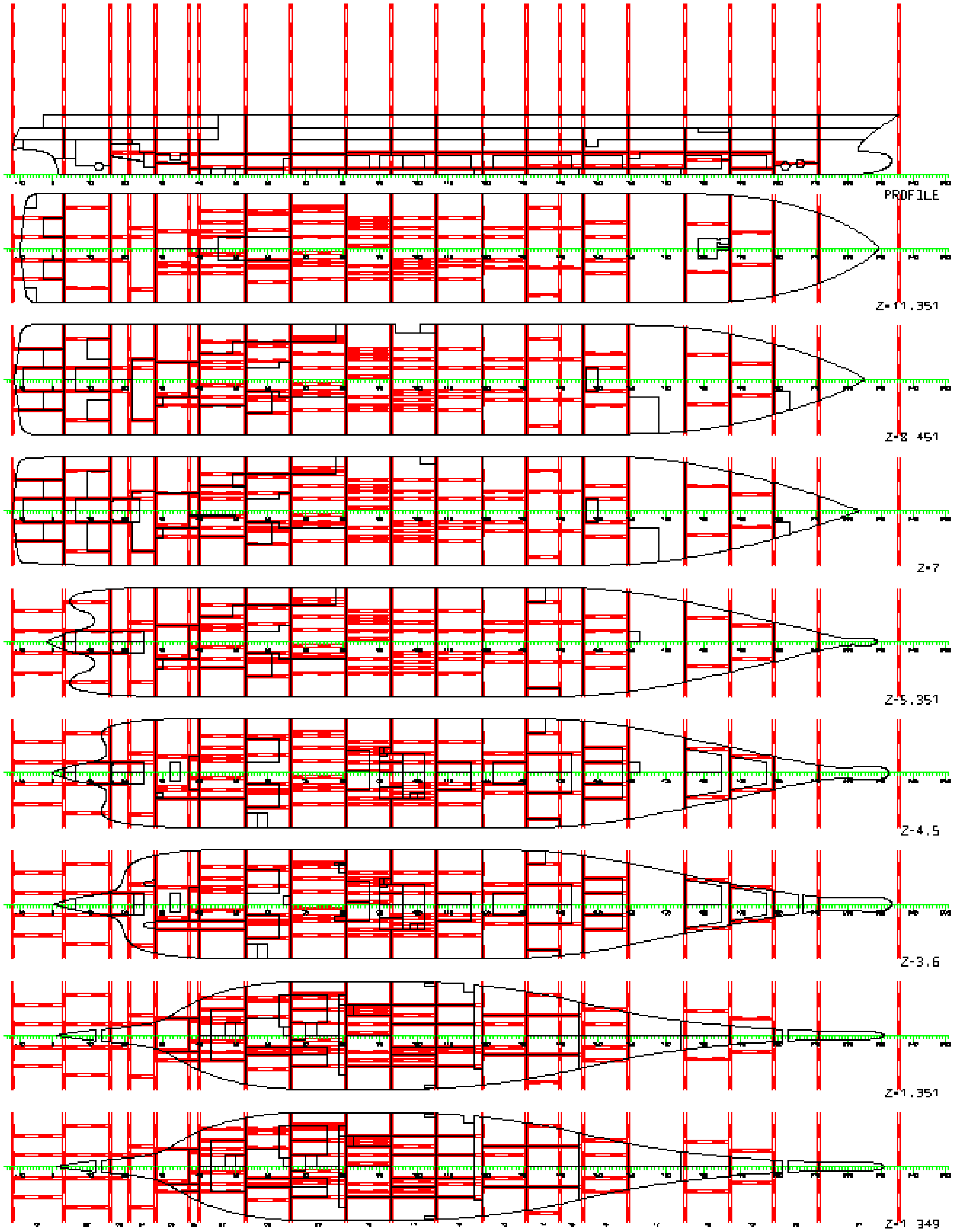

Figure 7: Subdivision used for calculations

5 Hydrodynamics

5.1 Speed power performance

The power at contractual speed is 14483kW.

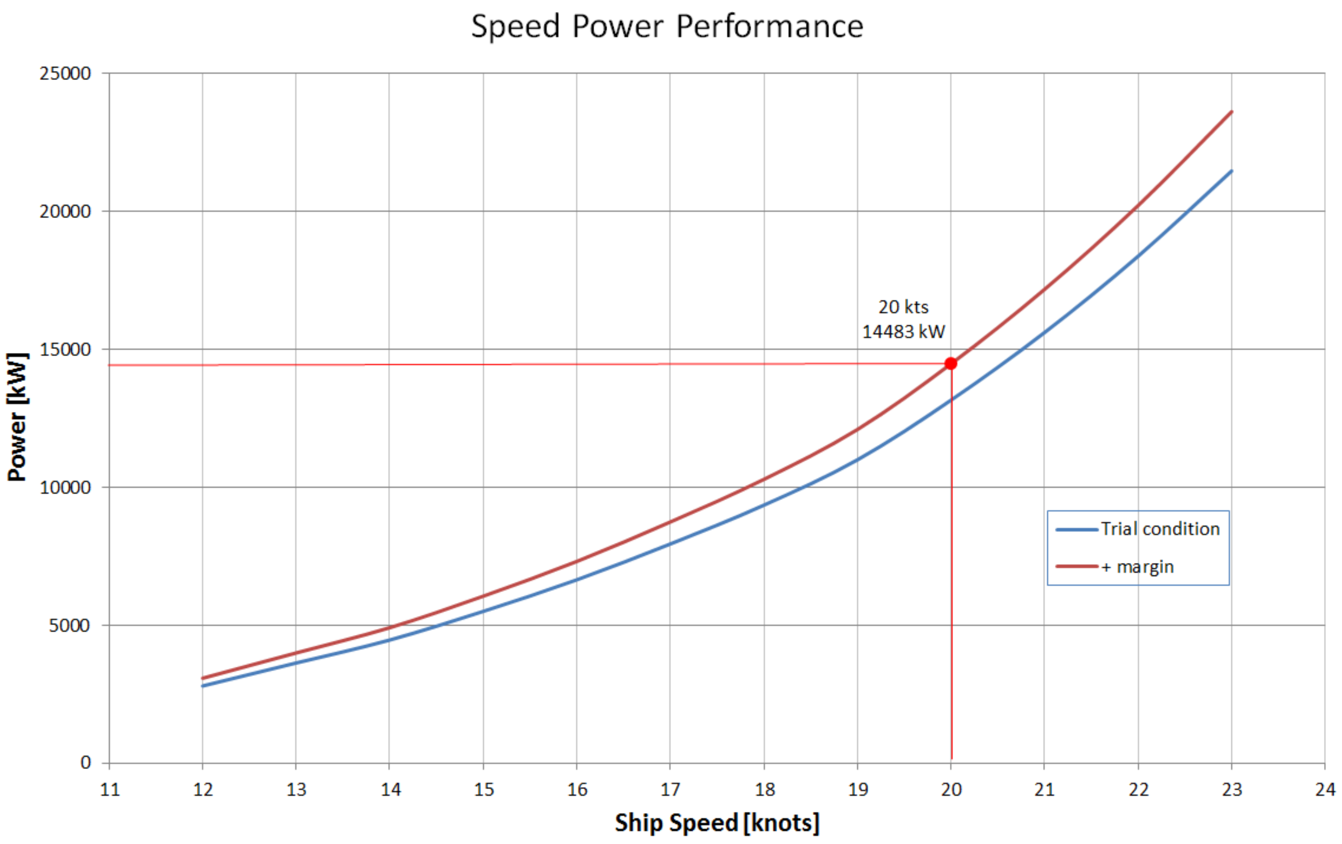

Figure 8: Speed power performance

5.2 Manoeuvrability

The ship is equipped with 2 bow thrusters of 2500 kW each, one stern thrusters and high lift rudders to sustain the required wind speed in the worst direction.

Under the given wind speed the ship will be able to keep its position without the help of tugs.

6 Intact stability

6.1 Loading conditions

The table below shows the loading conditions for further examination of the sample ship:

CASE	DESCRIPTION
LC10	10% SUPPLIES
LC10-SWP	10% SUPPLIES - Pools empty
DESIGN	CONTRACTUAL DEADWEIGHT
FB	MAX DRAFT

CASE		LC10	LC10-SWP	DESIGN	FB
Heavy fuel oil	t	84.1	84.1	750.0	819.3
Low sulfure HFO	t	0.0	0.0	0.0	0.0
Marine gas oil	t	47.6	47.6	250.0	466.1
Lubricating oil	t	40.0	40.0	40.0	40.0
Grey water	t	100.0	100.0	100.0	100.0
Laundry grey water	t	0.0	0.0	0.0	0.0
Black water	t	0.0	0.0	0.0	0.0
Treated water/Ballast	t	200.0	200.0	200.0	200.0
Water treatment	t	60.0	60.0	60.0	60.0
Potable water	t	85.7	85.7	300.0	837.3
Laundry water	t	15.8	15.8	100.0	155.0
Technical water	t	40.0	40.0	40.0	81.0
Heeling tanks	t	177.0	177.0	177.0	177.0
Ballast water	t	867.4	809.0	0.0	0.0
Miscellaneous tank	t	104.4	104.4	104.4	104.4
Miscellaneous HFO tank	t	0.0	0.0	0.0	0.0
Miscellaneous MGO tank	t	0.0	0.0	0.0	0.0
Swimming pools (SW)	t	0.0	0.0	0.0	0.0
Swimming pools (FW)	t	0.0	0.0	0.0	0.0
Passengers	t	111.0	111.0	111.0	111.0
Crew	t	55.5	55.5	55.5	55.5
Provisions	t	222.0	222.0	222.0	222.0
Hotel stores	t	115.0	115.0	115.0	115.0
Engine store	t	100.0	100.0	100.0	100.0
Miscellaneous store	t	200.0	200.0	200.0	200.0
Swimming pool	t	175.0	0.0	175.0	175.0
End of life provision	t	0.0	0.0	0.0	0.0
USABLE DEADWEIGHT	t	2800.7	2567.3	3100.0	4018.8

DEADWEIGHT	t	2800.7	2567.3	3100.0	4018.8
LIGHTWEIGHT	t	18346.5	18346.5	18346.5	18346.5
TOTAL DISPLACEMENT	t	21147.2	20913.8	21446.5	22365.3

MEAN DRAFT (Below keel)	(M)	5.866	5.818	5.927	6.118
TRIM (Positive by bow)	(M)	-0.075	-0.049	-0.119	-0.129
TRANSV. METAC. HEIGHT	(M)	15.502	15.546	15.485	15.384
GM (Solid)	(M)	2.904	2.997	3.003	3.243
FS correction	(M)	-0.191	-0.199	-0.206	-0.168
GM (Fluid)	(M)	2.713	2.799	2.797	3.075

Table 2: Loading condition details

6.2 GM Limiting curve

The following diagram shows the summary of the GM requirements together with the actual loading conditions.

Several limits are shown which all need to be complied with, in particular:

- limit of the intact stability criteria as defined by the IS code 2008
- limits for compliance with the damage stability requirements.

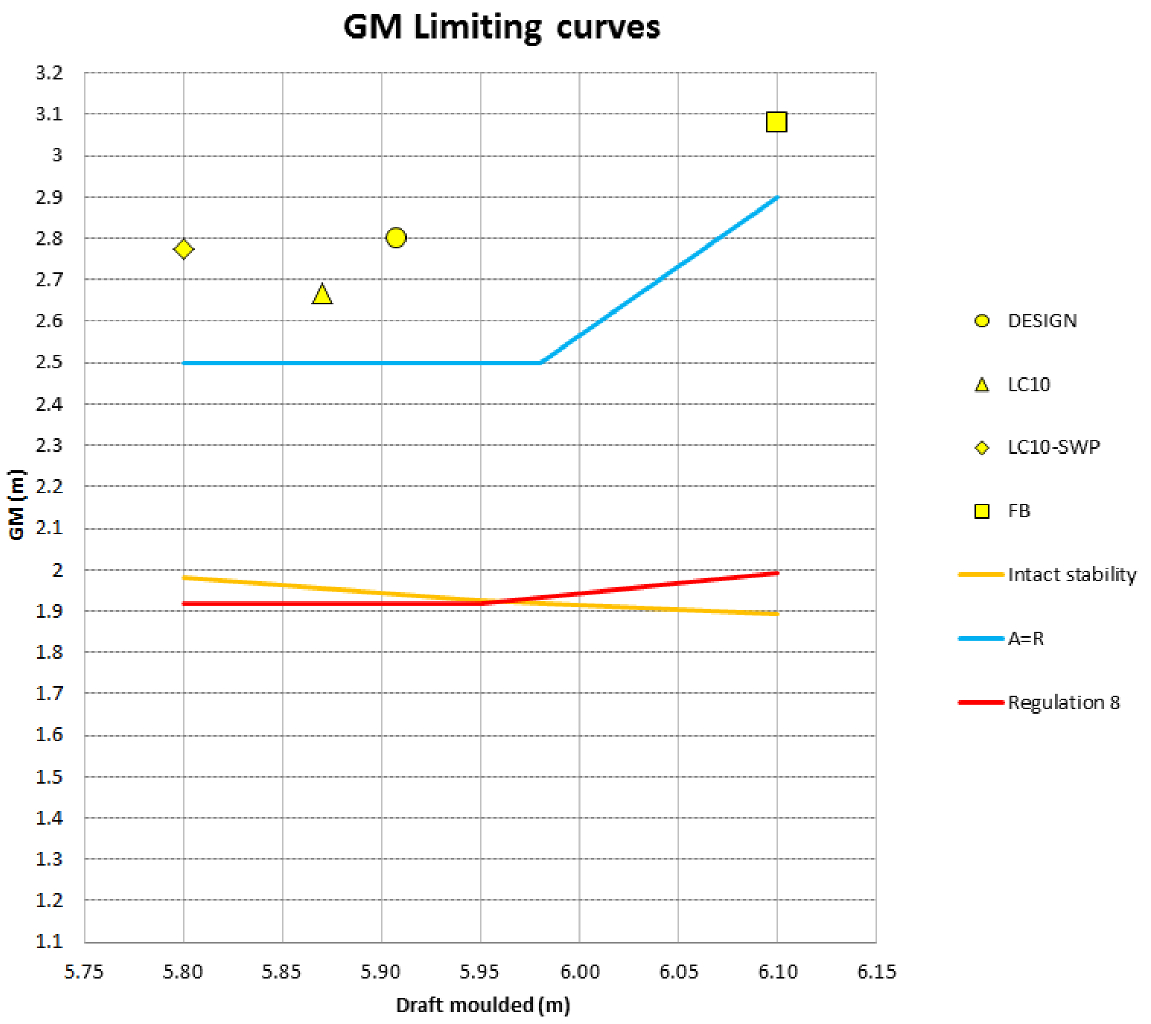

Figure 9: GM Limiting curve

7 Results of damage stability calculation

7.1 Attained index vs R

The following tables show the result of the damage stability calculations according SOLAS II-1.

ATTAINED AND REQUIRED SUBDIVISION INDEX

```
Subdivision length            219.139 m
Breadth at the load line       27.000 m
Breadth at the bulkhead deck   27.000 m
Number of persons N          1386

Required subdivision index R = 0.84824
Attained subdivision index A = 0.86648
```

INITDAMTAB		T	GM	A/R	A	A*WCOEF	WCOEF
DL	DAMP	6.100	2.900	1.024	0.86051	0.17210	0.200
DL	DAMS	6.100	2.900	1.034	0.86838	0.17368	0.200
PL	DAMP	5.980	2.500	1.015	0.85246	0.17049	0.200
PL	DAMS	5.980	2.500	1.032	0.86721	0.17344	0.200
LL	DAMP	5.800	2.500	1.048	0.88077	0.08808	0.100
LL	DAMS	5.800	2.500	1.056	0.88689	0.08869	0.100

Table 3: Attained index for each initial condition

DAMAGES	W*P*V*S	W*P*V
1-ZONE DAMAGES	0.30678	0.30678
2-ZONE DAMAGES	0.34462	0.34771
3-ZONE DAMAGES	0.15690	0.18941
4-ZONE DAMAGES	0.04641	0.09097
5-ZONE DAMAGES	0.00610	0.04000
6-ZONE DAMAGES	0.00052	0.01727
A-INDEX TOTAL	0.86134	0.99214

Table 4: Index according to number of zones for Portside

DAMAGES	W*P*V*S	W*P*V
1-ZONE DAMAGES	0.30678	0.30678
2-ZONE DAMAGES	0.34539	0.34771
3-ZONE DAMAGES	0.16748	0.18941
4-ZONE DAMAGES	0.04591	0.09097
5-ZONE DAMAGES	0.00576	0.04000
6-ZONE DAMAGES	0.00029	0.01727
A-INDEX TOTAL	0.87162	0.99214

Table 5: Index according to number of zones for Starboard

7.2 Reg 8 results

ZONE	NZONE	CASE	SFAC
13/14	2	PL/DMINP13-14.1.0-3	0.90460
13/14	2	LL/DMINP13-14.1.0-3	0.91328
07/08	2	DL/DMINP7-8.1.0	0.94978
05/06/07	3	DL/DMINP5-7.1.0	0.97443

Table 6: GM limits for s>0.9 acc. Reg 8.3

The corresponding GM limiting curves are shown in figure 7.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The information shown in this document and the associated files define a state-of-the-art for medium cruise vessels intended for worldwide operation in warm and temperate waters and it will transit regularly in Panama, Suez and Kiel canal.

The information provided is a part of the basic data required so that the work can be continued in this project in other work packages.

9 REFERENCES

[1] George Zaraphonitis, *GOALDS Deliverable 6.4 Evaluation of innovative designs,* Athens 2012

[2] Henning Luhmann, *Task 6: Damage Stability Calculations of GOALDS RoPax Designs, EMSA/OP/10/2013*, Oslo 2015

[3] Gabriele Bulian et al, *Considering collision, bottom grounding and side grounding/contact in a common non-zonal framework*, Proceedings of the 17th International Ship Stability Workshop, Helsinki 2019

10 ADDITIONAL INFORMATION

Following information is available as separated files:

- General Arrangment Drawing (pdf and dwg format)
- Napa data base, including hull form and internal geometry, loading conditions and damage stability data [NAPA db)

Acronym: FLARE
Project full title: Flooding Accident REsponse
Grant agreement No. 814753
Coordinator: BALance Technology Consulting GmbH

Deliverable 2.1.5

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Deliverable data

Deliverable No	2.1.5		
Deliverable Title	Sample Ship no 5		
Work Package no: title	WP2.1 Sample Ships		

Dissemination level	Public	**Deliverable type**	Report
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Responsible author	Mike Cardinale		
Co-authors			
Date of delivery	[dd-mm-yyyy]		
Approved			**Date [DD-MM-YYYY]**
Peer reviewer 1	Rodolphe Bertin		
Peer reviewer 2			

Document history

Version	**Date**	**Description**
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V01	**10.09.2019**	**Minor editorial changes and non-zonal approach results added**
V02	**25.09.2019**	**Updated version after 1st peer review**

The research leading to these results has received funding from the European Union Horizon 2020 Program under grant agreement n° 814753.
This report reflects only the author's view. INEA is not responsible for any use that may be made of the information it contains.

CONTENTS

List of symbols and abbreviations

DoA	Description of Action
EC	European Commission
PMT	Project Management Team
SG	Steering Group
QA	Quality Assurance
GT	Gross Tonnage
NAPA	Naval Architectural Package
MVZ	Main Vertical Zone
FEM	Finite Element Method
POB	Persons On Board

1 EXECUTIVE SUMMARY

This report describes sample ship no 5, a small cruise ship.

1.1 Problem definition

- To ensure realistic research for the response to flooding events it is necessary to have sample ships available, which may be used in other work packages of this project as well as made public available.
- The basic requirements for the sample ship are to reflect passenger ships design according to the latest SOLAS amendments (SOLAS2020)

1.2 Technical approach and work plan

- A design has been chosen which has been used in a similar way in the previous research projects EMSA3 [1]
- The original design has been upgraded by modification of internal watertight subdivision to reach the SOLAS2020 standard. Furthermore the GA and the tank plan details have been increased in order to have a more precise business model.
- The rooms arrangement, the openings and the connections have been updated within Napa software taking into account the achievement of eSAFE project [2] regarding the sequence of flooding in particular for the so called A-class bulkheads.

1.3 Results

- The selected design has been created to reach suitable degree of detail to provide reasonable continuation of the work.
- In particular the ship may form a valid basis for the cost benefit assessment of risk control options in WP7.
- This design is at a pre-contractual stage but ready to start detailed engineering and construction. The layout and information allows all kind of investigations for damage stability, however detailed information about internal systems, like piping, ducting and cabling cannot be provided.

1.4 Conclusions and recommendation

- The information provided is a part of the basic data so that the work can be continued in this project in other work packages.

2 INTRODUCTION

2.1 Task/Sub-task text

A number of sample ships of large cruise vessels and RoPax ferries, will be provided by the FLARE participants to reflect typical designs of the current fleet. As the focus is laid on large ships, the following limits will be applied:

Gross tonnage > 10,000 GT

Length > 120m

No of MVZ >2

It is anticipated that all ships comply with the future SOLAS requirements (SOLAS2020).

For this project the anticipated degree of detail in the information is based on realistic conceptual designs, conceptual GAP and NAPA model. No detailed information about the systems and components is needed, like the routing of pipes, ducts and cables. If for some work in the following work packages more detailed information is needed, suitable assumptions are to be made by the designers in the provision of such information.

The data of ships used as sample ships in this project is to be prepared to be published, so if existing ships are used a written confirmation by the owner/operator and designers is needed for such use.

The sample ships will be used in the other work packages and also as the basis for the impact of any risk control options.

For each ship a separate deliverable will be created containing a description of the ship, including a general arrangement drawing and the NAPA database.

3 BUSINESS MODEL

As the basis for the design of this ship a business model has been defined to define the basic parameters which need to be fulfilled. These parameters and the business model will be kept unchanged throughout the design process and also during further design studies in a later stage of this project.

The vessel is designed as a worldwide operating cruise vessel for itineraries of a range 9-21 days.

The cruise ship is oriented for cruises in arctic and antarctic regions. Pax experience is focused on observation and exploration.

The ship is "destination oriented" :

- Main public areas located on upper decks for enhanced observation experience;

- Unique restaurant for full day service;

- Large scenic observation lounges;

- No theatre, no casino, no pool;

Following main parameters are to be kept to maintain the business model of this vessel:

1. Number of persons on board: 478 (323 passengers and 155 crew)
2. Pax Accomodation as follow:
    - 158 Total pax cabins
    - 316 pax lower berths
    - 7 pax additional berths
    - Outside cabin ratio 100%
    - 4 Suites
    - 4 Window cabins
    - 150 Balcony cabins
    - Balcony cabins ratio (97%)
3. Crew accommodation as follow:
    - 81 Total crew cabins
    - 1 Captain Class cabin
    - 1 Senior Officer cabin
    - 11 Officer cabins (single/double)
    - 68 Crew cabins (double/triple/quadruple)
4. Space utilization details for public and service spaces :
    a. One Pax Restaurant with 320 seats and abt.650m2 with integrated galley
    b. Abt.1400 m² of other internal public spaces
    c. One Crew Mess with 60 seats
    d. One Off. Mess with 15 seats
    e. Abt. 1250 m² of outside public spaces
    f. One exploration bar
    g. One Explorer Lounge
    h. One SPA Area
    i. One Gym
    j. One embarkation area to RIBS
    k. One public area with:
        - Expedition area
        - Conference room
        - Shop & internet Bar
        - Hospital
    l. Abt. 30m2 for pantry
    m. One main laundry of abt.110m2
    n. One refrigerated garbage store
    o. Abt. 310m2 for provisions
    p. Abt. 320m2 for technical spaces
5. 3 pax lifts connecting all passenger decks
6. No public spaces below bulkhead deck
7. 3 service lifts (all connecting passenger decks e 1 of them connecting laundry also)

8. Longitudinal service corridor without any watertight door (or semi-watertight door to be closed during navigation) to connect provision embarkation area, provision stores, and laundry area
9. Tank capacities
    a. Marine Gas Oil 550 m3
    b. Lube Oil (storage) 28 m3
    c. Potable water 310 m3
    d. Heeling water 175 m3 (capacity for compensation of the static heeling angle caused by a wind speed of 43knots)
    e. Waste water untreated 165 m3
    f. Waster water treated 270 m3 (including dual purpose ballast/treated)
    g. Technical water 65 m3
    h. Water ballast dedicated 300 m3
10. Deadweight 1250t at design draught
11. One bow thruster and one aft thruster with sufficient power to sustain a transversal wind speed of 13.5m/s
12. Fresh water production system capable to produce 140t/day
13. Waste water treatment system capable to treat 135m3/day of waste water
14. Four Diesel generators
15. Propulsion system with two electric motors and shaft lines
16. Trial speed of 17knots at contractual draught, calm water, the four engines running at 85% of MCR, 15% of Sea Margin and the Hotel Load required in navigation
17. Engine plant capable to deliver the full load (propulsion at service speed and hotel load) with three main engines running on maximum 90% MCR and without sea margin. Each diesel generator capable to cover the Hotel load required in port
18. Operational profile: as an average 360 days per year in service, whereof 36% in port and 64% in navigation.

4 General Description of the Ship

This sample ship is a small cruise ship designed for exploration cruises worldwide with capacity of 478 persons on-board.

Life saving appliances are provided for 478 persons on-board for long international voyage. The vessel is a mono hull design with three main vertical zones and watertight subdivision below the bulkhead deck including partial bulkheads on the bulkhead deck.

Passenger cabins are located in three decks, crew cabins are located in five decks.

The vessel has a diesel-electric type propulsion plant located in two watertight compartments. Two electric motors, connected to shaft line, are separated by a longitudinal watertight bulkhead.

The ship has following main characteristics:

Length over all	~128 m
Length between perpendiculars	113.7 m
Subdivision length	125.8 m
Breadth	20.0 m
Subdivision draught	5.3 m
Height of bulkhead deck	7.23 m
Number of passengers	323
Number of crew	155
Gross tonnage	11800 GT
Deadweight	1250 t
No of pax cabins	158
GT/Stateroom	74.7
GT/Lower Bed	37.3
Service speed	16 knots
Trial speed	17 knots
Installed propulsion power	7000 kW
Installed power of main engines	10300 kW

4.1 Regulations

The design complies with all relevant IMO rules and regulations applicable for ships with contract after 1 January 2020, which includes following codes.

1. SOLAS1974 as amended, including probabilistic damage stability and "Safe Return to Port" (SOLAS2020)
2. Intact Stability Code (IS Code 2008)
3. ICE rules (Ice Class 1C)
3. Load line Convention
4. MARPOL, including fuel oil tank protection

4.2 General Arrangement

The following figures show the General Arrangement plan

Figure 1 Profile view

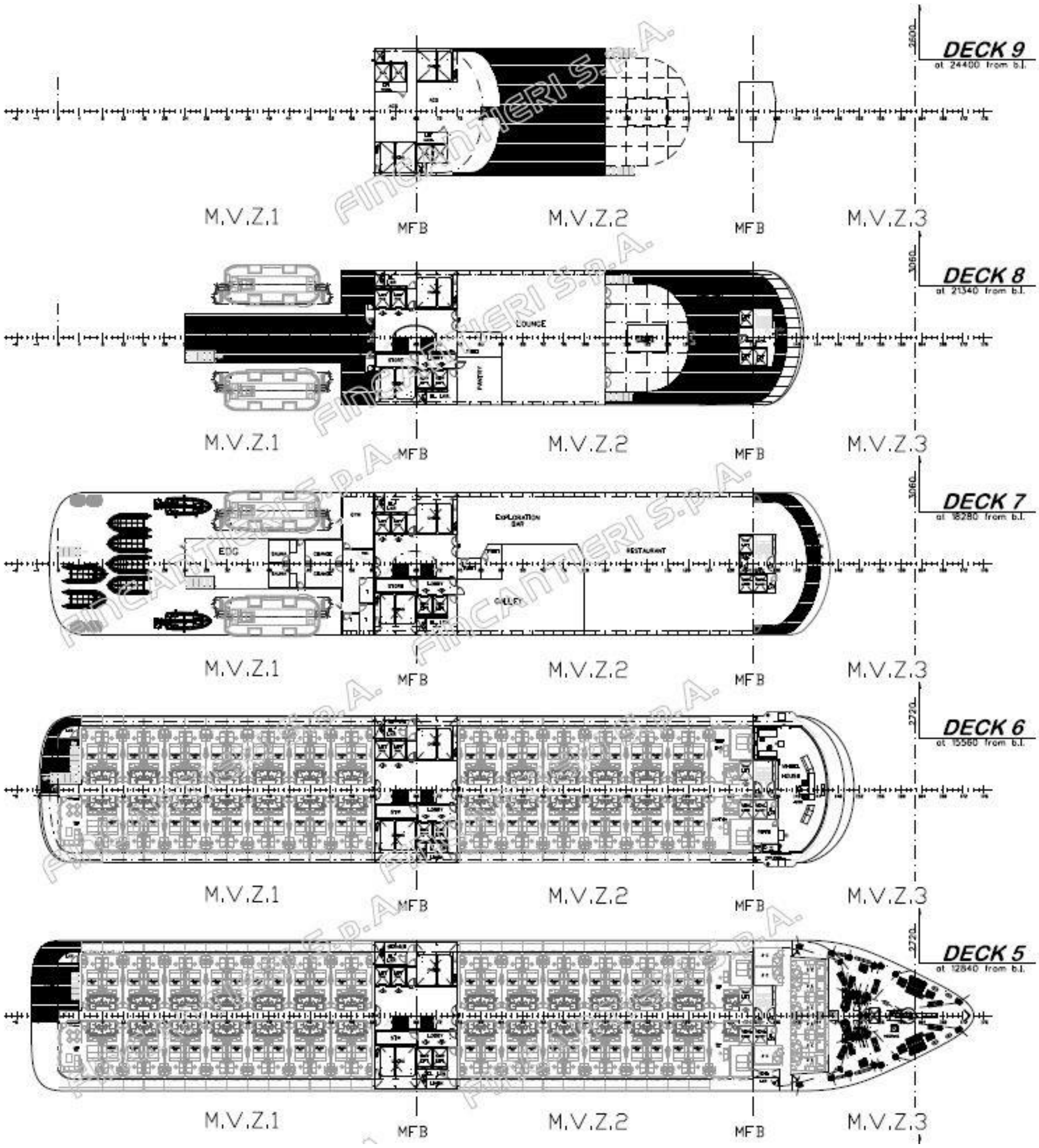

Figure 2 Decks 5 – 9

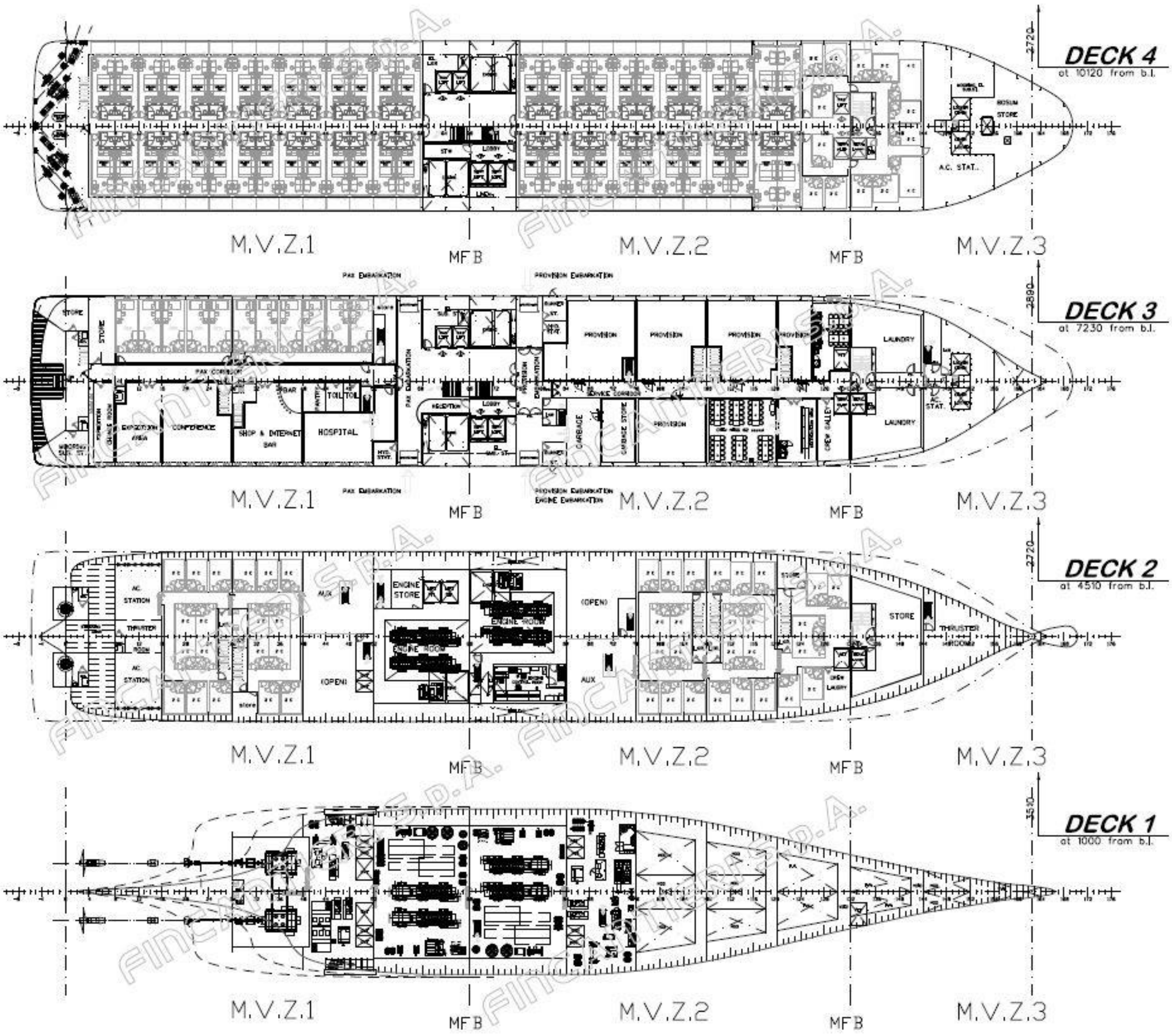

Figure 3 Decks 1 – 4

4.3 Hullform

The ship has a conventional modern hull form of a twin screw vessel with bulbous bow and slender skeg and transom stern.

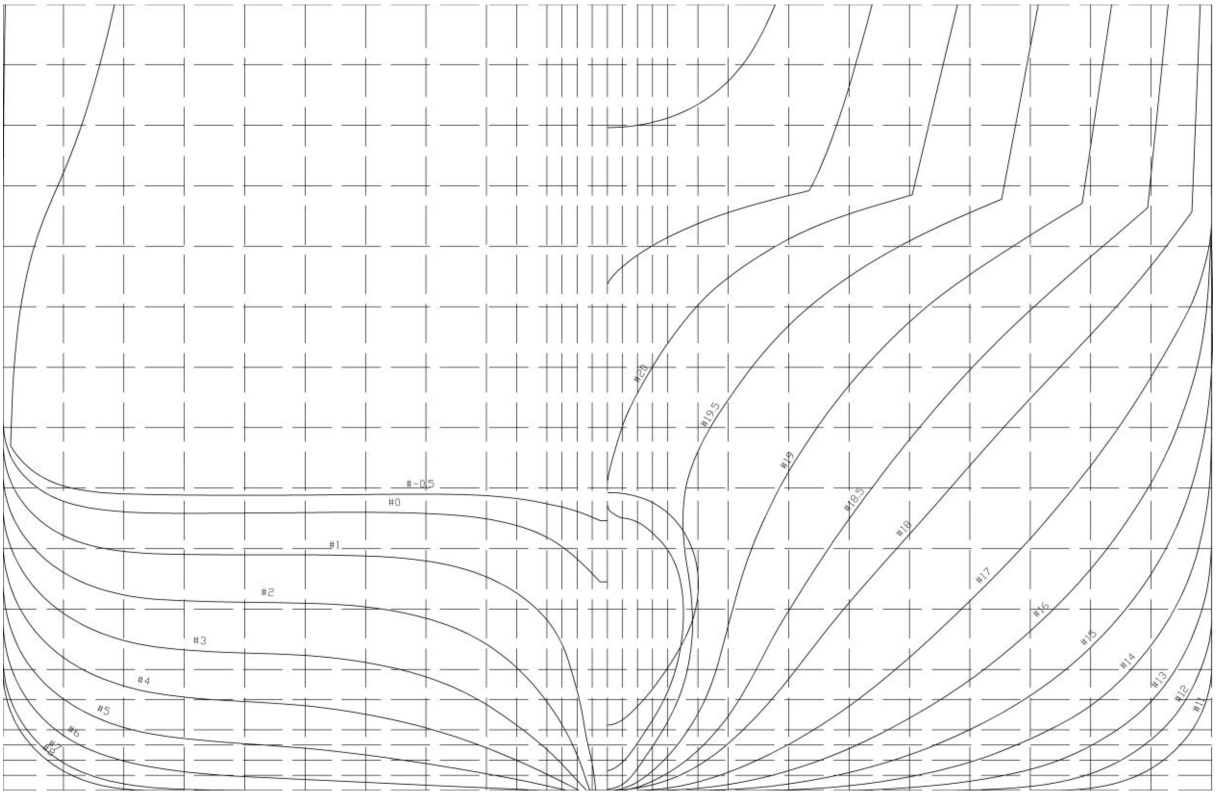

Figure 4 Bodyplan

4.4 Engine configuration

The engine configuration is based on a diesel-electric concept with 4 GEN-SETS.

The engine plant is designed to deliver the full load (propulsion at service speed and hotel load) with three main engines running on maximum 90% MCR and without sea margin. The hotel load required in port has to be covered by one engine only.

The Engine plant is based on four Diesel generators of 2575KW each

The anticipated hotel load is 2000 kW in port and 2800Kw in navigation under tropical conditions.

The propulsion system is based on two electric motors 3500KW each and two shaft lines

Scrubbers are not necessary as only MGO is used.

4.5 Tankplan

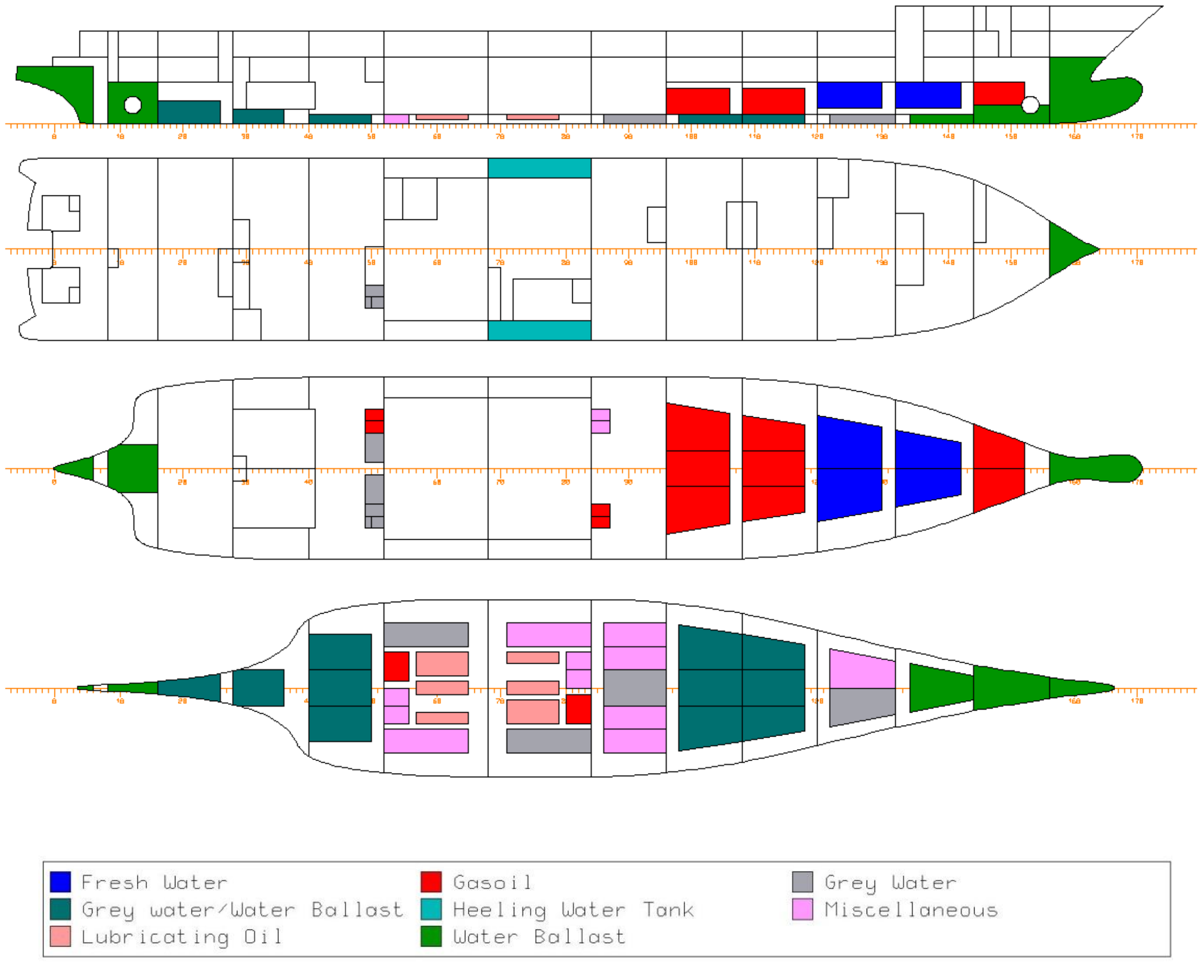

Figure 5 Tankplan

The following capacities are achieved for the various purposes:

Description	RHO	Volume	Requirement	Delta	Weight
	t/m³	m³	m³	m³	t
Marine Gas Oil	0.88	590	550	40	519.2
Lube Oil	0.9	29	28	1	26.1
Potable Water	1	315	310	5	315
Heeling Water	1	182	175	7	182
Waste Water untreated	1	167	165	2	167
Waste Water treated	1	289	270	19	289
Technical water	1	71	65	6	71
Water ballast dedicated	1.025	344	300	44	352.6

Table 1 Tank capacities

4.6 Subdivision

The watertight subdivision is typical for that ship type with two very large compartments for the engine rooms due to SRTP requirements. The ship has n.14 watertight compartments but n.17 zones have been defined for the generation of the damage cases. This approach permits to gain index in areas with complex watertight arrangements such as PEM and Main Engine rooms.

In order to improve damage stability results and protect main engines, two void spaces are located on the sides of the engine rooms. These void spaces are connected by double bottom cross flooding to avoid large heeling angles.

The two Propulsion Electric Motors (PEM) are located in the same compartment but they are separated by a longitudinal bulkhead on the centre line to comply with the SRTP requirements. Even in that compartment two void spaces (connected through double bottom) are arranged on the external sides of the PEM rooms. The forward transversal bulkhead of the PEMs compartment is not straight from side to side but it has a recess due to the longitudinal extension of the PEM therefore an additional small zone is used for the damage stability calculation according to SOLAS2020.

In the subdivision table an "UNDAMAGED AREA" has been defined in the central part of the ship. This is used to route pipes generating progressive flooding that may not be controlled by remote control valves.

The ship is provided with a continuous double bottom with a height of more than B/20.

The figure below shows the watertight subdivision and the damage zones used in the SOLAS2020 calculation of the attained index.

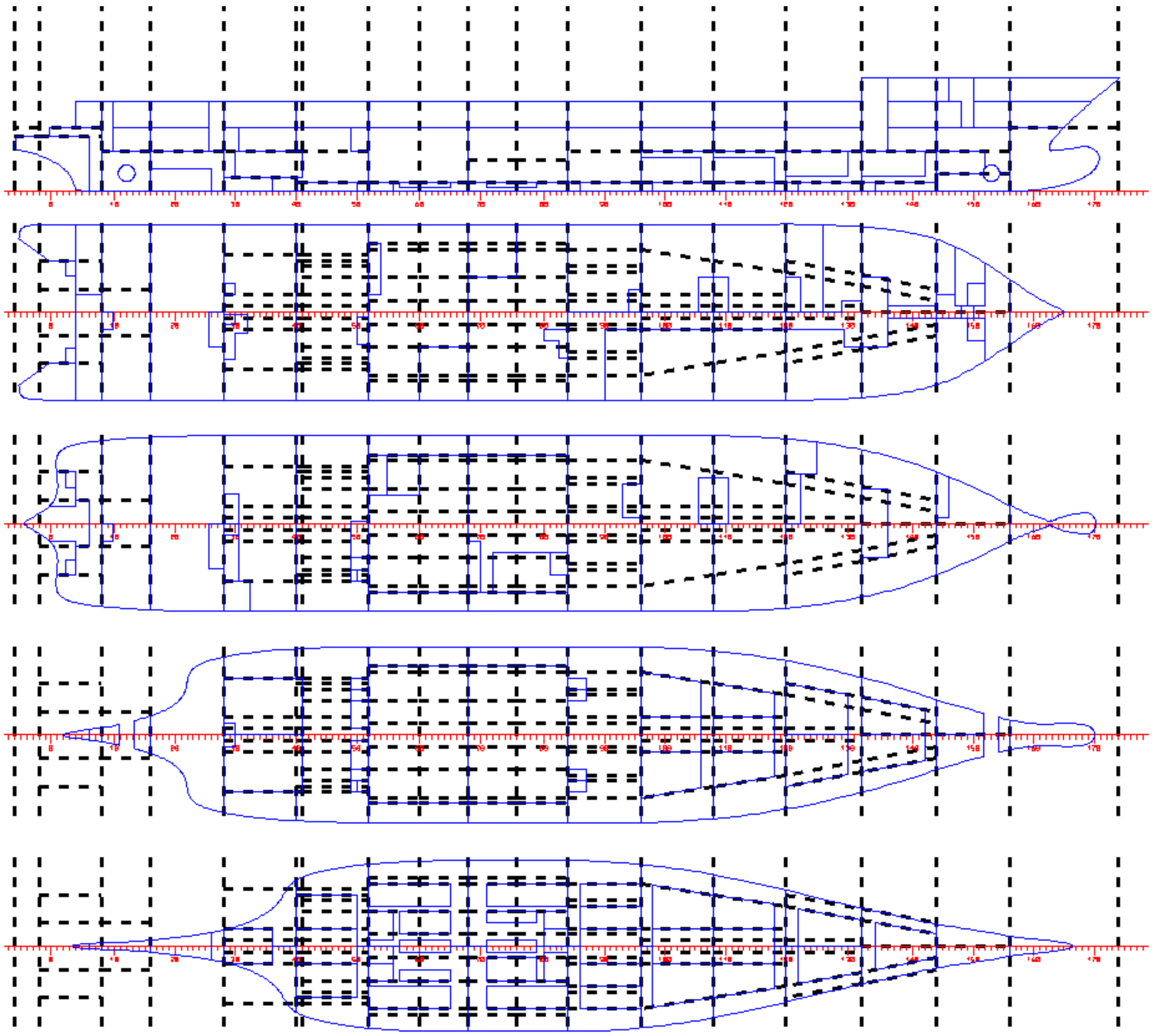

Figure 6: Subdivision used for calculations

5 Hydrodynamics

5.1 Speed power performance

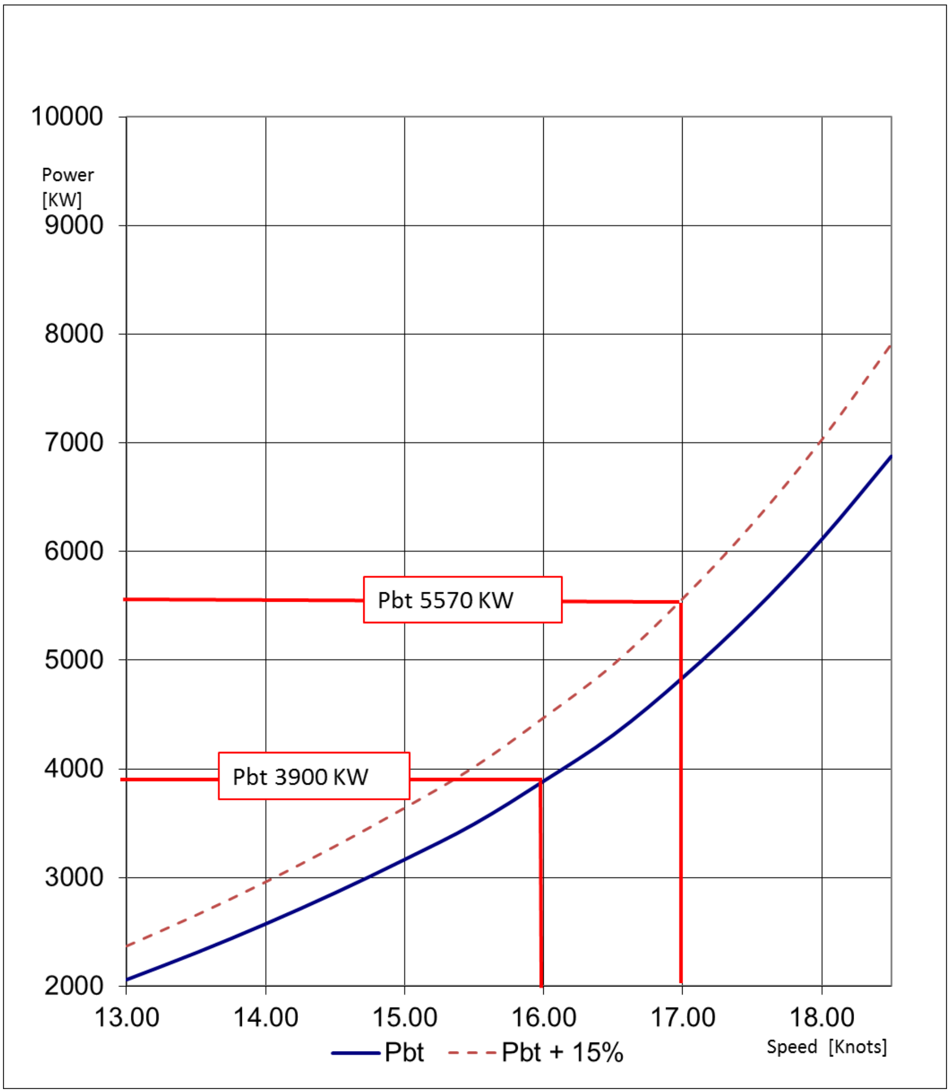

Figure 7: Speed power performance

5.2 Manoeuvrability

The ship is equipped with 1 bow and 1 stern thruster of 1200 kW each in order to sustain a wind speed of 13.5m/s in the transverse direction.

Under the given wind speed the ship will be able to keep its position without the help of tugs (open deep water condition).

6 Intact stability

6.1 Loading conditions

The table below shows the loading conditions designed for further examination of the sample ship:

NAME	TEXT	DW	GO	PW	GW	TGW	WB	SOLID
LD01	Contractual Deadweight	1250 t	470 t	210 t	100 t	70 t	0 t	230 t
LD02	10% consumables	877 t	51 t	32 t	100 t	205 t	202 t	157 t
LD03	100% consumables – max draught	1659 t	511 t	315 t	98 t	241t	0 t	230 t
LD04	ICE condition	1370 t	470 t	210 t	100 t	70 t	26 t	324 t

NAME	TEXT	Draught	Trim (positive by stern)	GM
LD01	Contractual Deadweight	5.09 m	0.03 m	1.40 m
LD02	10% consumables	4.90 m	0.39 m	1.36 m
LD03	100% consumables – max draught	5.30 m	-0.28 m	1.57 m
LD04	ICE condition	5.14 m	0.10 m	1.32 m

Table 2: Loading condition details

6.2 GM Limiting curve

The following diagram shows the summary of the GM requirements together with the actual loading conditions.

There are various limits shown which all need to be complied with, in particular there is the limit of the intact stability criteria as defined by the IS code 2008, and limits for compliance with the damage stability requirements.

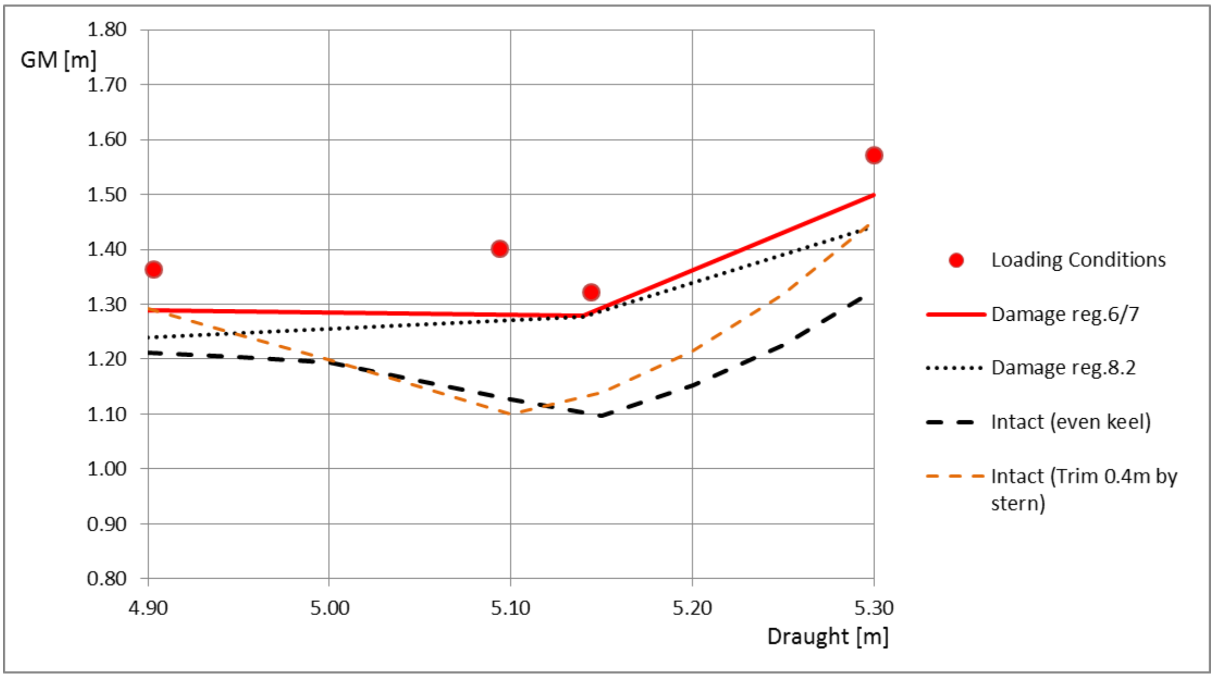

Figure 8: GM Limiting curve

7 Results of damage stability calculation

7.1 Attained index vs R

The following tables show the result of the damage stability calculations according SOLAS II-1.

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	125.80 m
Breadth at the load line	20.00 m
Breadth at the bulkhead deck	20.00 m
Number of persons N	478
Required subdivision index	R = 0.73229
Attained subdivision index	A = 0.74361

INIT	SIDE	T	GM	A/R	A	WCOEF	A*WCOEF
		m	m				
DL	PORT	4.90	1.29	1.04	0.76145	0.1	0.07614
DL	STBD	4.90	1.29	1.04	0.75958	0.1	0.07596
DP	PORT	5.14	1.28	1.00	0.73430	0.2	0.14686
DP	STBD	5.14	1.28	0.99	0.72316	0.2	0.14463
DS	PORT	5.30	1.50	1.03	0.75249	0.2	0.15050
DS	STBD	5.30	1.50	1.02	0.74756	0.2	0.14951

Table 3: Attained index for each initial condition

DAMAGES	W*P*V*S	W*P*V
1-ZONE DAMAGES	0.33485	0.33486
2-ZONE DAMAGES	0.33327	0.37156
3-ZONE DAMAGES	0.07312	0.17117
4-ZONE DAMAGES	0.00237	0.06285
5-ZONE DAMAGES	0.00000	0.02218
A-INDEX	**0.74361**	**0.96262**

Table 4: Index according to number of zones.

7.2 Reg 8 results

T	MINGM	MAXKG	DCRI	DAM
m	m	m		
4.900	1.239	9.742	R8.2-3	SDSR8.2P7-8.1.0
5.140	1.268	9.543	R8.2-3	SDSR8.2P3-4.1.0
5.300	1.441	9.218	R8.2-3	SDSR8.2P3-4.1.0

Table 5: GM limits for s>0.9 acc. Reg 8.2-3

The corresponding GM limiting curves are shown in figure 8.

7.3 Results non-zonal approach

In addition to the standard damage stability results the attained index following the non-zonal approach [3] has been calculated for collision, bottom grounding and side grounding/contact.

As the basis the SOLAS parameters for draughts, permeability and s-factor have been used. For each of the three categories of flooding events 50,000 breaches have been created. Then damage cases to be calculated and associated probabilities are obtained by grouping breaches leading to the same sets of flooded compartments.

The table below shows the number of damage cases that have been calculated and the results obtained for each draught:

Collision			
INIT	T m	N. Dam	ASI
DL	4.90	5742	0.7877
DP	5.14	5708	0.7642
DS	5.30	5710	0.7986

Side Grounding			
INIT	T m	N. Dam	ASI
DL	4.90	2758	0.8499
DP	5.14	2751	0.8477
DS	5.30	2839	0.8740

Bottom Grounding			
INIT	T m	N. Dam	ASI
DL	4.90	9224	0.9047
DP	5.14	9416	0.8917
DS	5.30	9244	0.8943

Table 6: Non-zonal approach results

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The information shown in this document and the associated files define a state-of-the-art for small cruise vessels intended for expedition in arctic and antarctic regions, the market for this ship had a rapid growth during last years.

9 REFERENCES

[1] Dimitris Konovessis et al, *Risk Acceptance Criteria and Risk Based Damage Stability, Final Report, part 2: Formal Safety Assessment, EMSA/OP/10/2013*, Oslo 2015

[2] Henning Luhmann et al, eSAFE - A joint industry project on Damage Stability for Cruise Ships - *Executive Summary*, Oslo 2018é

[3] Gabriele Bulian et al, *Considering collision, bottom grounding and side grounding/contact in a common non-zonal framework*, Proceedings of the 17th International Ship Stability Workshop, Helsinki 2019

10 ADDITIONAL INFORMATION

Following information is available as separated files:

- General Arrangment Drawing (pdf and dxf format)
- Napa data base, including hull form and internal geometry, loading conditions and damage stability data [NAPA db)

Acronym: FLARE
Project full title: Flooding Accident REsponse
Grant agreement No. 814753
Coordinator: BALance Technology Consulting GmbH

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The project has received funding from the European's Horizon 2020 research and innovation programme (Contract No.: 814753)

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Peer reviewer 1	Henning Luhmann (MW)		[2019-09-30]
Peer reviewer 2			

Document history

Version	Date	Description
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V02	30.09.2019	Corrections after review

The research leading to these results has received funding from the European Union Horizon 2020 Program under grant agreement n° 814753.
This report reflects only the author's view. INEA is not responsible for any use that may be made of the information it contains.

CONTENTS

List of symbols and abbreviations

DoA	Description of Action
EC	European Commission
PMT	Project Management Team
SG	Steering Group
QA	Quality Assurance
GT	Gross Tonnage
NAPA	Naval Architectural Package
MVZ	Main Vertical Zone
FEM	Finte Element Method
POB	Persons On Board

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List of tables

1 EXECUTIVE SUMMARY

This report describes sample ship no 6, a small size day ferry.

1.1 Problem definition

- To ensure realistic research for the response to flooding events it is necessary to have sample ships available, which may be used in other work packages of this project as well as made public available.
- The basic requirements for the sample ship are to reflect large passenger ships design according to the latest SOLAS amendments (SOLAS2020)

1.2 Technical approach and work plan

- A design has been chosen which has been used in a similar way in the previous research projects GOALDS [1] and EMSA3 [2]
- The original design has been upgraded by modification of main dimensions to reach the SOLAS2020 standard.

1.3 Results

- The selected design has been created to reach suitable degree of detail to provide reasonable continuation of the work.
- In particular the ship may form a valid basis for the cost benefit assessment of risk control options in WP7.
- This design is at a pre-contractual stage but ready to start detailed engineering and construction. The layout and information allows all kind of investigations for damage stability, however detailed information about internal systems, like piping, ducting and cabling cannot be provided.

1.4 Conclusions and recommendation

- The information provided may form on part of the basic data so that the work can be continued in this project in other work packages.

2 INTRODUCTION

2.1 Task/Sub-task text

A number of sample ships of large cruise vessels and RoPax ferries, will be provided by the FLARE participants to reflect typical designs of the current fleet. As the focus is laid on large ships, the following limits will be applied:

Gross tonnage > 10,000 GT

Length > 120m

No of MVZ >2

It is anticipated that all ships comply with the future SOLAS requirements (SOLAS2020). In this respect, RoPax ships do not need to comply with Stockholm Agreement.

For this project the anticipated degree of detail in the information is based on realistic conceptual designs, conceptual GAP and NAPA model. No detailed information about the systems and components is needed, like the routing of pipes, ducts and cables. If for some work in the following work packages more detailed information is needed, suitable assumptions are to be made by the designers in the provision of such information.

The data of ships used as sample ships in this project is to be prepared to be published, so if existing ships are used a written confirmation by the owner/operator and designers is needed for such use.

The sample ships will be used in the other work packages and also as the basis for the impact of any risk control options.

For each ship a separate deliverable will be created containing a description of the ship, including a general arrangement drawing and the NAPA database.

3 BUSINESS MODEL

As the basis for the design of this ship a business model has been defined to define the basic parameters which need to be fulfilled. These parameters and the business model will be kept unchanged throughout the design process and also during further design studies during a later stage of this project.

The ship is a day ferry with a roro deck for trucks and trailers and an additional garage deck for cars within the super structure for short international voyage. Stern ramp and bow ramp/door provides access from shore to the main roro deck. Access from shore to garage deck to be arranged by a bow door and a land based ramp at the forward end of the garage deck. For loading and unloading of the garage deck there to be located a fixed ramp between garage and main roro deck.

The ship is designed as a day ferry with suitable public rooms, like restaurants, shopping areas and lounges.

Following main parameters are to be kept to maintain the business model of this vessel:

1. Approx 1900 passenger
2. Approx 140 crew berths in mix of 90 single and two person cabins
3. Cargo capacity
    a. abt 800 m trailer lanes, width of lane 2900-3250mm, free height of trailer lanes 4,6 m in main roro deck
    b. abt.1050 car lanes, width of lane 2300mm, free height 2,1m in garage deck
4. Public rooms on lower decks
    a. Buffet restaurant
    b. Cafeteria
    c. Main lounge
    d. Secondary lounge
    e. Casino
    f. Kids room
    g. Tax free shop
    h. Fashion Shop
    i. Logo shop
    j. Sun deck
    k. Reception
5. Crew mess and recreation areas
6. Provision rooms, storage rooms and workshops according to ship size
7. Restrictions of main dimensions
    a. Maximum draught < 6,50m
8. Tank capacities
    a. LNG 250 m3
    b. Marine gas Oil 400m3
    c. Potable Water 700m3

9. Deadweight total 3800 t
    a. 1600 t Trailer
    b. 400 t cars
    c. 400 t potable water
    d. 100 t LNG
    e. 200 t fuel oil
    f. 60 t lub oil
    g. 300 t heeling water
    h. 80 t waste water
    i. 50 t special tanks
    j. 240 t stores and provision
    k. 190 t crew and passengers
    l. 180 t misc
10. Service speed 17 knots
11. Operational profile: as an average 360 days per year in service, whereof
    a. 56% in port
    b. 8% low speed (8,5 knots)
    c. 36% medium speed (16,5knots)

4 General Description of the Ship

The ship is a small day ferry with a roro deck for trucks and trailers and a garage deck for cars. The cargo handling for trucks and trailers is based on a drive-through concept with large stern ramps and a bow door and ramp on the bulkhead deck. The access to the garage deck is provided via fixed ramp between garage and main roro deck and via bow door in garage deck.

The ship is designed as a day ferry with suitable public rooms, like restaurants, shopping areas, lounges.

The ship has a diesel-electric power plant, with 2 shaft lines, bulbous bow and a transom stern. Ship's power plant supply power for propulsion and ship's network. The power plant consists of four generating sets; medium speed dual fuel (diesel / LNG) engines coupled to alternators. Propulsion is provided by two shaft lines; propellers driven by two electric propulsion motors. The anticipated service speed is with 17.0 kn, however the actual service speed may vary with the specific service.

Length over all	ABT. 162 m
Length between perpendiculars	146.72 m
Breadth	28.0 m
Subdivision draught	6.30 m
Height of bulkhead deck	9.20 m
Number of passengers	1900
Number of crew	100
Gross tonnage	28500
Deadweight	3800 t
No of cabins (crew)	91
Lane meter for trailers	ABT. 800
Lane maters for cars	ABT. 1060

Table 1 Main Dimensions

4.1 Regulations

The design complies with all relevant IMO rules and regulations applicable for ships with contract after 1 January 2020, which includes following codes.

1. SOLAS1974 as amended, including probabilistic damage stability and "Safe Return to Port" (SOLAS2020), Short international voyage
2. Intact Stability Code (IS Code 2008)
3. Load line Convention
4. MARPOL, including fuel oil tank protection
5. Marine Labour Convention 2006

4.2 General Arrangement

The following figures show the General Arrangement plan

Figure 1 General Arrangement upper decks

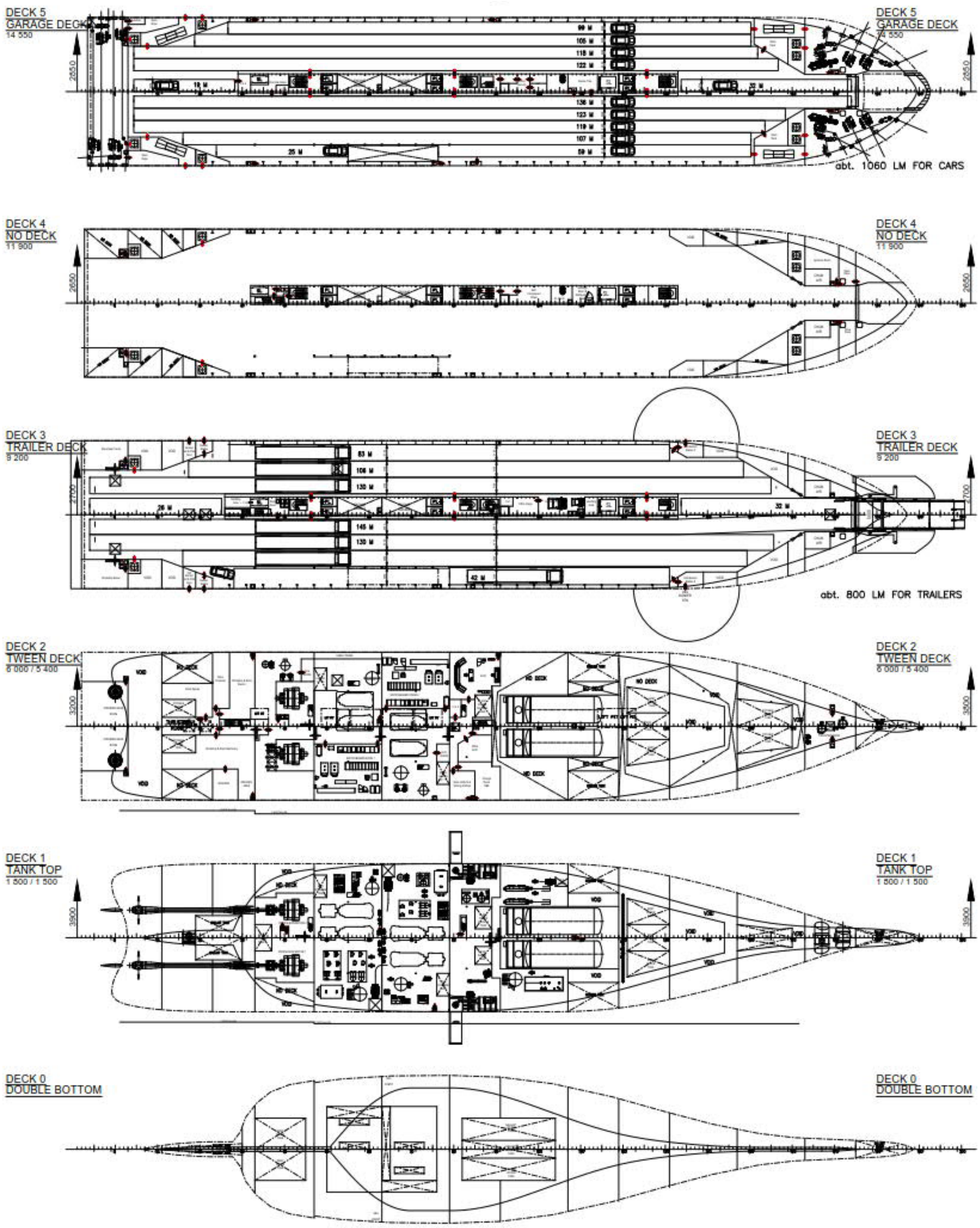

Figure 2 General Arrangement lower decks

4.3 Hullform

The ship has a conventional modern hull form of a twin screw vessel with bulbous bow and slender skeg and transom stern and a tunnel shaped aft body.

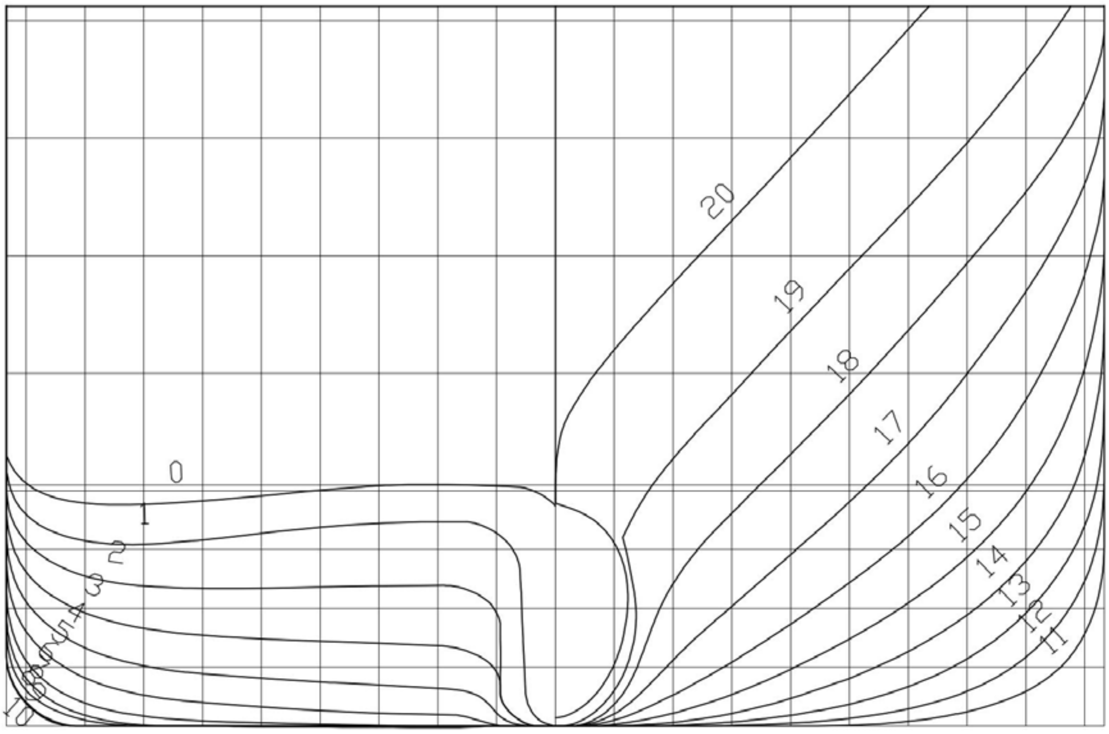

Figure 3 Bodyplan

4.4 Engine configuration

The engine configuration is based on a diesel-electric power plant with 4 medium sized dual fuel main engines, four generator sets. The propellers are driven by two electric propulsion motors.

4.5 Tankplan

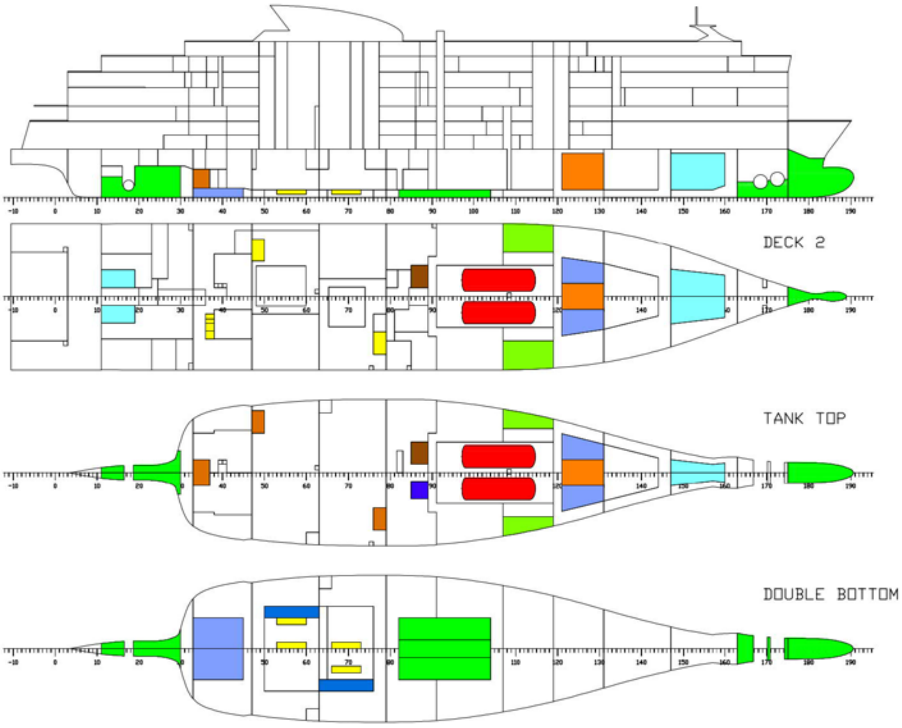

Figure 4 Tankplan

The following capacities are achieved for the various purposes:

NAME	VNET	WEIGHT	LCG	VCG	MOM
POTABLE WATER	704.6 m3	704.6 t	106.32 m	5.83 m	246mt
HEELING WATER	714.7 m3	714.7 t	90.31 m	5.68 m	254 mt
BALLAST WATER	976.1 m3	1000.5 t	75.20 m	2.58 m	501 mt
TECHNICAL WATER	65.1 m3	65.1 t	50.68 m	0.77 m	18 mt
LNG	534.2 m3	251.1 t	84.73 m	4.45 m	132 mt
GAS OIL	437.7 m3	376.4 t	82.40 m	4.78 m	125 mt
LUBRICATING OIL	107.3 m3	96.5 t	46.07 m	5.54 m	32 mt
GREY WATER	658.7 m3	658.7 t	86.71 m	4.51 m	422 mt

Table 2 Tank capacities

4.6 Subdivision

The watertight subdivision follows the needs from the functionality of the spaces, e.g. the size of the compartment for LNG tanks as well as the size of the main engine rooms.

Due to redundancy requirements as defined in SOLAS II/2 there are two independent engine rooms with generators and two own water tight rooms for the electric propulsion motors. These boundaries cause special attention for the damage stability. The LNG tanks are located in own watertight compartment like lower hold. The voids spaces around the tank areas and in the double bottom in such a way to allow instantaneous symmetrical flooding. The heeling water tanks are located on longitudinal location to minimize need of ballast for trimming the ship to even keel situation on departure conditions.

Deck 3 is the main cargo and bulkhead deck. Between deck 3 and 5 there are smaller buoyant spaces at the very end of cargo space to provide additional buoyancy. The access to these spaces is usually not needed during normal voyages but only during loading and unloading. Therefore these spaces can be closed watertight, without applying escape routes.

As required by SOLAS there is no access from the roro deck downwards, the minimum height of any opening is 2.5m above the deck.

The ship is provided with a continuous double bottom with a height of more than B/20 where is required and in way of tank area in forward part of the ship there are U-shaped dry tanks up to bulkhead deck 3.

The figure below shows the watertight subdivision and the damage zones used in the SOLAS2020 calculation of the attained index.

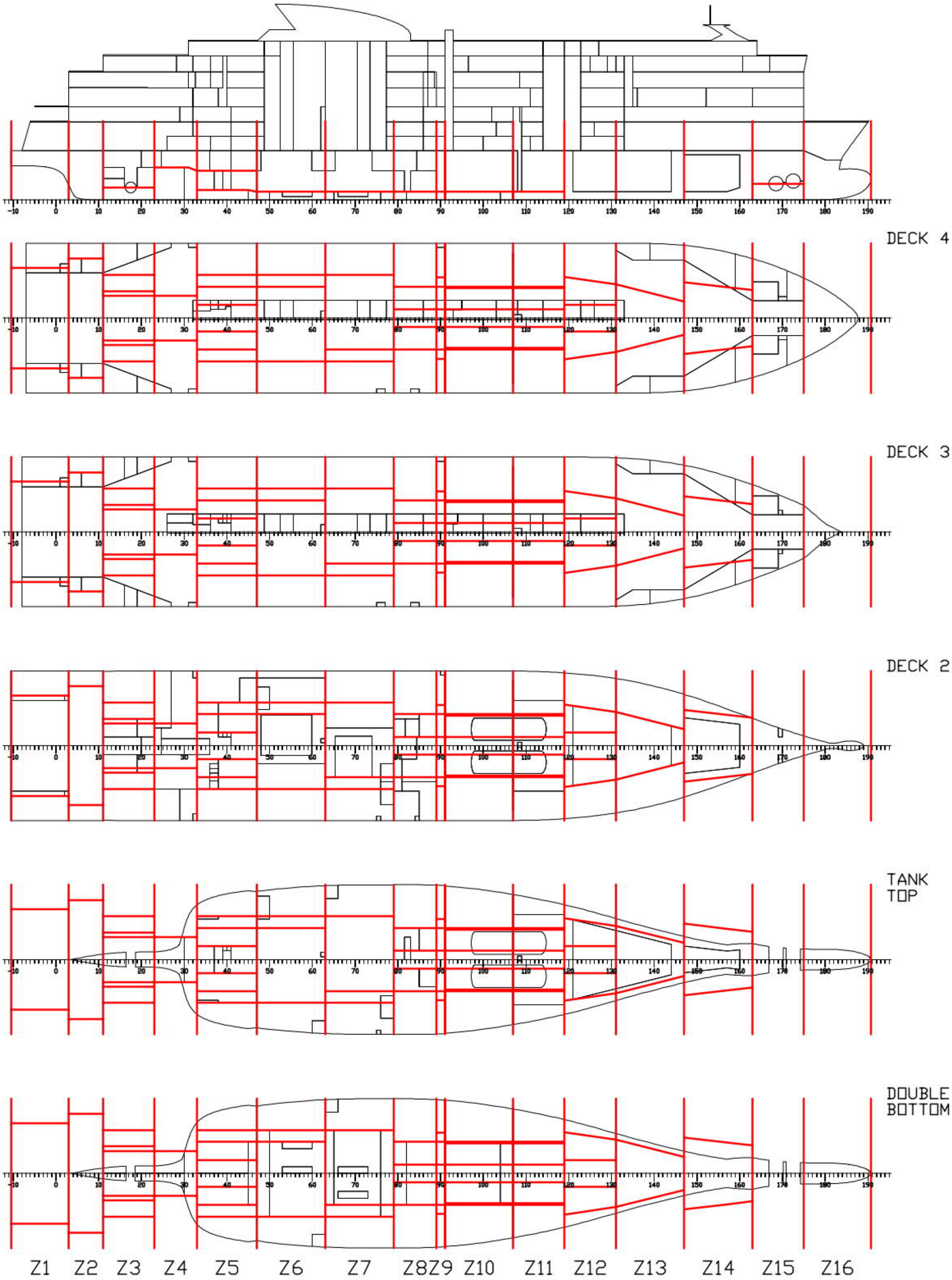

Figure 5 Subdivision used for calculations

5 Hydrodynamics

5.1 Speed power performance

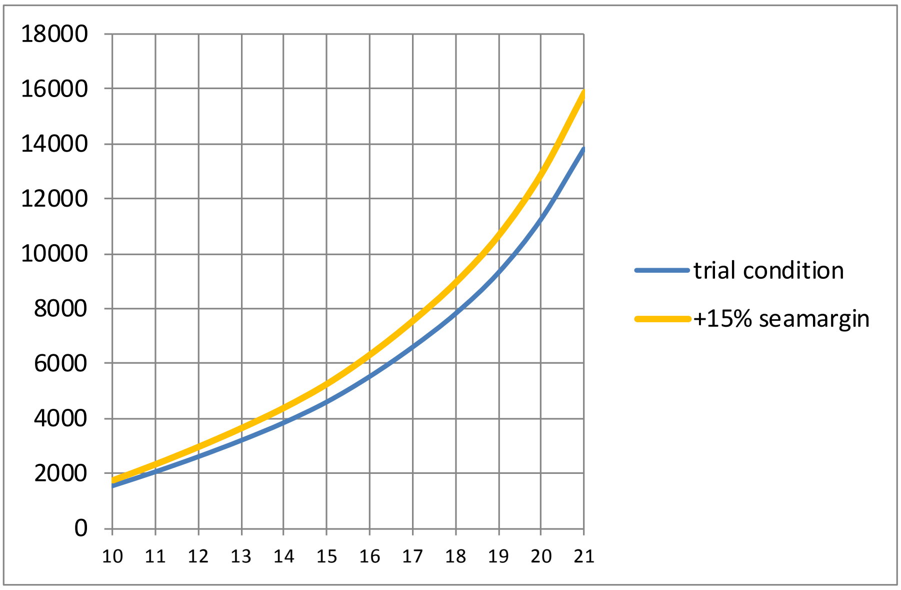

Figure 6 Speed power performance

5.2 Manoeuvrability

The ship is equipped with 2 bow thrusters of 1800 kW each, one stern thrusters of 900 kW to maintain the required wind speed in the worst direction.

6 Intact stability

6.1 Loading conditions

The table below shows the loading conditions designed for further examination of the sample ship:

NAME	TEXT	DW	CA	BW	GW	LNG	GO	PW
L2	Design draught, departure	3800 t	2000 t	0 t	40 t	100 t	200 t	400 t
L3	Spec case arrival 10% bunkers and stores	3239 t	2000 t	312 t	40 t	10 t	20 t	40 t
L4	Ballast draught, departure	2005 t	0 t	0 t	40 t	200 t	215 t	490 t
L5	Ballast draught, arrival	1318 t	0 t	370 t	40 t	200 t	22 t	49 t
L6	Max trailers and cars, 100 % Bunkers and stores	4525 t	2520 t	0 t	40 t	200 t	215 t	490 t
L7	Only cars, departure	2500 t	700 t	0 t	40 t	100 t	200 t	400 t
L8	Only cars, arrival	1939 t	700 t	312 t	40 t	10 t	22 t	40 t

NAME	TEXT	Draught	trim	GM
L2	Design draught, departure	6.10 m	0.02 m	4.75 m
L3	Spec case arrival 10% bunkers and stores	5.94 m	-0.02 m	4.83 m
L4	Ballast draught, departure	5.60 m	-0.01 m	5.33 m
L5	Ballast draught, arrival	5.40 m	-0.01 m	5.46 m
L6	Max trailers and cars, 100 % Bunkers and stores	6.30 m	0.06 m	4.84 m
L7	Only cars, departure	5.74 m	0.01 m	4.99 m
L8	Only cars, arrival	5.58 m	0.01 m	5.15 m

Table 3: Loading condition details

6.2 GM Limiting curve

The following diagram shows the summary of the GM requirements together with the actual loading conditions.

There are various limits shown which all need to be complied with, in particular there is the limit of the intact stability criteria as defined by the IS code 2008, and limits for compliance with the damage stability requirements.

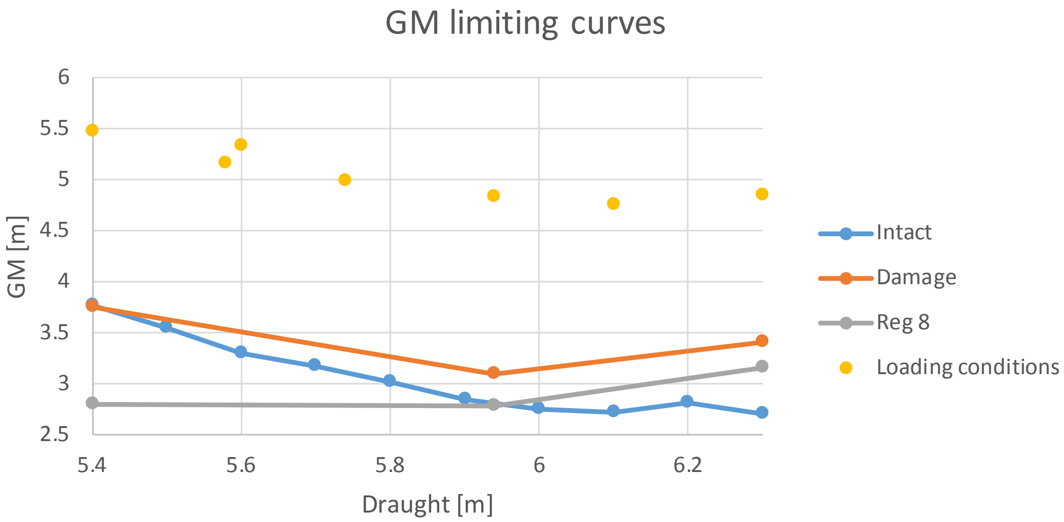

Figure 7 GM Limiting curve

7 Results of damage stability calculation

7.1 Attained index vs R

The following tables show the result of the damage stability calculations according SOLAS II-1.

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	160.958 m
Breadth at the load line	28.000 m
Breadth at the bulkhead deck	28.000 m
Total number of persons on board	2000
Required subdivision index SOLAS2020	R = 0.8611
Required subdivision index SOLAS2009	R = 0.7907
Attained subdivision index	A = 0.8892

Init	Damtab	T	A	A/R	A*WCOEF	WCOEF
DL	DAMP	5.4	0.95958	1.11	0.095958	0.1
DL	DAMS	5.4	0.95755	1.11	0.095755	0.1
DP	DAMP	5.94	0.8946	1.04	0.17892	0.2
DP	DAMS	5.94	0.88401	1.03	0.176802	0.2
DS	DAMP	6.3	0.86068	1.00	0.172136	0.2
DS	DAMS	6.3	0.84827	0.99	0.169654	0.2
Total					0.889225	

Table 4: Attained index for each initial condition

	S-side	P-side	Average P+S
Damages	P*V*S*W	P*V*S*W	P*V*S*W
1 -zone	0.369	0.369	0.369
2 -zone	0.38275	0.38439	0.38357
3 -zone	0.1115	0.1176	0.11455
4 -zone	0.02042	0.02189	0.021155
5 -zone	0.00076	0.00114	0.00095
A-index total	0.88443	0.89402	0.889225

Table 5: Index according to number of zones.

7.2 Reg 8 results

T	MINGM	DCRI	DAM
5.4	2.80	S-REG8	MS8-9.1.0-1
5.94	2.78	S-REG8	MS8-9.1.0-1
6.3	3.15	S-REG8	MS8-9.1.0-1

Table 6: GM limits for s>0.9 acc. Reg 8.3

The corresponding GM limiting curves are shown in figure 7.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The information shown in this document and the associated files defines a state-of-the-art medium size day ferry.

9 ADDITIONAL INFORMATION

Following information is available as separated files:

- General Arrangement Drawing (pdf format)
- Napa data base, including hull form and internal geometry, loading conditions and damage stability data (NAPA db)

Acronym: FLARE
Project full title: Flooding Accident REsponse
Grant agreement No. 814753
Coordinator: BALance Technology Consulting GmbH

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Deliverable Title	Sample Ship o 7		
Work Package no: title	WP2.1 Sample Ships		

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Co-authors			
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Peer reviewer 1	Anna-Lea routi (MT)		
Peer reviewer 2			

Document history

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V03	**22.8.2019**	Version after review
V03	**15.02.2021**	GAP replaced in figure 3

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POB	Persons On Board
GAP	General Arrangement Plan
GM	Metacentric height
KG	vertical centre of gravity
VCG	vertical centre of gravity
LCG	longitudinal centre of gravity
FSM	free surface moment
DL	lightest service draught
DP	partial draught
DS	deepest subdivision draught

List of figures

List of tables

1 EXECUTIVE SUMMARY

This report describes sample ship no 7, a large RoPax ferry.

1.1 Problem definition

- To ensure realistic research for the response to flooding events it is necessary to have sample ships available, which may be used in other work packages of this project as well as made public available.
- The basic requirements for the sample ship are to reflect large passenger ships design according to the latest SOLAS amendments (SOLAS2020)

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- In particular the ship may form a valid basis for the cost benefit assessment of risk control options in WP7.
- This design is at a pre-contractual stage but ready to start detailed engineering and construction. The layout and information allows all kind of investigations for damage stability, however detailed information about internal systems, like piping, ducting and cabling cannot be provided.

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A number of sample ships of large cruise vessels and RoPax ferries, will be provided by the FLARE participants to reflect typical designs of the current fleet. As the focus is laid on large ships, the following limits will be applied:

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It is anticipated that all ships comply with the future SOLAS requirements (SOLAS2020). In this respect, RoPax ships do not need to comply with Stockholm Agreement.

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The data of ships used as sample ships in this project is to be prepared to be published, so if existing ships are used a written confirmation by the owner/operator and designers is needed for such use.

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3 BUSINESS MODEL

As the basis for the design of this ship a business model has been defined to define the basic parameters which need to be fulfilled. These parameters and the business model will be kept unchanged throughout the design process and also during further design studies during a later stage of this project.

The ship is a large modern cruise ferry with a roro deck for trucks and trailers, a large lower hold for cars and an additional car deck within the super structure for short international voyage.

The ship is designed as an overnight ferry with a large number of cabins and suitable public rooms, like restaurants, shopping areas, conference centre, lounges and a spa area.

Following main parameters are to be kept to maintain the business model of this vessel:

1. Approx 1000 passenger cabins
2. Approx 200 crew berths in single cabins
3. Cargo capacity
    a. 1500 m trailer lanes, width of lane 3000mm, free height of trailer lanes 4.6 m
    b. 1000 cars, with no trucks. Cars may be stowed in lower hold and hoistable car deck
4. Public rooms on lower decks
    a. Night club / lounge 2 decks 1600 m2
    b. Buffet restaurant 1000 m2
    c. 2 special restaurants
    d. Tax Free shop 1000m2
    e. Spa area 350 m2
    f. Sea view Lounge 500 m2
    g. conference area 800 m2
    h. sun deck
    i. Cafés and snack bars
    j. Shopping mall
    k. Reception
    l. Driver restaurant
5. Crew mess and recreation areas
6. Provision rooms, storage rooms and workshops according to ship size
7. Restrictions of main dimensions
    a. Length over all < 230m
    b. Maximum draught < 6.80m
8. Tank capacities
    a. Heavy Fuel Oil 1000 m3
    b. Marine gas Oil 700m3
    c. Potable Water 1200m3
9. Deadweight total 6750 t
    a. 2800 t Trailer

b. 600 t cars
c. 800 t potable water
d. 800 t fuel oil
e. 100 t lub oil
f. 450 t heeling water
g. 400t waste water
h. 200t special tanks
i. 400 t stores and provision
j. 200 t crew and passengers

10. Service speed 21.5 knots at 85% MCR
11. Operational profile: as an average 360 days per year in service, whereof
    a. 17% in port
    b. 13% low speed (12 knots)
    c. 17% medium speed (15 knots)
    d. 54% high speed (20 knots)

4 GENERAL DESCRIPTION OF THE SHIP

The ship is a large modern cruise ferry with a roro deck for trucks and trailers, a large lower hold for cars and an additional car deck within the super structure. The cargo handling is based on a drive-through concept with large stern ramps and a bow door and ramp on the bulkhead deck. The access to the other cargo areas is provided via internal ramps.

In addition a hoistable car deck is provided to allow for sufficient car capacity.

The ship is designed as an overnight ferry with a large number of cabins and suitable public rooms, like restaurants, shopping areas, conference centre, lounges and a spa area.

The propulsion concept is based on a twin screw plant with CPP and 4 geared main engines. 4 auxiliary diesel generators are provided to supply the energy for the hotel services. The anticipated service speed is with 21.5kn in the medium range of similar vessels, however the actual service speed may vary with the specific service.

Main dimensions

Length over all	Apprx 229m
Length between perpendiculars	214.32 m
Subdivision length	227.97 m
Breadth	33.2 m
Subdivision draught	6.70 m
Height of bulkhead deck	9.70 m
Number of passengers	3300
Number of crew	200
Gross tonnage	70000
Deadweight	6900 t
No of cabins	1000
Lanemeter	1500
No of cars	1000

Table 1 Main dimensions

4.1 Regulations

The design complies with all relevant IMO rules and regulations applicable for ships with contract after 1 January 2020, which includes following codes.

1. SOLAS1974 as amended, including probabilistic damage stability and “Safe Return to Port” (SOLAS2020), Short international voyage
2. Intact Stability Code (IS Code 2008)
3. Load line Convention
4. MARPOL, including fuel oil tank protection
5. Marine Labour Convention 2006

4.2 General Arrangement

The following figures show the General Arrangement plan

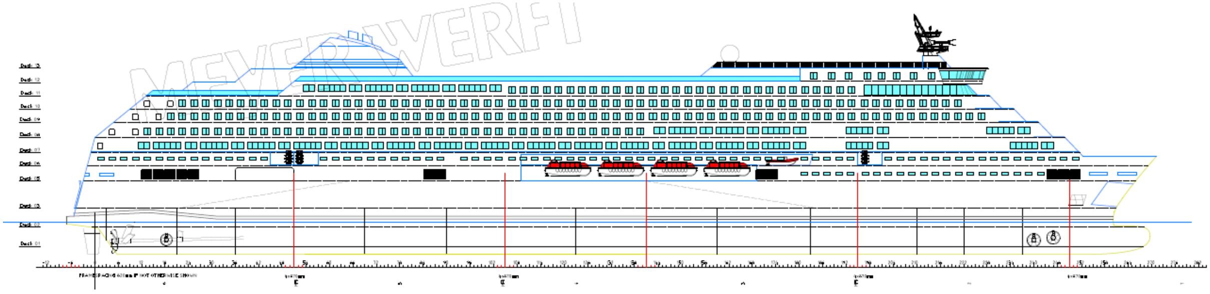

Figure 1 Profile view

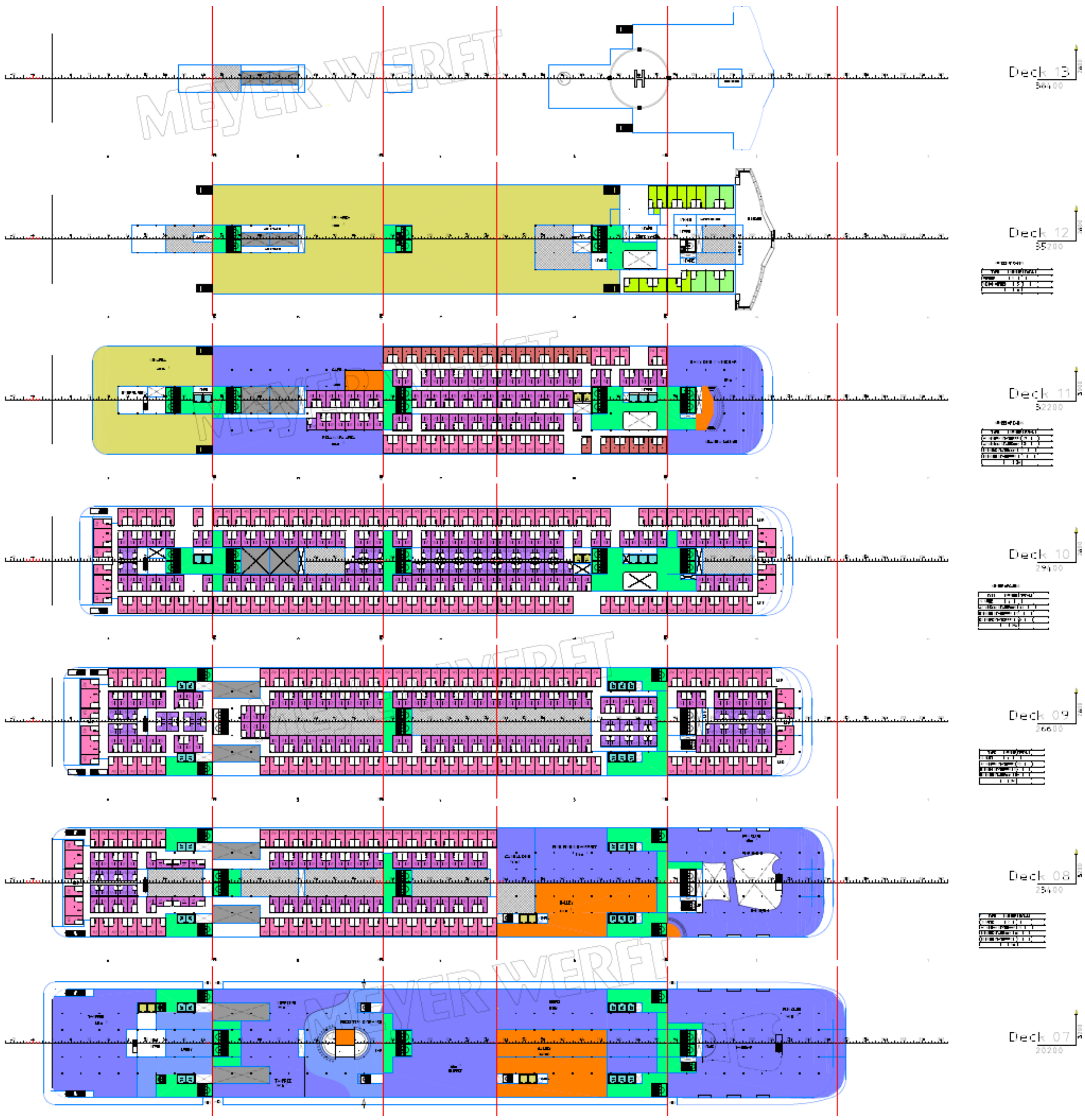

Figure 2 GAP Deck 7 – 13

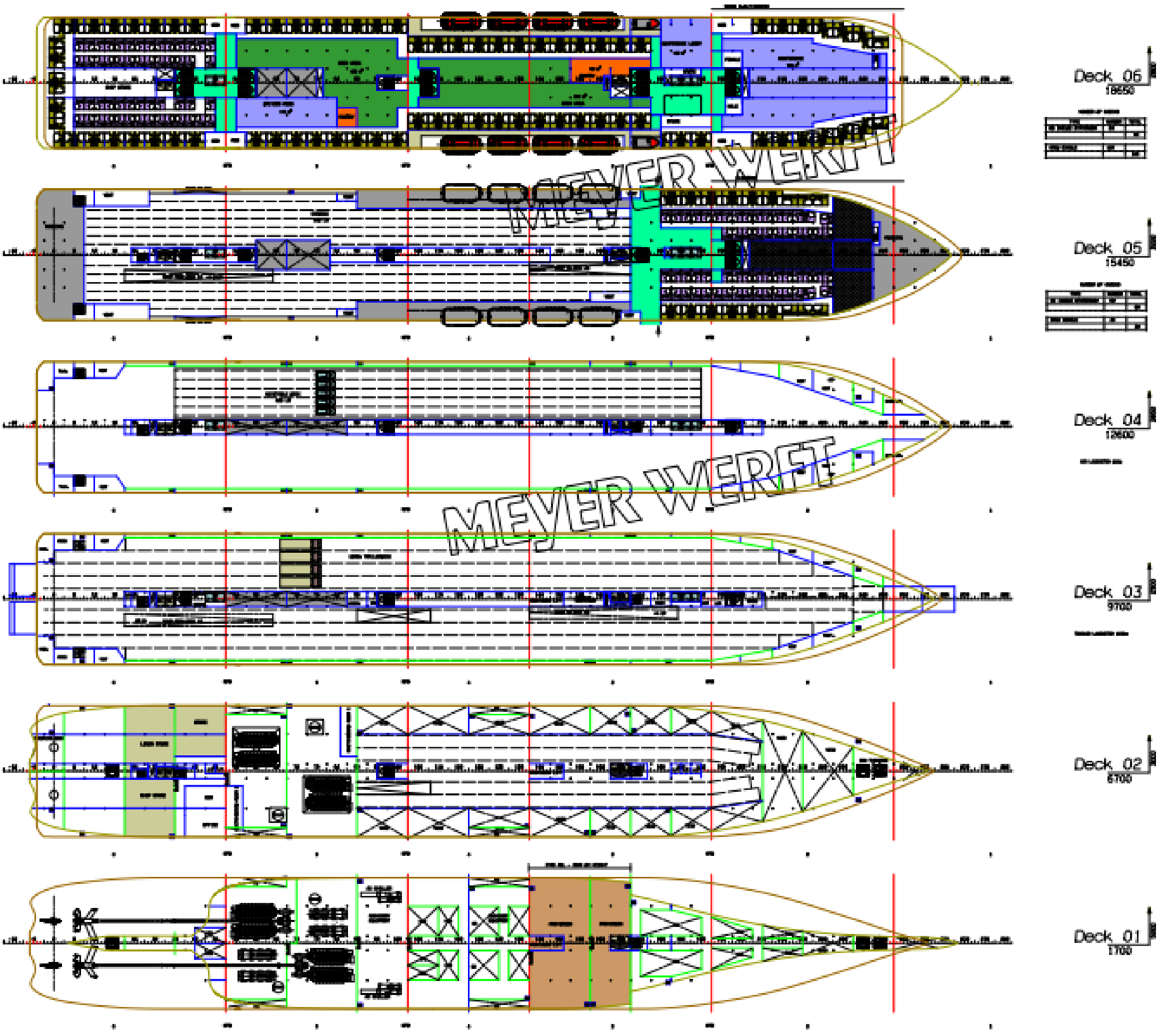

Figure 3 GAP Decks 01 – 06

4.3 Hullform

The ship has a conventional modern hull form of a twin screw vessel with bulbous bow and slender skeg and transom stern and a tunnel shaped aft body.

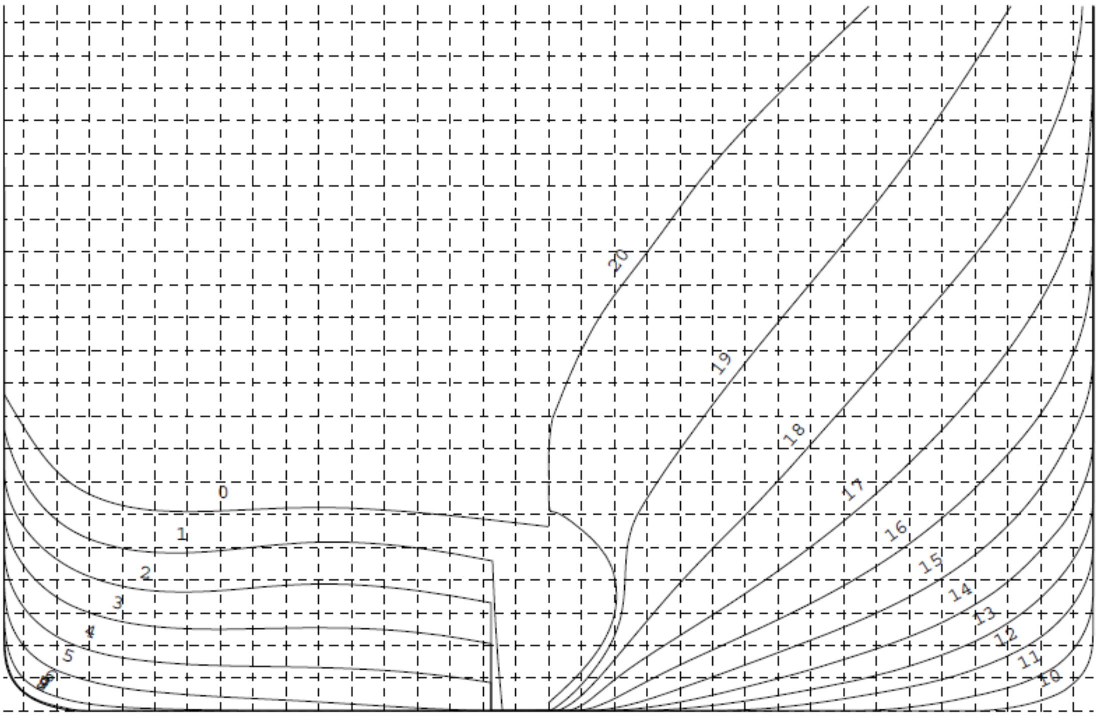

Figure 4 Bodyplan

4.4 Engine configuration

The engine configuration is based on a shaft driven diesel plant with 4 medium sized main engines, four generator sets. Exhaust gas cleaning is provided with closed loop scrubbers and SCR catalysators.

4.5 Tankplan

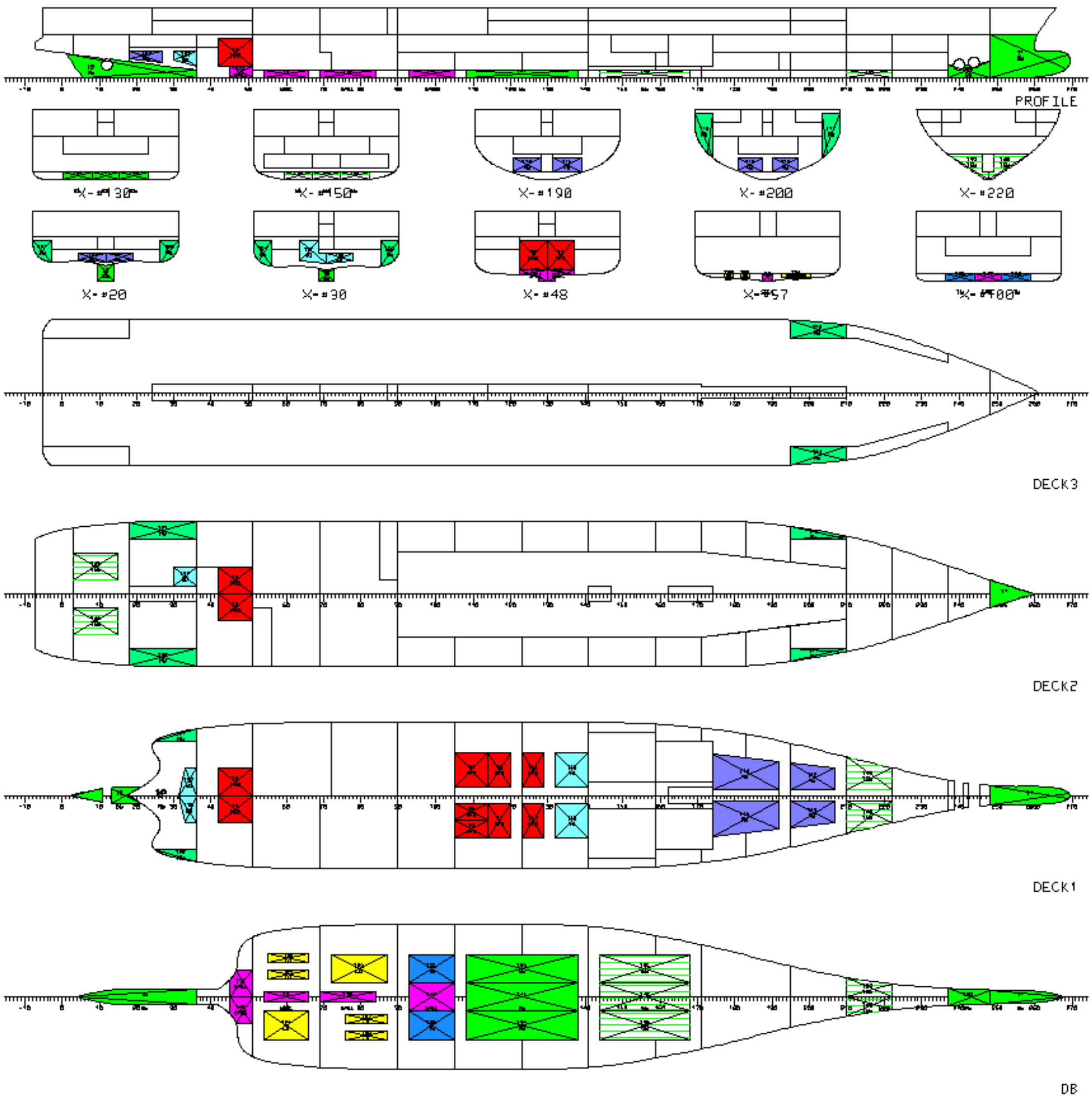

Figure 5 Tankplan

The following capacities are achieved for the various purposes:

NAME	Volume	WEIGHT	LCG	VCG	FSM
POTABLE WATER	1135,7 m3	1135,7 t	136,52 m	3,56 m	1409 mt
HEELING WATER	1379,9 m3	1379,9 t	104,61 m	8,98 m	439 mt
BALLAST WATER	1517,5 m3	1555,4 t	121,13 m	2,20 m	1923 mt
TECHNICAL WATER	212,0 m3	212,0 t	81,43 m	0,85 m	434 mt
HEAVY FUEL OIL	1388,6 m3	1333,0 t	72,41 m	4,27 m	1279 mt
GAS OIL	558,9 m3	480,7 t	80,79 m	4,12 m	617 mt
LUBRICATING OIL	181,5 m3	163,4 t	58,33 m	1,27 m	457 mt
SPECIAL TANKS	271,9 m3	271,9 t	60,50 m	1,08 m	385 mt
GREY WATER	590,5 m3	590,5 t	128,16 m	0,89 m	1226 mt
TREATED GREY WATER	942,9 m3	942,9 t	104,73 m	5,14 m	1588 mt

Table 2 Tank capacities

4.6 Subdivision

The watertight subdivision follows the needs from the functionality of the spaces, e.g. the size of the lower hold as well as the size of the main engine rooms.

Due to redundancy requirements as defined in SOLAS II/2 the engine rooms are quite large and cause special attention for the damage stability. The voids spaces around the large lower hold are designs in such a way to allow instantaneous symmetrical flooding.

Deck 3 is the main cargo and bulkhead deck. Between deck 3 and 5 there are smaller buoyant spaces at the very end of cargo space to provide additional buoyancy. The access to these spaces is usually not needed during normal voyages but only during loading and unloading. Therefore these spaces can be closed watertight, without applying escape routes.

As required by SOLAS there is no access from the roro deck downwards, the minimum height of any opening is 2.5m above the deck. The hatches to the ramps leading to the large lower hold as well as to the provision area are assumed to be watertight.

The ship is provided with a continuous double bottom with a height of more than B/20.

The figure below shows the watertight subdivision and the damage zones used in the SOLAS2020 calculation of the attained index.

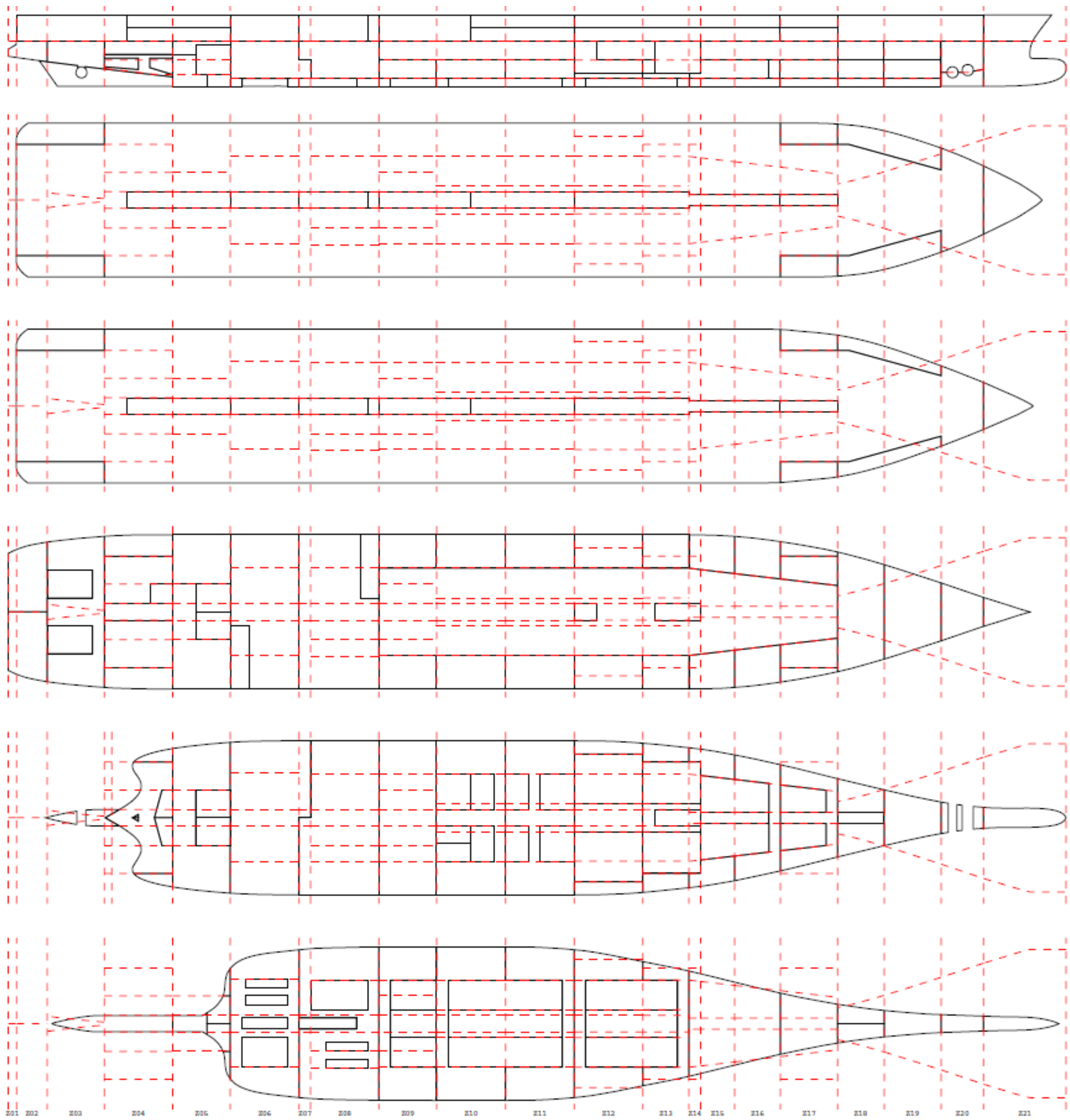

Figure 6 Subdivision used for calculations

5 HYDRODYNAMICS

5.1 Speed power performance

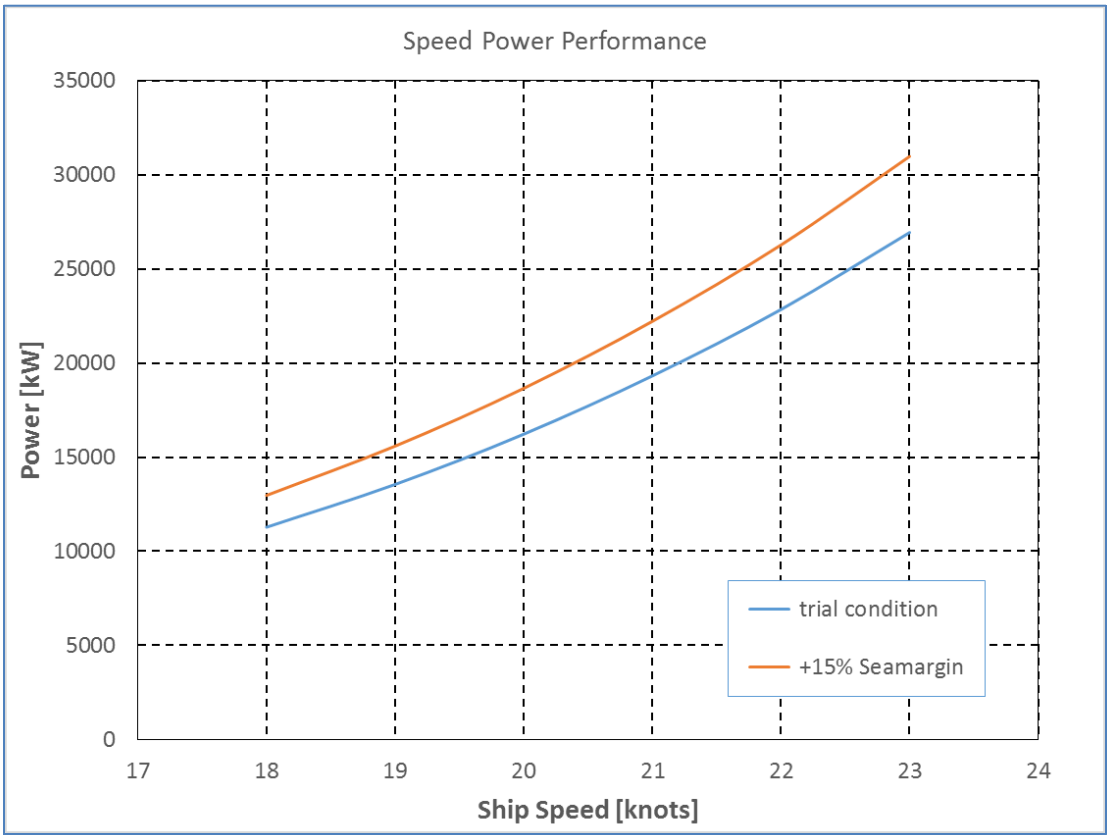

Figure 7 Speed power performance

5.2 Manoeuvrability

The ship is equipped with 2 bow thrusters of 2500 kW each, one stern thrusters and high lift rudders to maintain the required wind speed in the worst direction.

Under the given wind speed the ship will be able to keep its position without the help of tugs.

6 INTACT STABILITY

6.1 Loading conditions

The table below shows the loading conditions designed for further examination of the sample ship:

NAME	TEXT	Deadweight	Cargo	Ballast Water	Grey Water	Treated Grey Water	Heavy Fuel Oil	Potable Water
LD21	Trailer and cars 100% consumables	6900 t	3400 t	0 t	200 t	200 t	600 t	800 t
LD25	Trailer and cars 10% consumables	5992 t	3400 t	328 t	200 t	200 t	222 t	196 t
LD31	Only cars, 100% consumables	4981 t	1481 t	0 t	200 t	200 t	600 t	800 t
LD35	Only cars, 10% consumables	4213 t	1481 t	319 t	200 t	200 t	222 t	196 t
LD41	Only Pass, 100% consumables	3500 t	0 t	0 t	200 t	200 t	600 t	800 t
LD45	Only pass, 10% consumables	3163 t	0 t	749 t	200 t	200 t	222 t	196 t

NAME	TEXT	Draught	trim	GM
LD21	Trailer and cars 100% consumables	6,69 m	0,05 m	5,34 m
LD25	Trailer and cars 10% consumables	6,55 m	0,00 m	5,24 m
LD31	Only cars, 100% consumables	6,38 m	0,15 m	5,57 m
LD35	Only cars, 10% consumables	6,27 m	0,08 m	5,46 m
LD41	Only Pass, 100% consumables	6,16 m	0,05 m	5,82 m
LD45	Only pass, 10% consumables	6,10 m	0,07 m	5,85 m

Table 3: Loading condition details

6.2 GM Limiting curve

The following diagram shows the summary of the GM requirements together with the actual loading conditions.

There are various limits shown which all need to be complied with, in particular there is the limit of the intact stability criteria as defined by the IS code 2008, and limits for compliance with the damage stability requirements.

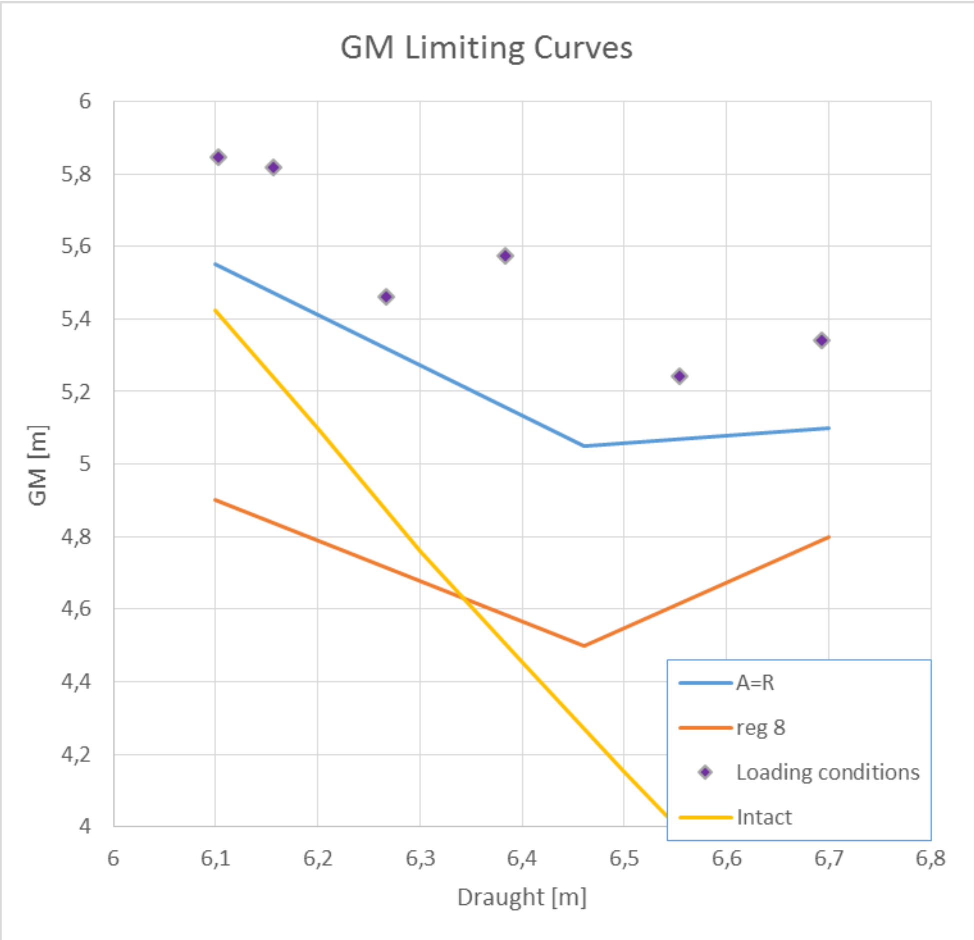

Figure 8 GM Limiting curve

7 RESULT OF DAMAGE STABILITY CALCULATIONS

7.1 Attained index vs R

The following tables show the result of the damage stability calculations according SOLAS II-1.

ATTAINED AND REQUIRED SUBDIVISION INDEX

```
Subdivision length             227.971 m
Breadth at the load line        33.200 m
Breadth at the bulkhead deck    33.200 m
Number of persons N1           1200
Number of persons N2           2296

Required subdivision index R (SOLAS2009) = 0.8330
Required subdivision index R (SOLAS2020) = 0.8810
Attained subdivision index A = 0.89475
```

INITDAMTAB		T m	GM m	A/R	A	A*WCOEF	WCOEF
DL	DAMP	6.090	5.550	1.11	0.92547	0.09255	0.100
DL	DAMS	6.090	5.550	1.11	0.92598	0.09260	0.100
DP	DAMP	6.456	5.061	1.07	0.89426	0.17885	0.200
DP	DAMS	6.456	5.061	1.07	0.89349	0.17870	0.200
DS	DAMP	6.700	5.111	1.06	0.87899	0.17580	0.200
DS	DAMS	6.700	5.111	1.06	0.88129	0.17626	0.200

Table 4: Attained index for each initial condition

DAMAGES	W*P*V*S	W*P*V
1-ZONE DAMAGES	0.29544	0.29547
2-ZONE DAMAGES	0.34291	0.34680
3-ZONE DAMAGES	0.17163	0.19089
4-ZONE DAMAGES	0.06079	0.07872
5-ZONE DAMAGES	0.01813	0.03387
6-ZONE DAMAGES	0.00585	0.01138
A-INDEX TOTAL	0.89475	0.95713

Table 5: Index according to number of zones.

7.2 Reg 8 results

Draught	Minimum GM	Maximum KG	Criterion	Damage case
6,09	2,74112	18,3674	S-REG8	R8P5-6.1.0-1
6,456	2,88866	17,5902	S-REG8	R8P5-6.1.0-1
6,52482	2,94914	17,4245		
6,7	3,21246	16,8935	S-REG8	R8S5-6.1.0

Table 6: GM limits for s>0.9 acc. Reg 8.3

The corresponding GM limiting curves are shown in figure 7.

7.3 Results non-zonal approach

In addition to the standard damage stability results the attained index following the non-zonal approach [3] has been calculated for collision, bottom grounding and side grounding/contact.

As the basis the SOLAS parameters for draughts, permeability and s-factor have been used. For each of the three categories of flooding events 50,000 breaches have been created.

Initial condition	Draught	Attained Index Collision	Attained Index Bottom grounding	Attained Index Side grounding/contact
DS	6.700	0.93749	0.95631	0.95468
DP	6.456	0.95196	0.95841	0.95686
DL	6.090	0.97296	0.9622	0.96522

Table 7 Attained index acc. non-zonal approach

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The information shown in this document and the associated files defines a state-of-the-art large RoPax ferry, which are widely used in the Baltic as overnight ferry.

9 REFERENCES

[1] George Zaraphonitis, *GOALDS Deliverable 6.4 Evaluation of innovative designs,* Athens 2012

[2] Henning Luhmann, *Task 6: Damage Stability Calculations of GOALDS RoPax Designs, EMSA/OP/10/2013*, Oslo 2015

[3] Gabriele Bulian et al, *Considering collision, bottom grounding and side grounding/contact in a common non-zonal framework*, Proceedings of the 17th International Ship Stability Workshop, Helsinki 2019

10 ADDITIONAL INFORMATION

Following information is available as separated files:

- General Arrangement Drawing
- Napa data base, including hull form and internal geometry, loading conditions and damage stability data [NAPA db)

Acronym: FLARE
Project full title: Flooding Accident REsponse
Grant agreement No. 814753
Coordinator: BALance Technology Consulting GmbH

Deliverable 2.1.8

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Deliverable data

Deliverable No	2.1.8		
Deliverable Title	Sample Ship no 8		
Work Package no: title	WP2.1 Sample Ships		

Dissemination level	Public	**Deliverable type**	Report
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Co-authors			
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Peer reviewer 2			

Document history

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This report reflects only the author's view. INEA is not responsible for any use that may be made of the information it contains.

CONTENTS

List of symbols and abbreviations

DoA	Description of Action
EC	European Commission
PMT	Project Management Team
SG	Steering Group
QA	Quality Assurance
GT	Gross Tonnage
NAPA	Naval Architectural Package
MVZ	Main Vertical Zone
FEM	Finite Element Method
POB	Persons On Board

1 EXECUTIVE SUMMARY

This report describes sample ship no 8, a large RoPax ferry.

1.1 Problem definition

- To ensure realistic research for the response to flooding events it is necessary to have sample ships available, which may be used in other work packages of this project as well as made public available.
- The basic requirements for the sample ship are to reflect large passenger ships design according to the latest SOLAS amendments (SOLAS2020)

1.2 Technical approach and work plan

- A design has been chosen which has not been used before in similar research project and it has not been built. The original design has been upgraded by modification of main dimensions to reach the SOLAS2020 standard.
- The rooms arrangement, the openings and the connections have been updated within Napa software taking into account the achievement of eSAFE project [2] regarding the sequence of flooding in particular for the so called A-class bulkheads.

1.3 Results

- The selected design has been created to reach suitable degree of detail to provide reasonable continuation of the work.
- In particular the ship may form a valid basis for the cost benefit assessment of risk control options in WP7.
- This design is at a pre-contractual stage but ready to start detailed engineering and construction. The layout and information allows all kind of investigations for damage stability, however detailed information about internal systems, like piping, ducting and cabling cannot be provided.

1.4 Conclusions and recommendation

- The information provided is a part of the basic data so that the work can be continued in this project in other work packages.

2 INTRODUCTION

2.1 Task/Sub-task text

A number of sample ships of large cruise vessels and RoPax ferries, will be provided by the FLARE participants to reflect typical designs of the current fleet. As the focus is laid on large ships, the following limits will be applied:

Gross tonnage > 10,000 GT

Length > 120m

No of MVZ >2

It is anticipated that all ships comply with the future SOLAS requirements (SOLAS2020). In this respect, RoPax ships do not need to comply with Stockholm Agreement.

For this project the anticipated degree of detail in the information is based on realistic conceptual designs, conceptual GAP and NAPA model. No detailed information about the systems and components is needed, like the routing of pipes, ducts and cables. If for some work in the following work packages more detailed information is needed, suitable assumptions are to be made by the designers in the provision of such information.

The data of ships used as sample ships in this project is to be prepared to be published, so if existing ships are used a written confirmation by the owner/operator and designers is needed for such use.

The sample ships will be used in the other work packages and also as the basis for the impact of any risk control options.

For each ship a separate deliverable will be created containing a description of the ship, including a general arrangement drawing and the NAPA database.

3 BUSINESS MODEL

As the basis for the design of this ship a business model has been defined to define the basic parameters which need to be fulfilled. These parameters and the business model will be kept unchanged throughout the design process and also during further design studies during a later stage of this project.

The ship is a modern ferry for short international voyages, fuelled with LNG/MDO and with 2 RoRo deck for trucks and trailers, 1 RoRo car deck and additional partial or hoistable car decks.

The ship is designed as a ferry for the daily routes on the Baltic Sea. For this reason is present on board only a low number of passenger cabins while wide area are dedicated to public spaces. Other than restaurants and lounges, a large part is reserved to shopping. Special attention was paid to guarantee an effective and fast cargo loading and unloading.

Following main parameters are to be kept to maintain the business model of this vessel:

1. Number of persons on board: 2800 (2617 passengers and 183 crew)
2. Pax accommodation as follow:
    a. 45 cabins arranged for 4 persons (2 sofa beds + 2 upper bed)
3. Crew accommodation as follow:
    a. 2 Single Master/Chief Engineer cabins
    b. 1 Single Senior Officer cabin
    c. 14 Single Officer cabins
    d. 83 Double Crew cabins
4. Cargo capacity and loading
    a. 2300 m trailer lanes, width of lane 3000mm, free height of trailer btw. 4.4 m and 4.8 m
    b. 852 cars, with no trucks. Cars may be stowed in hostable car decks
    c. 2 stern ramps, 2 bow ramp
5. Space utilization details for public and service spaces
    a. Reception, 20 seats
    b. Shops, abt. 3050 m2
    c. Teen Lounge, 20 seats
    d. Meeting room, 18 seats
    e. Conference room, 38 seats
    f. Seating Air Lounge, 250 seats
    g. Drivers Lounge, 80 seats
    h. Comfort Lounge, 129 seats
    i. Business Lounge, 134 seasts
    j. Plaza Bar, 208 seats
    k. International Cafè, 296 seats
    l. Fast Food, 340 seats
    m. Self Service, 358 seats
    n. Pub and Slot area, 312 seats
    o. Restaurant "A La Carte", 100 seats
    p. Officer & Crew Mess, abt. 140 m^2
    q. Officer Day Room, abt. 25 m^2
    r. Crew Day Room, abt. 30 m^2
    s. Smoker's Room, abt. 30 m^2
6. Provision rooms, storage rooms and workshops according to ship size
7. Tank capacities
    a. LNG (geometric volume) 670 m^3
    b. Marine Diesel Fuel (MDF) 500 m^3
    c. Lubricating Oil (LO) 210 m^3
    d. Grey Water and Black Water 540 m^3

e. Fresh Water 580 m³

f. Ballast water 2250 m³

g. Heeling Water 700 m³ (capacity for compensation of the static heeling angle caused by a list of 2.0 deg at design draught)

h. Distilled Water 30 m³

8. Deadweight 5300 t at design draught
   a. 3122 t Trailer
   b. 672 t cars
   c. 190 t passengers and crew
   d. 160 t provision and stores
   e. 320 t trim and heeling water
   f. 262 t LNG
   g. 74 t MDF
   h. 70 t LO
   i. 320 t Fresh Water
   j. 60 t Black and Grey Water
   k. 40 t Miscellanous and machinary tanks
   l. 10 t Owner Supply
9. 2 twisted spade rudders with propeller hub, 2 bow thrusters, 2 aft thrusters and 2 fin stabilizers
10. 4 medium speed Dual Fuel engines. Each set of 2 engines shall be coupled to 1 gearbox with clutch couplings, connected to shaft line and CPP
11. 3 Duel Fuel generating sets and 2 shaft alternators
12. Trial speed of 26.9 knots at contractual draught, calm water, with 4 engines at 90% of MCR, 10% of Sea Margin, with Shaft Generator not engaged

4 General Description of the Ship

The ship is a LNG fuelled ferry. The LNG tanks were arranged in the space traditionally dedicated to lower hold car. Furthermore various stores are arranged under the bulkhead deck.

The RoRo cargo is located above the bulkhead deck (between deck 3 and 7), with deck 3 and 5 capable to host trucks and cars.

The public spaces and passengers cabins mainly occupy deck 8, 9 and 10. Deck 10 includes also crew areas.

Main dimensions

Length over all	213 m
Length between perpendiculars	195.4 m
Subdivision length	213.0 m
Breadth	31.5 m
Subdivision draught	7.1 m
Height of bulkhead deck	10.3 m
Number of passengers	2617
Number of crew	183
Gross tonnage	abt. 50000 GT
Deadweight	5300 t
No of cabins (crew and pax)	145
Lanemeter	2310
No of cars	852

4.1 Regulations

The design complies with all relevant IMO rules and regulations applicable for ships with contract after 1 January 2020, which includes following codes.

1. SOLAS1974 as amended, including probabilistic damage stability and “Safe Return to Port” (SOLAS2020), Short international voyage
2. Intact Stability Code (IS Code 2008)
3. Load line Convention
4. MARPOL, including fuel oil tank protection

4.2 General Arrangement

The following figures show the General Arrangement plan

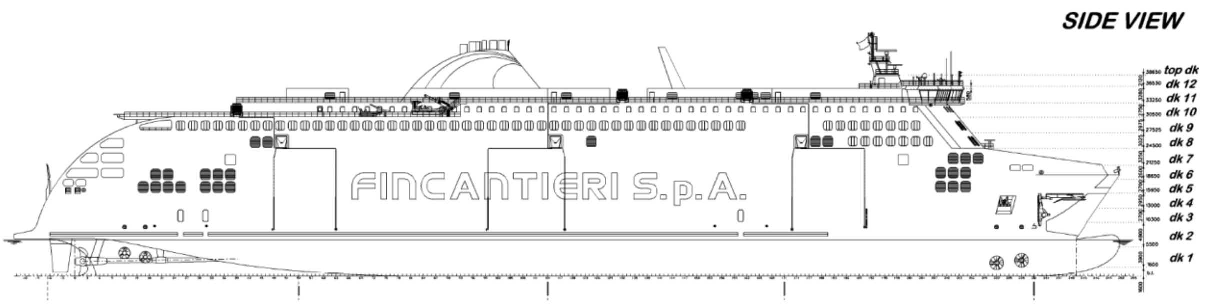

Figure 1 Profile view

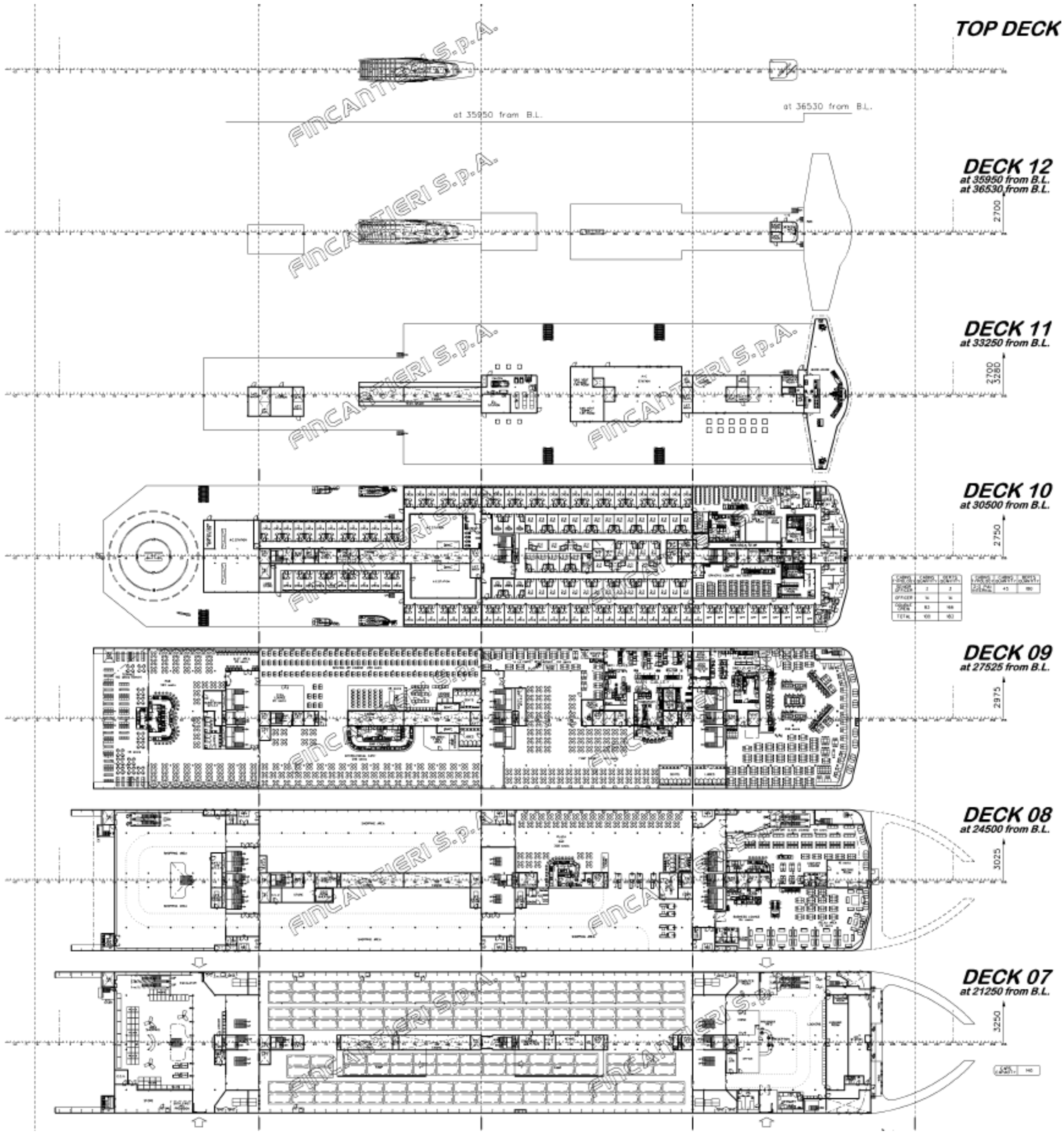

Figure 2 Deck 7 – 12 and Top

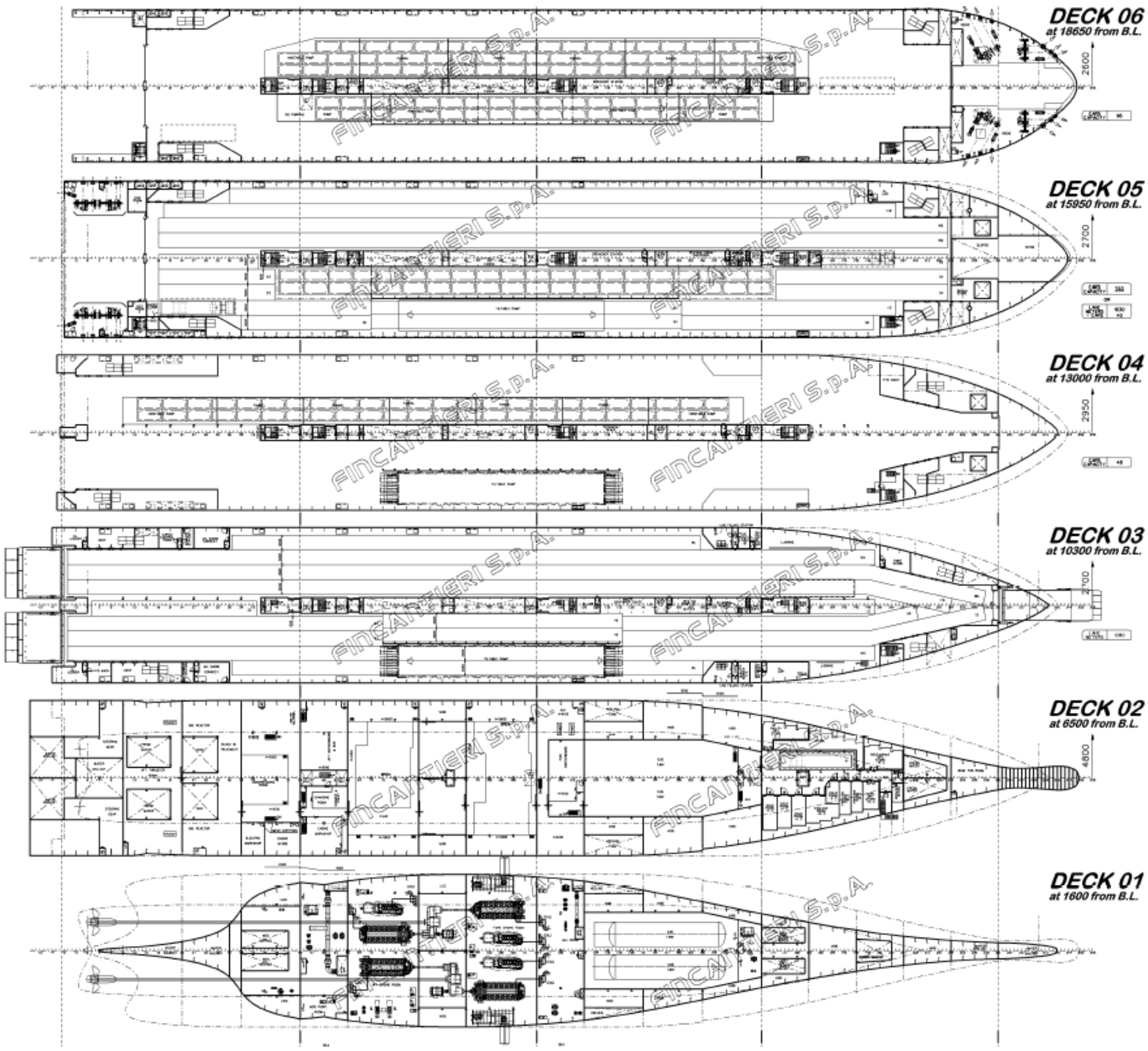

Figure 3 Decks 01 – 06

4.3 Hullform

The ship has a conventional modern hull form of a twin screw vessel with bulbous bow and slender skeg and transom stern.

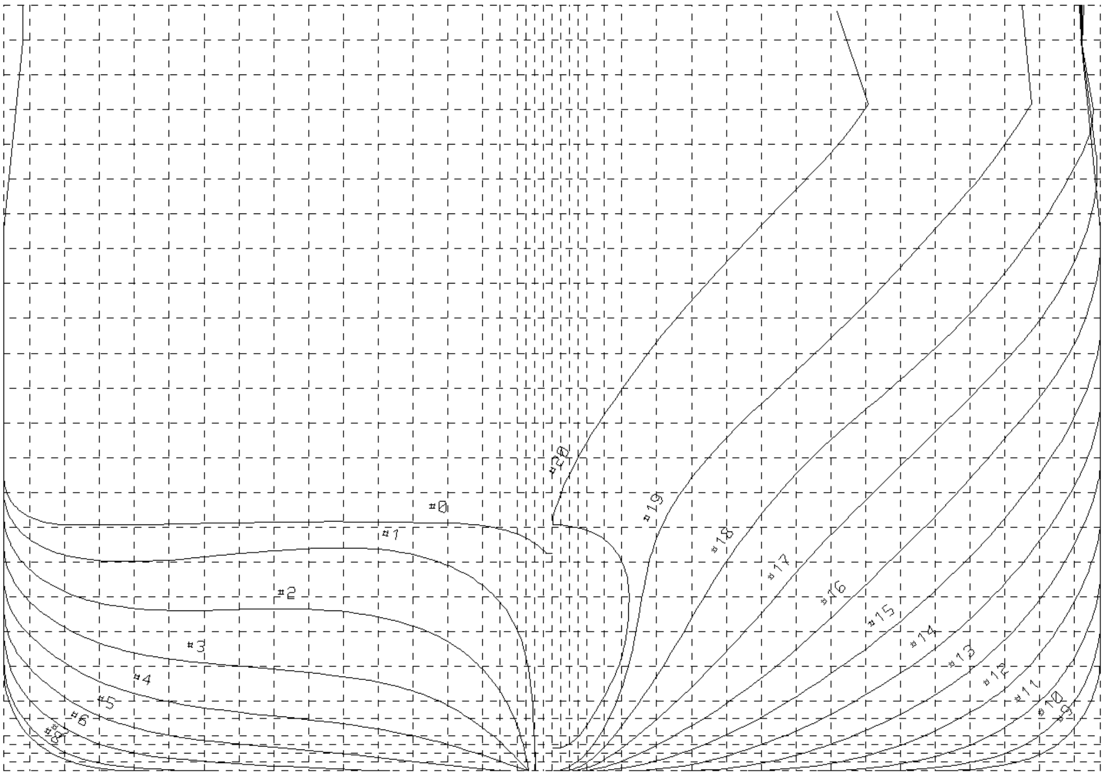

Figure 4 Bodyplan

4.4 Engine configuration

The engine configuration is based on a shaft driven diesel plant with 4 main engines, 2 shaft generators and 3 generator sets.

Each main engine provides a max. continuous rating of 13740 kW for a total of 56960 kW. Each generator set provides an output of 2600 kW and each shaft generator an output of 3600 kW.

The emission requirements are fulfilled thank to the adoption of LNG.

4.5 Tankplan

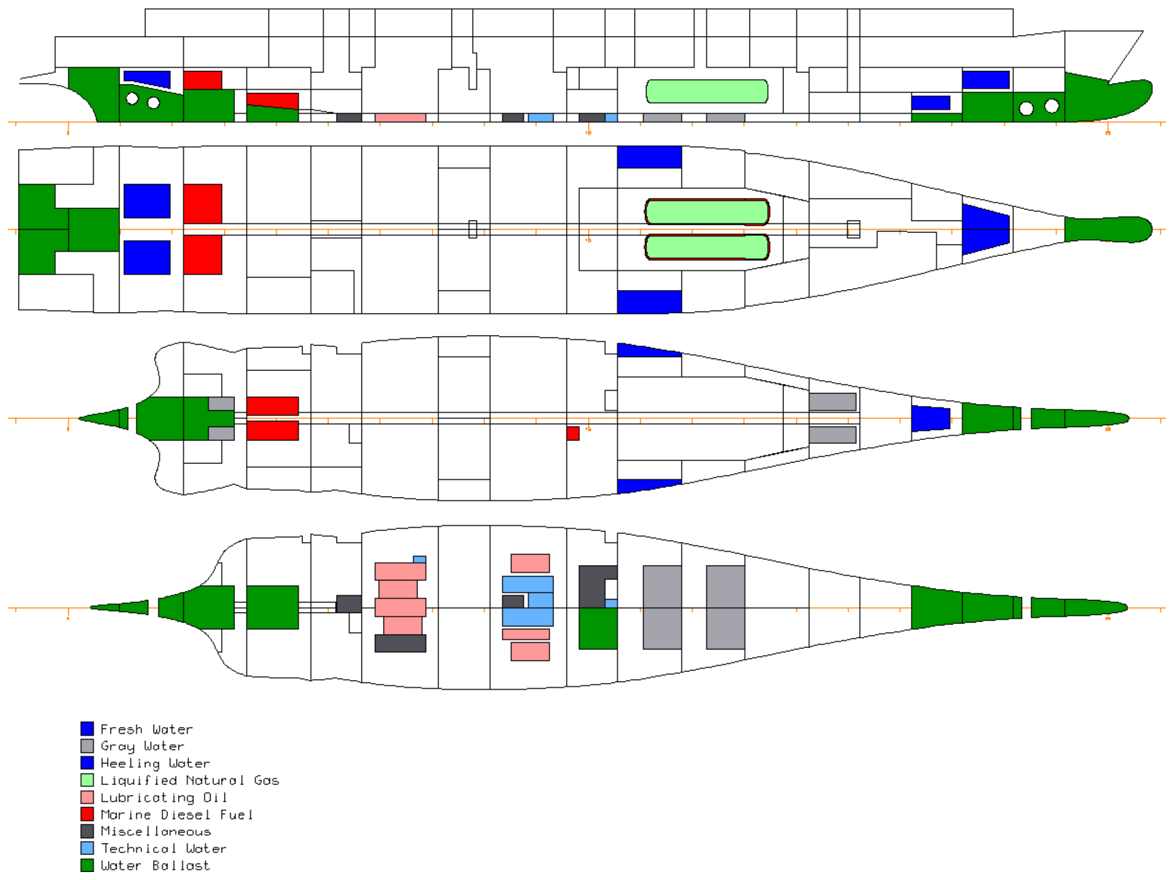

Figure 5 Tankplan

The following capacities are achieved for the various purposes:

Description	RHO	Volume	Requirement	Delta	Weight
	t/m3	m3	m3	m3	t
FRESH WATER	1.00	651	580	71	651
GREY WATER	1.00	546	540	6	546
HEELING WATER	1.00	781	700	81	781
LIQUIFIED NATURAL GAS	0.43	678	670	8	292
LUBRICATING OIL	0.90	217	210	7	195
MARINE DIESEL FUEL	0.86	551	500	51	474
TECHNICAL WATER	1.00	131	30	101	131
BALLAST WATER	1.01	2373	2250	123	2385

Table 1 Tank capacities

4.6 Subdivision

The watertight subdivision required special effort, considering the large number of passengers and the high power installed in comparison to the main dimensions of the vessel.

Particular attention was paid to the engine and gear box rooms in order to fulfil both the SRtP and the stability requirements. The main philosophy consisted to arrange machineries in 3 different transversal compartments, as follow:

1. Aft compartment: 2 main engines and 1 generator set
2. Mid compartment: 2 gear box and 2 shaft generator
3. Fore compartment: 2 main engines and 2 generator set

Furthermore in the mid compartment, due to SRtP requirements, each gear box and shaft generator is located in a watertight longitudinal compartment. To avoid excessive list in damage condition the two gear box compartments are protected on sides (below the bulkhead deck) wing void spaces connected through double bottom.

Similarly, 3 void spaces are arranged around the wide compartment containing the two LNG tanks.

Deck 3 is the main cargo and bulkhead deck. In order to increase the stability damaged conditions involving the RoRo cargo area, smaller buoyant spaces are located at sides close both to the stern and to the bow. The access to these spaces is usually not needed during normal voyages but only during loading and unloading. Therefore these spaces can be closed with weatertight doors.

As required by SOLAS there is no access from the RoRo deck downwards, the minimum height of any opening is 2.5m above the deck.

The ship is provided with a continuous double bottom with a height of more than B/20.

In the subdivision table an "UNDAMAGED AREA" has been defined in the central part of the ship. This is used to route pipes generating progressive flooding that may not be controlled by remote control valves.

The figure below shows the watertight subdivision and the damage zones used in the SOLAS2020 calculation of the attained index.

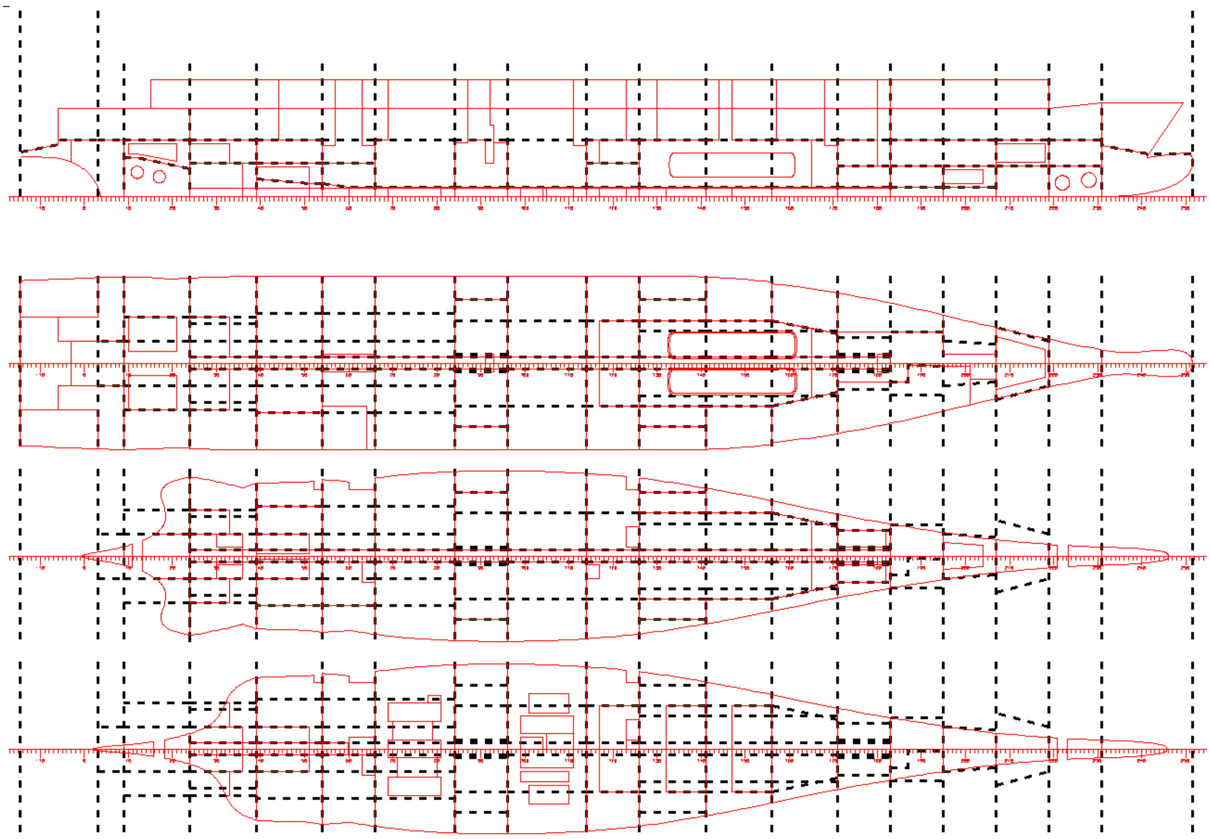

Figure 6: Subdivision used for calculations

5 Hydrodynamics

5.1 Speed power performance

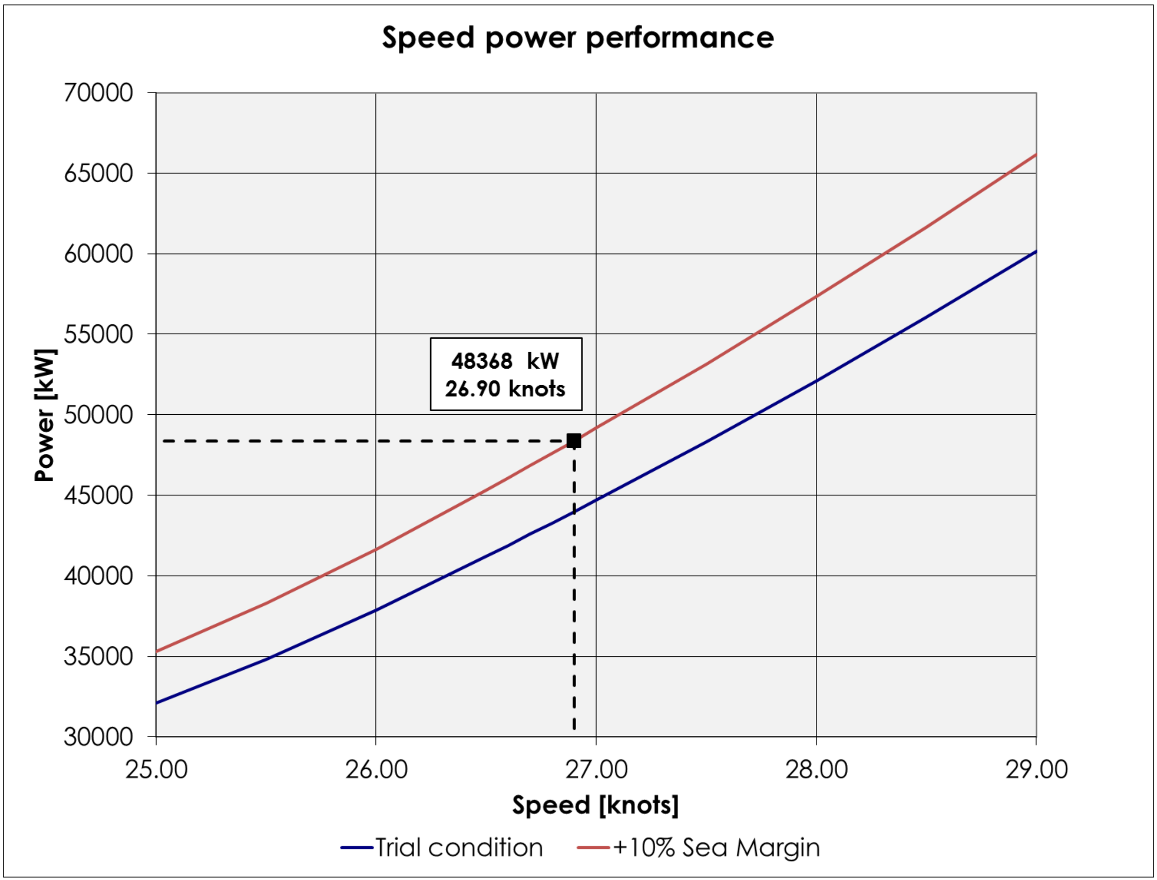

Figure 7: Speed power performance

5.2 Manoeuvrability

The ship is equipped with 2 bow thrusters, 2 stern thrusters and 2 twisted spade rudders with propeller hub.

6 Intact stability

6.1 Loading conditions

The table below shows the loading conditions designed for further examination of the sample ship:

Name		LOA01	LOA02	LOA03	LOA04	LOA05
Description		5300 DWT DEPARTURE T=6.92m	100% consumables with cargo	10% consumables with cargo	100% consumables without cargo	10% consumables without cargo
DWT	**t**	5300	6240	5803	2381	1466
CARS	**t**	672	324	324	0	0
TRAIL	**t**	3122	4273	4273	0	0
FW	**t**	320	457	46	580	58
MDF	**t**	74	74	7	438	43
LNG	**t**	262	262	26	262	26
LO	**t**	70	70	70	70	70
MIS	**t**	40	40	40	40	40
WB	**t**	0	0	0	251	193
HEEL	**t**	320	320	320	320	320
GWT	**t**	60	60	480	60	500
PROV	**t**	160	160	16	160	16
POB	**t**	190	190	190	190	190
OWN	**t**	10	10	10	10	10

Name	**Description**	**T**	**TR**	**GM**
		m	**m**	**m**
LOA01	5300 DWT DEPARTURE T=6.92m	6.92	-0.03	3.51
LOA02	100% consumables with cargo	7.10	0.00	3.56
LOA03	10% consumables with cargo	7.02	0.00	3.53
LOA04	100% consumables without cargo	6.34	0.03	4.38
LOA05	10% consumables without cargo	6.16	0.00	4.39

Table 2: Loading condition details

6.2 GM Limiting curve

The following diagram shows the summary of the GM requirements together with the actual loading conditions.

There are various limits shown which all need to be complied with, in particular there is the limit of the intact stability criteria as defined by the IS code 2008, and limits for compliance with the damage stability requirements.

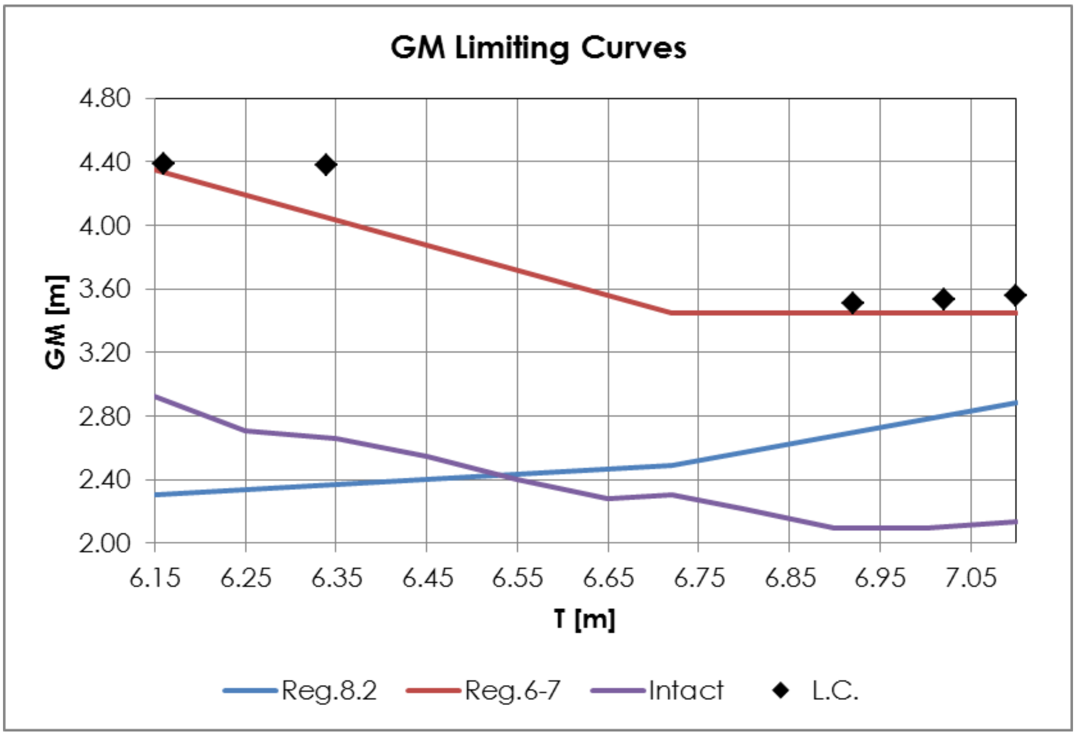

Figure 8: GM Limiting curve

7 Results of damage stability calculation

7.1 Attained index vs R

The following tables show the result of the damage stability calculations according SOLAS II-1.

ATTAINED AND REQUIRED SUBDIVISION INDEX

Subdivision length	213.00 m
Breadth at the load line	31.50 m
Breadth at the bulkhead deck	31.50 m
Number of persons N	2800
Required subdivision index	R = 0.87304
Attained subdivision index	A = 0.88248 (sum of W*P*V equals 0.967208)

INIT	SIDE	T	GM	A/R	A	WCOEFF	A*WCOEFF
		m	m				
DL	PORT	6.15	4.35	1.08	0.94176	0.1	0.09418
DL	STBD	6.15	4.35	1.08	0.94173	0.1	0.09417
DP	PORT	6.72	3.50	1.02	0.89145	0.2	0.17829
DP	STBD	6.72	3.50	1.02	0.89144	0.2	0.17829
DS	PORT	7.10	3.50	0.97	0.84687	0.2	0.16937
DS	STBD	7.10	3.50	0.97	0.84687	0.2	0.16937

Table 3: Attained index for each initial condition

DAMAGES	W*P*V*S
1-ZONE DAMAGES	0.31587
2-ZONE DAMAGES	0.35108
3-ZONE DAMAGES	0.16339
4-ZONE DAMAGES	0.04226
5-ZONE DAMAGES	0.00988
A-INDEX	**0.88248**

Table 4: Index according to number of zones.

7.2 Reg 8 results

T	MINGM	MAXKG	DCRI	DAM
m	m	m		
6.15	2.30	16.47	R8.2-3	SDSR8.2S10-11.1.0
6.72	2.49	15.73	R8.2-3	SDSR8.2S4-5.1.0-2
7.10	2.89	15.17	R8.2-3	SDSR8.2S4-5.1.0-2

Table 5: GM limits for s>0.9 acc. Reg 8.2-3

The corresponding GM limiting curves are shown in figure 8.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The information shown in this document and the associated files defines a state-of-the-art RoPax ferry, which is used in the Baltic as daily ferry.

9 REFERENCES

[1] George Zaraphonitis, *GOALDS Deliverable 6.4 Evaluation of innovative designs,* Athens 2012

[2] Henning Luhmann, *Task 6: Damage Stability Calculations of GOALDS RoPax Designs, EMSA/OP/10/2013*, Oslo 2015

[3] Gabriele Bulian et al, *Considering collision, bottom grounding and side grounding/contact in a common non-zonal framework*, Proceedings of the 17th International Ship Stability Workshop, Helsinki 2019

10 ADDITIONAL INFORMATION

Following information is available as separated files:

- General Arrangment Drawing (pdf and dwg format)
- Napa data base, including hull form and internal geometry, loading conditions and damage stability data [NAPA db)