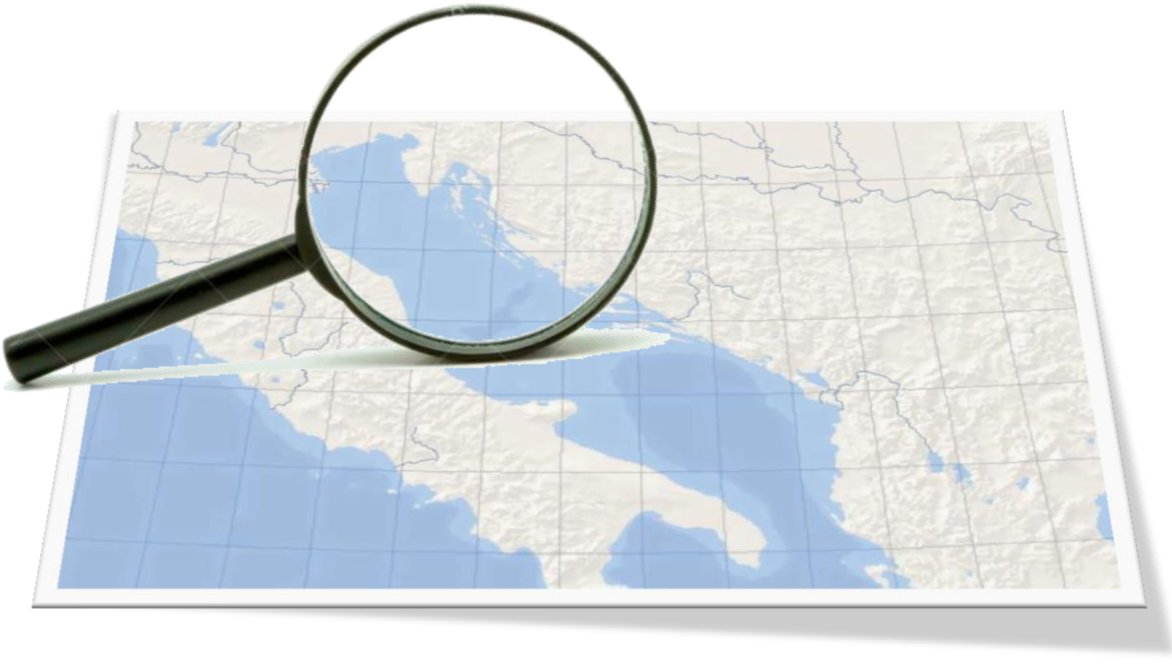
UNIVERSITY OF RIJEKA

Faculty of Maritime Studies in Rijeka

Maritime study
LNG FSRU Krk



Rijeka, 2017

Name	MARITIME STUDY – LNG FSRU KRK
Client:	EKONERG - Energy and Environmental Protection Institute d.o.o. Koranska 5, 10000 Zagreb Hrvatska
Contractor:	Faculty of Maritime Studies in Rijeka University of Rijeka Studentska 2, 51000, Rijeka Hrvatska
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1 INTRODUCTION

This study has been made on the basis of a contract between EKONERG, d.o.o. as the client and the Maritime Faculty of Rijeka University as the contractor.

The subject matter is the making of a maritime study for the Krk LNG FSRU terminal within the Open procurement process for "Services of preparation of the design and permitting documentation for the construction of the Krk LNG terminal and consulting services relating to obtaining of all necessary permits and approvals: FEED preparation and main design preparation for Krk LNG FSRU terminal and obtaining of construction permit and LNG FSRU terminal power supply system documentation."[1]

The aim of this study is to propose a sea traffic and navigation solution and measures of maritime safety for the area of the future LNG FSRU terminal on the island of Krk with regard to the respective regulations, i.e. provisions of the contract. The conclusions of this study, i.e. their implementation by persons authorised to do so, shall ensure the carrying out of access, stay and departure of referent LNG carriers and other ships in the specified area in a safe way, i.e. a way in which a satisfactory level of sea and marine life safety is secured.

The study is based on existing legal regulations of the Republic of Croatia and in this respect, it is based on the following assumptions:

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– characteristics of considered ships comply with the requirements set forth by the provisions of the International Convention for the Safety of Life at Sea, 1974 (SOLAS 74), the International Convention for the Prevention of Pollution from Ships 1973/78 (MARPOL 73/78), the International Convention on Load Lines, 1966 (LOADLINE 1966), the International Convention on Tonnage Measurements of Ships, 1969 (TONNAGE 1969), as amended, or as required by the relevant and applicable technical rules of the Croatian Register of Shipping;
– the FSRU meets all requirements that a ship in international navigation must meet, i.e. those that have been specified by the SOLAS Convention and other international conventions accepted within the International Maritime Organisation and ratified by the Republic of Croatia;
– additionally, the FSRU meets all requirements, especially those related to structural safety, prescribed by the flag state as well as technical requirements prescribed by the authorised recognised organisation (RO) and the authorised recognised security organisation (RSO); in this sense, it is presumed that the recognised organisation is a member of the IACS or the Croatian Register of Shipping;
– characteristics of ships used for transport of liquefied gas meet the requirements prescribed by The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code), as amended;
– characteristics of ships that are not subject to international conventions and characteristics of yachts and boats comply with requirements prescribed by the authorised administration of the respective flag states;

[1] *Floating Storage and Regasification Unit - FSRU. In the remaining text, the standard English abbreviation for a unit used in importing LNG and its re-gasification, will be used. The term terminal, in this study, only applies to land facilities, their infrastructure and equipment. The term floating terminal is deemed as technically and legally inaccurate and will therefore not be used.*

- the ships' masters and crew meet the requirements prescribed by the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, as amended, as well as requirements of the International Safety Management Code, as defined in Chapter IX of the SOLAS Convention;
- the actions of the master and crew of ships, yachts and boats are reasonable, and are carried out in a way in which an prudent seafarer would act; behaviour that significantly contradicts the rules of the profession or that is aimed at harming people or causing damage to the environment or property is not the subject matter of this study;
- ships, yachts and boats use in the usual waterways; the use of other waterways, which ships, yachts and boats, depending on their size or own characteristics, do not use or use only on an exceptional basis, are considered only if the rules of the profession justify it or as a reasonable alternative to the existing waterways;
- characteristics of communication devices between ships, yachts and boats as well as other means of surveillance and data collecting correspond with the nominal effective range, i.e. the declared reliability.

The study follows working, management and technological presumptions of relevant and valid documents and recommendations of the International Maritime Organisation and other international expert bodies that deal with navigational safety and environmental protection, as well as the recognised national regulations.

The study does not include internal procedures or instructions that maritime companies or other legal subjects in maritime traffic at the terminal in question, might issue their employees. In addition, the study does not include procedures and measures in respect of navigational safety or environmental protection that are not directly linked to the LNG FSRU terminal, i.e. the LNG carrier.

The study is mostly based on the most recent data available whenever possible or appropriate. Older sources are used in cases where there is a lack of data. When deciding between more reliable or more recent sources, as a rule, priority is given to sources of greater reliability. In particular, the study adopts data and conclusions, wherever appropriate, from earlier studies relative to the LNG terminal on the island of Krk, especially:

- Import terminal for liquefied natural gas on the island of Krk - Environmental Impact Study, Oikon, 2013,
- The choice of location for the terminal for liquefied natural gas in the area of Kvarner and Rijeka Bay, Ekonerg, 2008,
- The Study on the Environmental Impact of the terminal for liquefied natural gas on the island of Krk, Ekonerg, 2009,
- Adria LNG Maritime Study, Faculty of Maritime Studies in Rijeka, 1994,
- Sea traffic and navigation studies for waterways in the counties of Primorje-Gorski Kotar, Lika-Senj, Zadar and Šibenik-Knin, Faculty of Maritime Studies in Rijeka, 2015,
- Krk LNG terminal Maritime Study, Faculty of Maritime Studies in Rijeka, 2016.

The layout of the terminal is based on documents received by the client, especially documents made within the FEED study drafted by the company Tractebel, Brussels.

Finally, the maritime study is restricted exclusively to the maritime safety and marine environment protection, i.e. the measures with which their efficient implementation is ensured, as is specified by the contract between the client and contractor. Other aspects of the project in question are not taken into account, i.e. not included in this study.

The text of the maritime study has been written in accordance with the common standards of maritime traffic safety and recent scientific developments. Consequently, the conclusions, findings and opinions in this study have been put forward objectively, in accordance with the available scientific and expert knowledge of the maritime traffic technology, i.e. in accordance with the accepted rules of science, profession and skill.

This maritime study, in its entirety or parts, except for those expressions and sections expressing generally recognized scientific knowledge, shall not be used in order to make other, official or unofficial documents without the approval of the client, i.e. contractor However, the maritime study can be used only for the purpose of implementation of the FSRU LNG terminal Krk by the Ekonerg and LNG Hrvatska.

2 NAVIGATIONAL FEATURES OF THE NAVIGABLE AREA

2.1 WATERWAY

The main waterway to the LNG FSRU terminal is the sea passage through Kvarner, i.e. between the eastern coast of the Istrian peninsula and islands of Lošinj and Cres and through the passage of Vela Vrata. The other noteworthy waterway runs through Kvarnerić and the passage Srednja Vrata (Middle Gate) between the islands of Krk and Cres, however that waterway shall not be used for LNG carriers so it will not be discussed further.

Ships arriving at Rijeka Bay have, as a possible destination, the ports of Rijeka and Sušak, Brajdica Container Terminal, "3. Maj" shipyard, "Viktor Lenac" ship repair yard, Bay of Bakar (INA Urinj Terminal, LPG port Sršćica, ro-ro terminal, Podbok Terminal for bulk cargo), Omišalj Oil Terminal on the island of Krk and, on a lesser scale, port of Opatija.

The main entry-exit waterway running through Kvarner can further be divided into two parts: wider sea area at the entry into Kvarner and narrower area of Vela Vrata and Rijeka Bay.

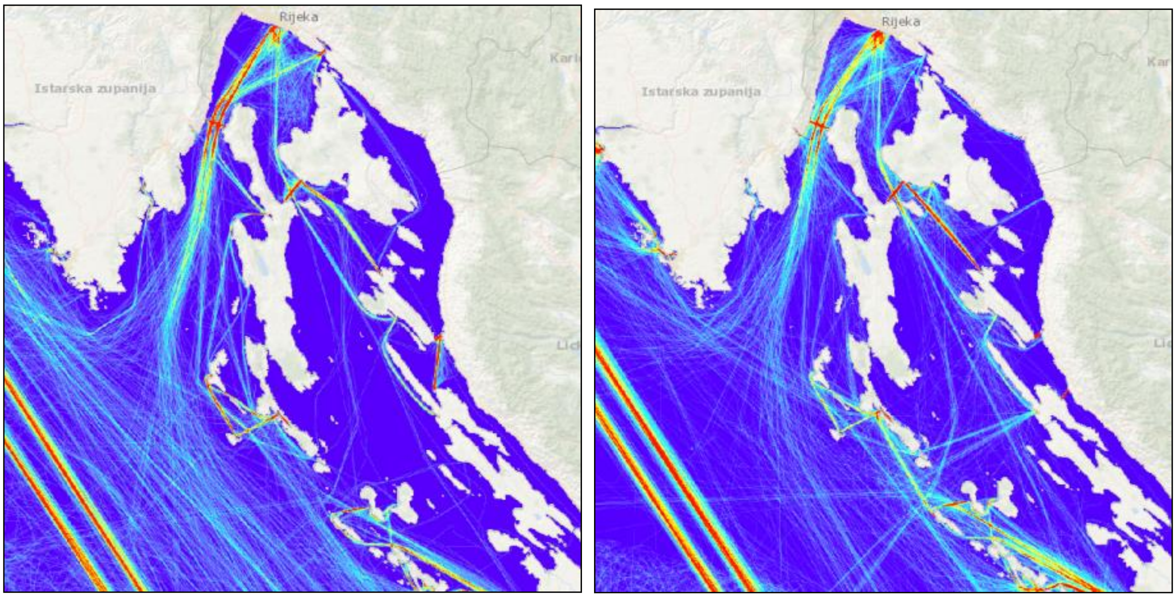

Image 1 Waterways and the related traffic density (AIS images - January and July 2014)

On the open sea above Kvarner, maritime traffic takes place along the coast from and to northern Adriatic ports (Trieste, Kopar and Venice), as well as to and from Ba of Rijeka. From the navigational stand ships that sail out of or into Kvarner intersect with the course of sail of ships sailing along the coast; the available manoeuvre area is sufficient and the angle at which intersection is carried out is close to a right angle. There is no significant navigational danger at the unrestricted area of entrance into Kvarner. At the entrance into Kvarner, the Galijola Isle is located as the only place in that area that represents a certain navigational danger due to possible stranding. The Isle is well marked using harbour lights and radar beacon and as such can be detected on time using a shipboard radars. Ships sailing towards ports in the Rijeka Bay mostly pass west of Galijola Isle except during strong south winds when smaller ships (L<120 m) usually use the waterway between the islands of Unije and Lošinj. The island Zaglav is located approximately 0,6 M off the western coast of Cres, south of Cape Pernat, and is also well marked using lighthouse. Being close to the shore, it does not pose significant threat to navigation. The depths over Kvarner are around 50 m.

At the passage of Vela Vrata (width of 2,3 to 2,8 M) a traffic separation scheme is established, specifying the general course in a way that all ships longer than 20 m sailing northeast and entering

Rijeka Bay, must navigate close to the coast of Cres, i.e. must use the east track of the traffic separation scheme, whilst ships sailing southwest, i.e. leaving Rijeka Bay must use the west track. At Vela Vrata, traffic of ro-ro passenger ferries between the island of Cres and the coast of Istria, i.e. between the ports of Brestova - Porozina takes place. These ships sail vertically with respect to the main route. The time of the voyage of the ro-ro ferries is relatively short, i.e. around 30 minutes. The depths at Vela Vrata are around 55 to 65 m.

At the entrance into Rijeka Bay north of the traffic separation scheme is a junction of navigation routes of ships sailing in and out of Rijeka Bay from various directions, i.e. terminals. The second junction is located in the middle part of Rijeka Bay at the intersection of routes of ships sailing from Vela Vrata for Bakar Bay or Omišalj oil terminal and ships from Srednja Vrata sailing for the ports of Rijeka and Opatija.

2.2 ORIENTATION POINTS AND LANDMARKS ON THE WATERWAY

Rijeka Bay is a marine area located between the northeastern coast of the Istrian peninsula and Croatian coast up to Bakar Bay on one side and western coast of the island of Krk and northern coast of the island of Cres on the other. Orientation landmarks on the western coast of Rijeka Bay are the bell tower at Brseč, the places of Mošćenice and Mošćenička Draga, the tower on the Cape of Cesar, the church in Veprinac and the peak of Mt. Učka (1,401 m) marked by an antenna mast. Orientation landmarks on the northern coast of Rijeka Bay are the bell tower at Kastav, the edifices of Rijeka, the bell tower and walls at Trsat, the industrial plants west of the entrance into Bakar Bay as well as Krk Bridge and the islet of Sv. Marko at the entrance into the Tihi Channel. At the eastern coast of Rijeka Bay, i.e. the coast of the island of Krk, the most prominent orientation landmarks are the bell tower at Omišalj, the oil and terminal, the cities of Malinska and the church on the Cape Glavotok. On the island of Cres the steep and dark capes of Jablanac and Grota. A lighthouse emitting red light with a range of 6 M in the Port of Opatija and a lighthouse emitting white light with a range of 15 M in the area of Mlaka in the port of Rijeka. There is a lighthouse in front of the Port of Omišalj on the Cape Tenka Punta with a range of 7 M. North of the cape there is a shallow marked by a lateral marking with light (4 M) and around 0,6 M west there is a mark of isolated danger with white light (4 M).

The area of Kvarner is an area between the eastern coast of the Istrian peninsula, from the Cape Kamenjak to the Port of Plomin, and western shores of the island of Cres, Unije, Lošinj and Ilovik, towards the Vela Vrata Strait. Orientation landmarks on the coast of the Istrian peninsula are the lighthouse Porer, with a white light 25 M in range, the coastal towns of Medulin and Ližnjan, the Cape Crna Punta with a lighthouse with white light 10 M in range, the deeply indented bay of the Port of Plomin, the peak of Mt. Učka and a series of harbour lights along the coast.

At the entrance to the Vela Vrata Strait on the coast of the Istrian peninsula are: a lighthouse on the Cape of Sv. Andrija (white light 5 M in range), a lighthouse on the Cape of Brestova (red light 13 M in range), a lighthouse on the cove of Brestova (green light 4 M in range), and a lighthouse on the Cape of Šip (red light 8 M in range). The passage is marked on the coast of the island of Cres with a lighthouse on the jetty in the cove of Porozina (red light 3 M in range), a lighthouse on Cape Prestenice (white light 10 M in range), and a lighthouse on Cape Starganac (green light 8 M in range).

The shores of the island of Cres are extremely steep and the range of hills streches along the entire length of the island. The highest peaks are Orlinj (604 m), Gorice (648 m), Sis (639 m) in the northern part and Helm (482 m) in the middle part, whereas the heights on the southern part of the island are significantly lower (60-80 m). The most prominent landmarks along the western coast of the island are the lights of the fish farm in the cove of Veli Bok (yellow lights 2 M in range), the signalisation on the entrance to the Port of Cres at Cape Kovačine (red light 8 M in range) and Cape Križice (green light 4 M in range), a lighthouse on the rock of Zaglav (white light 10 M in range), a lighthouse on the islet of Zeča (white light 8 M in range and red light 6 M in range) and a lighthouse on the islet of Visoki (white light 6 M in range).

The isle of Galijola is located about 4,6 M northwest of the island Unije and about 7,2 M west of the Cape Osor on Lošinj. It is marked by adequate navigation lights (white light 12 M in range and Racon equipment (C)).

The island of Unije is characterised by a range of hills on the south part of the island, with the peak Kalk (132 m) at the end. Not far off the northwestern coast there is Samunćel reef marked by a cardinal mark, as well as the shallow of Arbit in front of the south cape of the same name. The lighthouses are located on the Cape of Lakunja (white light 8 M in range), the Cape of Vnetak (white light 10 M in range and red light 7 M in range) as well as the Port of Unije (red light 3 M in range).

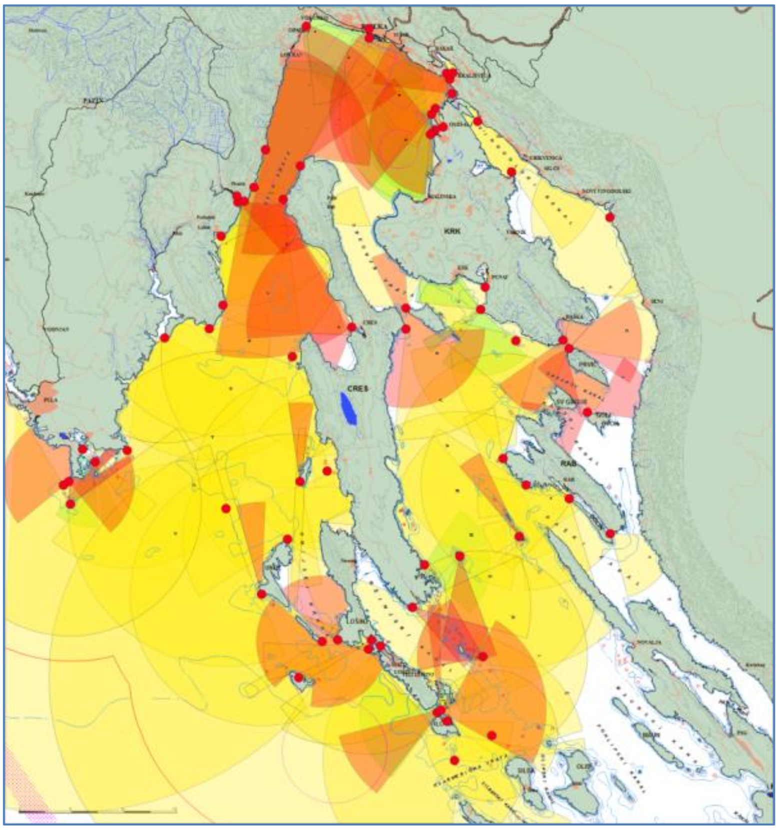

Image 2 Lighthouse coverage (range > 5M) – waterways towards the ports of the Rijeka Bay

The island of Susak is covered by terraced sediments of yellowish sand, steep shores with the highest peak Garba (96 m) on which stands a lighthouse with white light 19 M in range. Also, there are lights in the Port of Susak (green 2 M in range and red 2 M in range).

Lošinj is located in the southern part of Kvarner with a range of hills and mounds stretching along the entire length of the island which serve as valuable orientation landmarks, with the highest peak of Televrina (589 m) on Mt. Osoršćica. The northern part of the island is steep and bare whilst the rest is cultivated and wooded. Useful orientation landmarks on the western part of the island are the lights of the lighthouse on the Cape of Kurila (white light 8 M in range and red light 6 M in range), a lighthouse on the islet Zabodaski (red light 4 M in range), a lighthouse on the islet of Murtar (white light 8 M in range) and a lighthouse on Cape Madona (green light 3 M in range).

The island Ilovik is located at the southern part of the island of Lošinj and is separated from it by the Ilovik strait. At the western part of the island, there are partially cultivated slopes of the Krišine hill (78 m), on the eastern part of the island there is Vela straža hill (92 m) that slopes steeply towards the shore, whereas on the southeast part there is a low, rocky and narrow Cape Radovan.

The islet of Grujica is located 2 M south of Ilovik and houses a lighthouse with white light 10 M in range and a radar beacon marked (O). Between Grujica and the island of Lutrošnjak there is Kvarnerička strait that leads to Kvarnerić. From there to Rijeka Bay the route leads through Srednja vrata, i.e. the passage between the island of Krk and Plavnik and the island of Krk and Cres with a width of around 2,6 M in its narrowest part and around 3,8 M at its widest part. The significant orientation landmarks are the islet of Galun, the lighthouse on Cape Negrit (green light 5 M in range), Manganel (white light 8 M in range) and the lighthouse on Cape Glavotok (red light 3 M in range) on the coast of the island of Krk and the place Beli near the coast of the island of Cres. The waterway is not used by ships in international navigation, i.e. ships that transport hazardous loads and as such is not discussed further.

2.3 NAVIGATION AND COMMUNICATION COVERAGE

In accordance with the available equipment (mandatory and/or common), to determine the position of the ship, terrestrial/coastal navigation, radar navigation and satellite navigation are used.[2]

Radar navigation. Across the entire navigation area the coast is predominately high and steep and the position of ships can be determined visually or by using radar devices with certainty and on time in all weather conditions. Due to the very good reflection with regard to the configuration of the coastline, radar navigation can be used to determine position with great accuracy even at distances exceeding 30 M (with a radar antenna high enough).

Satellite navigation. Satellite navigation (mostly the Global Positioning System (GPS) i.e. GLONASS) can be used in the entire area of the Adriatic as well as Kvarner i.e. Rijeka Bay. Accuracy, availability, reliability, time interval between two successive positions of the ship and system capacity are in order and meet the international standards in full. In the observed area, as well as the rest of the Adriatic, there is no system that enhances the accuracy of the GPS signal, i.e. DGPS.

Communication coverage. In the observed area of the Adriatic, all ships that use radio traffic may also use the services of coastal radio stations of the Republic of Croatia. In navigation a watch service is determined by international rules of radio traffic and services to protect life at sea and safe navigation and is run on the VHF channel 16, and for vessels equipped with VHF DSC equipment on VHF DSC channel 70. If there is no urgent request for radio link, all communications can be done over the working channels of coastal radio stations of the Republic of Croatia. Due to good coverage, it is possible to use GSM mobile telephony almost on the entire navigational area, except in areas going towards the open sea, i.e. the border of the territorial sea and at greater distances from inhabited islands.

In the observed navigational areas, vessels can use the services of the coastal radio stations Rijeka Radio and Split Radio, call sign (9AR and 9AS), VHF - radiotelephony on channels 04, 07, 16, 20, 21, 23, 24, 28 and 81 as well as MF – radiotelephony.

Surveillance of maritime traffic. Surveillance of the movement of maritime traffic in the observed area is done by the Vessel Traffic Service Centre (VTS) in Rijeka.

The national SAR centre (MRCC Rijeka) in coordination with other sub centres deals with the search and rescue and performs control of safety of maritime traffic in the observed navigational areas. The office is reachable at VHF channel 16 and telephone number 195.

The pilot service, harbour master office and VTS service are available 24 hours a day on VHF radio channel of the VTS sector, i.e. channels 14 and 62. In outside areas of the coastal sea (sectors A and

[2] Here it is assumed that the simultaneous use of primary and secondary methods of determining the position of vessels will be carried out.

B) channels 10 and 60 are used. Also, in all observed navigational areas, the harbour master's office and the VTS service are accessible via the VHF radio channel of the VTS sector.

In the Rijeka Port, under the Port of Rijeka authority, there is a port control centre that uses VHF channel 9, whose primary purpose is to organise the management of ships inside of the port basins, anchorages and approaching waterways as well as coordinating pilotage and towing of ships.

Weather reports. Weather reports and warnings for seafarers are transmitted daily on VHF channels 67, 69 and 73.

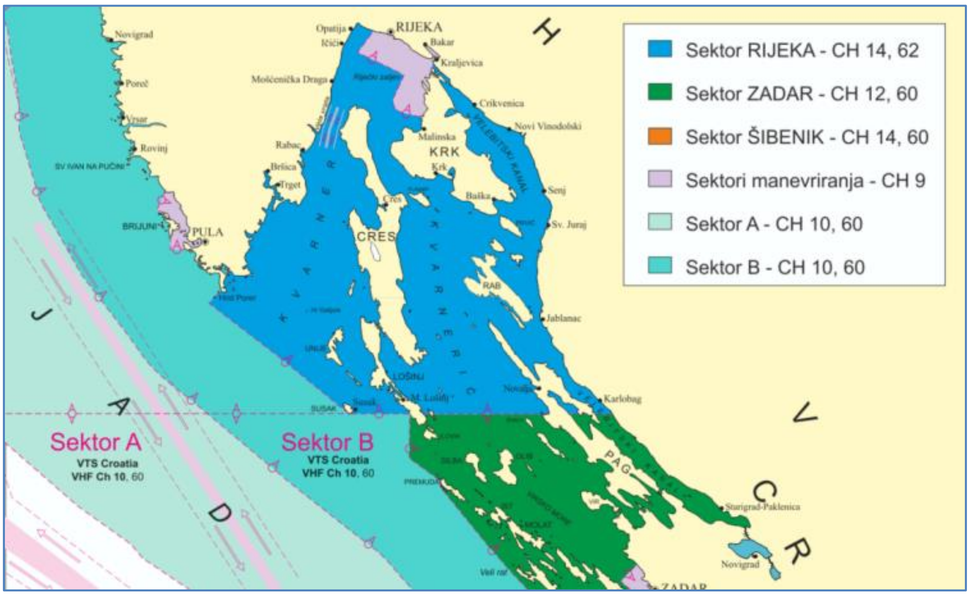

Image 3 VHF channels of harbourmaster's offices and pilotage services

Magnetic conditions. The elements of the Earth's magnetic field are: magnetic variation, magnetic inclination and the total intensity of the Earth's magnetism, which consists of vertical and horizontal components. The value of magnetic variation and the value of the horizontal component of the Earth's magnetic field are especially important for navigation. Magnetic variation in the Adriatic Sea (2012) varies in the range of approximately 2,5°E in the area of Venice up to 3,5°E in the area of the Strait of Otranto. The annual change in magnetic variation is extremely small and totals at around 7,1'E in the north part up to 6,2'E in the south part of the Adriatic Sea. According to data from 2012, the value of magnetic variation for the navigation area of Rijeka totalled at 2°56' E. The annual change of magnetic variation totals at 6' E.

In the area of the Adriatic Sea, magnetic anomalies have been observed in the area of Lošinj - Rijeka and in the southern part of the Adriatic in the area of Jabuka - Svetac - Vis, especially due to the geologic structure of mountains along the coast as well as eruptive rocks of the isles of Brusnik and Jabuka. In these areas, it is advised to check on a more regular basis the position of the magnetic compass; also, devices that do not depend on the Earth's magnetism should be used, as much as possible, to determine the position of ships.

2.4 SEA TRAFFIC

In the observed area, there is one port of particular international significance (Rijeka), 27 ports of county significance and 76 ports of local significance. Also, there are 30 registered ports of nautical tourism in the navigation area, 10 of which are marinas, 7 dry marinas, 5 berths and 8 anchorages.[3]

Cargo ports i.e. terminals on the area of Rijeka Bay include:

- Rijeka basin,
- Sušak basin,
- Bakar basin (quays Podbok and Goranin),
- container terminal Brajdica,
- terminal for liquid cargo, Omišalj Oil terminal (JANAF),
- industrial ports Bakar and Sršćica (INA oil refinery-Rijeka).

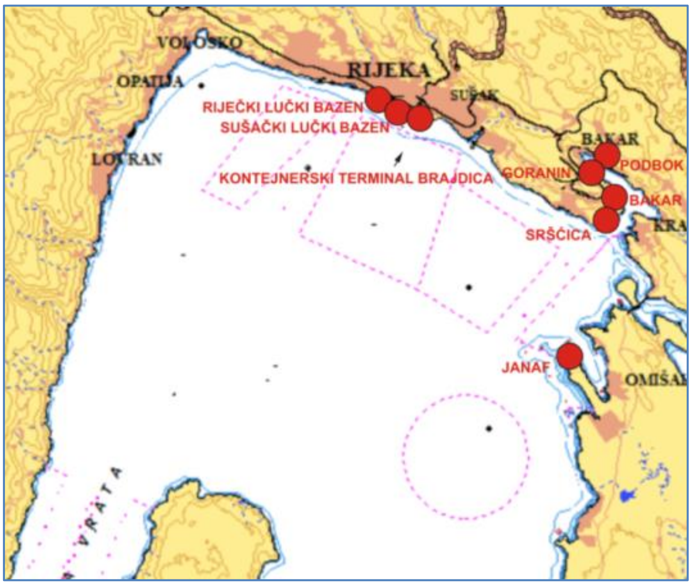

Image 4 Position of cargo ports in the area of Rijeka Bay

Port basins Rijeka, Sušak, Bakar, container terminal Brajdica and the Omišalj Oil terminal cover the port areas of the Port of Rijeka authority and represent ports open for public traffic with particular significance to the Republic of Croatia.

Rijeka basin. The area of this basin represents the central part of the Port of Rijeka and is situated in front of the town. It covers the area from the Istrian quay in the east part up to the Zagreb quay in the west part as well as the area of the breakwater 1,786 m in length. It comprises of 9 quays in total (Zagreb, Prague, Bratislava, Visinov gat, Budapest, Orlandov gat, Vienna, De Franceschi and Istria) as well as 3 specialised terminals (Passenger terminal, Terminal for conditioned cargo and Terminal for grain). The total amount of berths for cargo ships is 16, whilst the smaller passenger, fishing and public ships are berthed at 20 berths. The depths at the quays allow accomodation of ships with the largest draft of about 12 m, i.e. PanaMax-sized ships, up to 225 m in length (Budapest quay). The quays are designed to handle the transhipment of general and bulk cargo, whilst timber is also handled on a

3 Regulation on the classification of ports open to public traffic in the area of Primorsko-goranska County (Official Gazette 3/2015)

regular basis. Part of the Rijeka basin is used to handle fishing boats as well as berth yachts. Larger passenger and ro-ro passenger ships can also be berthed at the passenger terminal at the depth of 7,5 m. Part of the passenger terminal is intended for berthing high-speed crafts (HSC) as well.

Sušak basin. The basin is located east of the Rijeka basin and includes 3 quays (Senj, Vinodol and Ružić) as well as breakwater Sušak which is also used for berthing ships. It is used for smaller cargo ships (the depths along the quay total at 6,5 m at most) for the transport of general and bulk cargo as well as timber. The coastal edge along the north part of the basin is used for high-speed passenger boats.

Brajdica container terminal. The terminal is used for handling and storing containers, ro-ro trailers and other vehicles as well as handling heavy packages and stone blocks. The total length of the coast is 628 m, with the deepest point of 13,5 m and the possibility to handle 2 container ships as long as 367 m, at the same time. The annual capacity of the terminal totals at 600,000 containers.

Bakar basin. The basin is located at the western part of Bakar Bay. It consists of two terminals. At the northeast part there is berth Podbok for handling bulk cargo and on the southwest side there is quay Goranin with a ro-ro ramp. The quay with the greatest depth of 9 m is usually used for smaller coastal boats for transport of bulk cargo and timber. Podbok terminal is used for handling bulk cargo (coal, iron ore, cement and other bulk cargo). The terminal has an operative coast 385 m in length, with sea depth of 18,5 m and an open warehouse area for storing 400,000 tonnes of cargo.

Omišalj Oil terminal (JANAF). The terminal is situated at the northern part of the island of Krk, at the western side of the Omišalj Bay, on the Tenka Punta peninsula. The berths are located at the eastern part of the peninsula. The terminal consists of two identical berths with a T-shaped steel construction with an individual length of 120 m, with depths of 30 m along the berth. The world's biggest tankers can access the terminal, whilst tankers transporting crude oil (average size is AFRAMAX or SUEZMAX) are the most common, as well as tankers used for transport of oil products with tonnage up to 40,000 tonnes.

Shipyards. Shipyard ports in the area of Rijeka Bay consist of three shipyards, with the 3. May shipyard used for the construction of new ships, whilst Kraljevica and Viktor Lenac shipyards are used as ship repair yards. 3. Maj isn't characterised by heavier maritime traffic whilst the other two shipyard are accommodate ships sailing internationally trade with a length exceeding 100 m (Viktor Lenac) whilst Kraljevica accommodate smaller ships that usually sail within the country.

INA industrial ports. Industrial ports in Bakar Bay (petroleum ports Bakar and Sršćica) are ports belonging to INA oil refinery and used to handle petroleum products (Bakar) and liquefied petroleum gas (Sršćica) The coast of petroleum port is 465 m long and consists of 8 berths which are usually used for smaller coastal tankers and tankers used for transport of oil products with tonnage up to approximately 40,000 tonnes. The coastal depths reach up to 10,5 m. Industrial port of Sršćica consists of one quay 66,8 m long with depths up to 10 m. It is usually used for handling smaller LPG carriers with deadweight up to 5,000 tonnes that carry compressed liquefied petroleum gas.

Sea traffic. The total number of ships that entered in previous years (2014 -2016) in the area of Rijeka Bay is approximately 4,700 (there were 4,674 entries in 2016) out of which approximately 900 were foreign ships. In general, domestic traffic includes fishing and passenger ships as well as tugboats in the area of the port of Rijeka, whilst foreign ships that enter are mostly cargo ships (tankers, container ships and ships for transporting bulk and general cargo) that sail towards cargo quays in the area of Rijeka Bay (basins Rijeka and Sušak, Brajdica container terminal, quays at Bakar Bay, Omišalj oil terminal and Viktor Lenac and Kraljevica shipyards). The largest ships that enter the ports of Rijeka Bay are container ships up to 366 m in length and tankers used to transport crude oil with deadweight up of 330,000 tonnes, i.e. around 330 m in length and 60 m in width.

The total amount of handled cargo in ports in the area of Rijeka Bay totals at around 13,000,000 tonnes, with most of the cargo being handled at the Omišalj oil terminal, around 50% of the total amount. Following Omišalj oil terminal, the second greatest amount of handled cargo is carried out at INA refinery terminals of Bakar and the container traffic at the container terminal of Brajdica where 161.883 TEU was handled in 2015, and 177.401 TEU in 2016.[4]

[4] Includes cargo handled in ports under the jurisdiction of the port of Rijeka authority (Rijeka, Sušak, Brajdica, Bakar-Podbok/Goranin, Omišalj oil terminal) as well as cargo handled in the terminals of Bakar's INA refinery

Basin	Number of entries	Traffic (t)	Type of cargo
2014			
Rijeka	328 cargo ships 822 passenger ships 893 fishing boats	2.312.847 192.500 passengers	general and bulk cargo, timber
Sušak	17		general and bulk cargo, timber
Brajdica	389		containers
Bakar	41	1.188.945	bulk cargo and timber
Omisalj	57	4.882.695	crude oil and oil products
Shipyard 3. Maj	7	N/P	N/P
Viktor Lenac shipyard	75	N/P	N/P
Kraljevica shipyard	31	N/P	N/P
Petroleum port	260	2.042.509	oil products
Sršćica	25		liquefied petroleum gas
2015			
Rijeka	1,784 domestic ships 834 foreign ships	3.137.720 144,377 passengers 35,316 head of cattle - Raša	general and bulk cargo, timber
Sušak	48		general and bulk cargo, timber
Brajdica	346		containers
Raša[5]	148		cattle, timber and stone
Bakar	47	1.167.164	bulk cargo and timber
Omisalj	80	6.595.537	crude oil and oil products
Shipyard 3. Maj	6	N/P	N/P
Viktor Lenac shipyard	93	N/P	N/P
Kraljevica shipyard	36	N/P	N/P
Petroleum port	295	1.637.516	oil products
Sršćica	24		liquefied petroleum gas
2016			
Rijeka	2,081 domestic ships 685 foreign ships	3.235.821 163,364 passengers 55,237 head of cattle - Raša	general and bulk cargo, timber
Sušak	33		general and bulk cargo, timber
Brajdica	362		containers
Raša	184		cattle, timber and stone
Bakar	32	598.167	bulk cargo and timber
Omisalj	91	7.325.173	crude oil and oil products
Shipyard 3. Maj	25	N/P	N/P
Viktor Lenac shipyard	59	N/P	N/P
Kraljevica shipyard	52	N/P	N/P
Petroleum port	288	2.084.705	oil products
Sršćica	27		liquefied petroleum gas

Table 1 Maritime traffic in the navigation area of Rijeka Bay[6]

5 Port Raša, i.e. Raša basin is located on the eastern coast of Istria, 60 km off Rijeka, in a naturally protected bay. Used for handling cattle, timber and stone. Within the Raša basin, there are two separate terminals for handling cattle and timber. The port basin covers an area of approximately 700.000 m2 whilst the greatest depths on the berths are 10 m. The port basin is under the authority of the port of Rijeka.

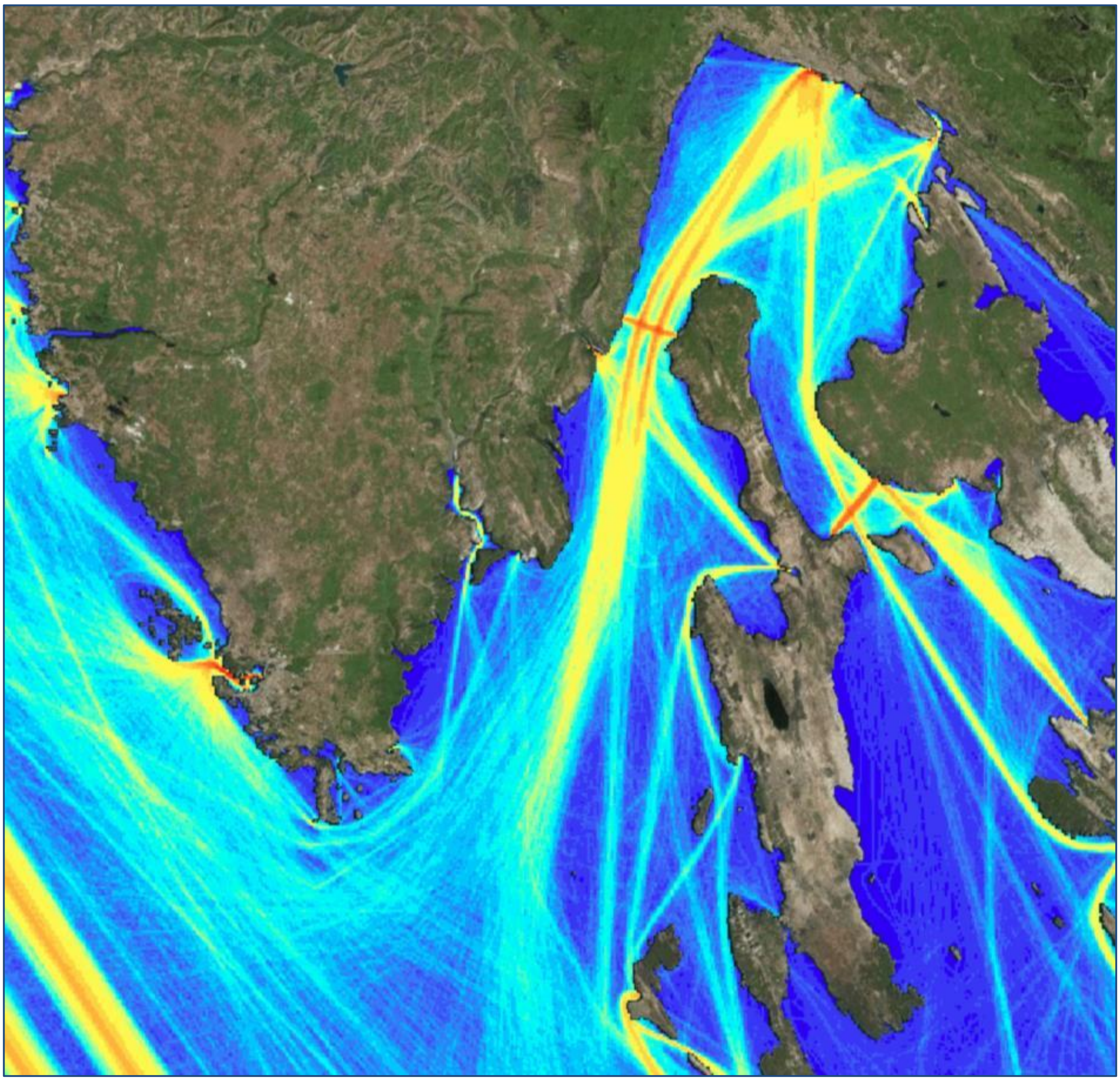

Image 5 Traffic load in the area of access waterways (AIS data – 2014)1

Passenger traffic at the Rijeka Bay is not substantial and it totalled 234,416 passengers in 2014 with the majority of passengers boarding at the passenger terminal in Rijeka totalling at 192,500 passengers. The majority of passenger traffic is related to passenger liners, high-speed boats sailing towards Cres and Mali Lošinj as well as islands of Rab and Pag, where 149,194 passengers were transported in 2014 and 140,825 in 2016. Two high-speed passenger liners sail daily toward said islands.[7]

It should be stressed that cargo traffic had been falling in the last decade with the exception of the last three years when a slight increase was recorded, at the same time passenger traffic remained relatively stable. A slight increase in cargo as well as passenger traffic is to be expected in the coming years. The increase is expected because of the arrival of a greater number of tankers, container ships and ships

[6] The source of the data is the Port of Rijeka Authority as well as Rijeka's Harbour Master's Office - annual reports (number of vessels - Rijeka basin, amount of cargo in Bakar and Sršćica petroleum ports).

[7] Data provided by the AZOLPP.

used for transport of bulk cargo, i.e. the increase in the amount of cargo and the larger number of cruise ships sailing nationally or internationally.[8]

When it comes to other ports in Rijeka Bay, a more significant maritime traffic is recorded in the ports of local significance - Opatija, Bakar, Kraljevica, Omišalj and Malinska. Maritime traffic in said ports is primarily related to the traffic of fishing boats and smaller passenger boats, with international traffic and cruise ship traffic only taking place in Opatija (at the anchorage). For example, a total of 13 cruise ships sailing internationally entered the anchorage of the Port of Opatija in 2014.

In the observed navigation area, there are 27 ports of county significance open for public traffic. Out of the total number, there are 22 ports which are exclusively reserved for passenger traffic whilst 6 ports accept ro-ro passenger ships. Ro-ro passenger traffic takes place in the following ports of county significance:

- Lopar (island Rab),
- Mali Lošinj (island Lošinj),
- Merag (island Cres),
- Mišnjak (island Rab),
- Porozina (island Cres) and
- Valbiska (island Krk).

Out of the mentioned ports, only traffic at the Porozina - Brestova route has a certain impact on the navigation of LNG carriers towards their destination terminal, as such, only the said traffic will be observed hereafter, whilst other traffic in the navigation area of the county will be disregarded.

The Port of Porozina is located on the island of Cres at the point of passage Vela Vrata. The port has three ro-ro ship ramps that link the island of Cres to the eastern Istrian coast and the Port Brestova. Two berths are used for the berthing of ro-ro passenger boats. A shore 28 m in length with depths of approximately 3,5 m is located in the inner part of the western quay. A new quay approximately 50 m in length, with depths of 4,5 to 5 m that handles larger ro-ro ships, has been built at the eastern part of the port. Behind the new quay, there is a small port that the locals use for their vessels. Port Brestova has two quays of approximately the same depth. The port is exposed to north and north-east winds.-

Ports Rabac and Plomin that are also situated in the Istria County accept smaller passenger boats, whereas Port Plomin accepts fishing boats as well. The importance of the said ports in the Istria County can be seen in the fact that the ships using the said ports intersect with the main waterway leading to Rijeka Bay. Ro-ro passenger boats sailing via the Brestova - Porozina route intersect that waterway at a right angle.

The majority of the maritime traffic in the ports of county and local significance, takes place during the summer months when the majority of the passenger boats are used for one day trips and the locals use their own boats.

8 In 2016, 17 cruisers sailing internationally entered the port of Rijeka, whilst in 2014, there were only 7. Approximately 10 smaller cruisers (up to 35 m in length) sailing nationally set out from the port of Rijeka on a weekly basis in the summer months. A rise in the number of cruisers entering the port of Rijeka is expected in the coming years as well.

Line	Number of passengers 2013	Number of passengers 2014	Number of vehicles 2013	Number of vehicles 2014
VALBISKA - MERAG	762.526	806.316	367.208	394.121
BRESTOVA - POROZINA	548.486	501.114	235.259	218.248
VALBISKA - LOPAR	85.449	84.350	30.626	29.152
MALI LOŠINJ - ILOVIK - SUSAK - UNIJE - MARTINŠĆICA - CRES - RIJEKA	74.351	69.930	-	-
NOVALJA - RAB - RIJEKA	88.561	79.264	-	-
	Number of passengers 2015	**Number of passengers 2016**	**Number of vehicles 2015**	**Number of vehicles 2016**
VALBISKA - MERAG	1.025.199	1.068.453	422.546	426.716
BRESTOVA - POROZINA	545.700	575.893	218.006	226.189
VALBISKA - LOPAR	106.717	106.024	37.774	36.693
MALI LOŠINJ - ILOVIK - SUSAK - UNIJE - MARTINŠĆICA - CRES - RIJEKA	72.677	70.371	-	-
NOVALJA - RAB - RIJEKA	76.729	70.454	-	-

Table 2 Maritime traffic on state passenger and ro-ro passenger lines in the observed area that have or might have impact on the navigation of LNG carriers towards the LNG terminal (Agency for Coastal Maritime Liner Services)1

Line	Number of lines (daily)	Type of ship
VALBISKA - MERAG	26	ro-ro passenger ship
BRESTOVA - POROZINA	26	ro-ro passenger ship
VALBISKA - LOPAR	8	ro-ro passenger ship
MALI LOŠINJ - ILOVIK - SUSAK - UNIJE -MARTINŠĆICA - CRES - RIJEKA	2	high-speed passenger boats
NOVALJA - RAB - RIJEKA	2	high-speed passenger boats

Table 3 Maritime passenger liner traffic and ro-ro passenger traffic (summer months - high season) in the observed area that have or might have impact on the navigation of LNG carriers towards the LNG terminal (Agency for Coastal Maritime Liner Services)

Foreign boats and yachts. The number of foreign boats entering the ports in the area of Rijeka's harbourmaster's office in 2014 totalled at 11,123, out of which 406 were yachts, whereas in 2016, that number increased to 13,974, i.e. 793 yachts. It is important to stress that the said vessels used in nautical tourism do not usually sail in the area of Rijeka Bay but in other navigation areas of Kvarner and Kvarnerić. The biggest impact on maritime safety of LNG carriers can occur at access waterways in areas of Kvarner between the coasts of Istria and Cres.

For the winter months in 2016, 2,288 vessels were berthed in the area, most of which in the ports and marinas of Punat, Cres, Rab, Mali Lošinj and Opatija.

Fishing boats. Fishing traffic in the area of Primorsko-goranska County usually takes place in the area of the Rijeka Bay, on the waterways to the open sea in the area of Kvarner as well as areas of Kvarnerić and between the islands of Krk, Rab and Cres.

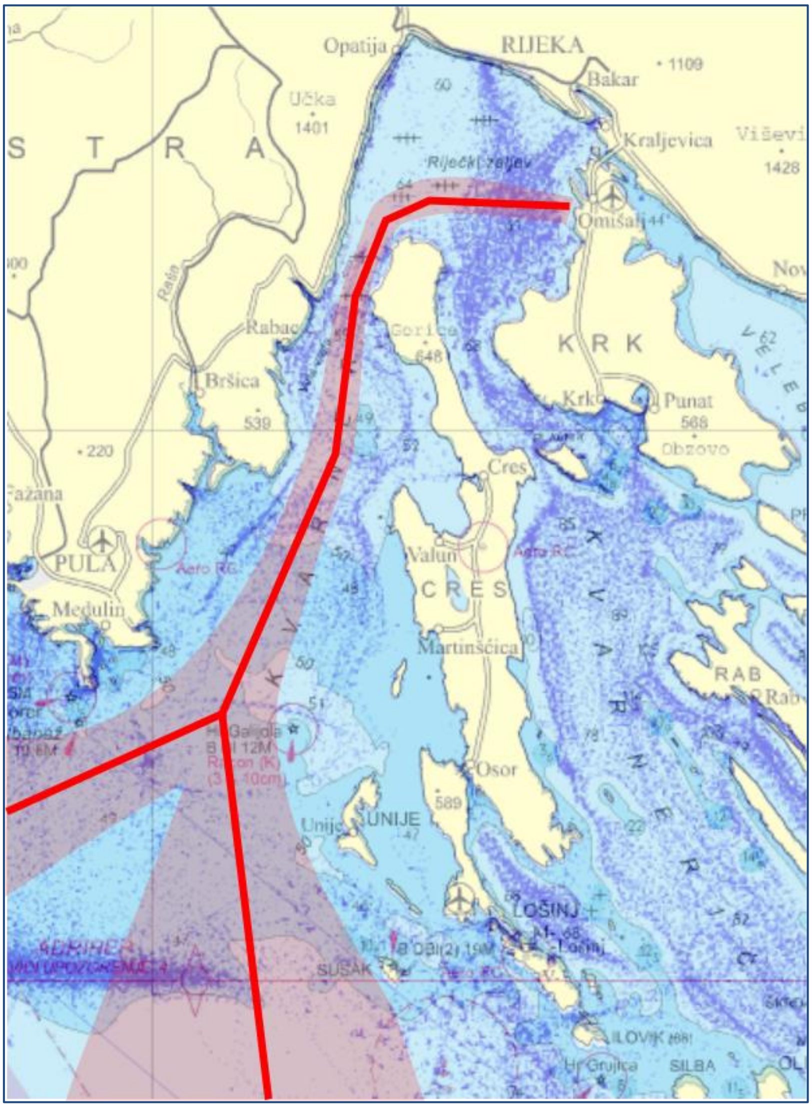

Image 6 Areas of fishing boat traffic (blue dots) on the access waterways of the LNG carrier route (according to data collected by the Ministry of Agriculture)

In the registers of ships of Rijeka's Harbour Master's Office in 2016, there were 67 fishing ships (53 of which were purse seiners) and 784 fishing boats. The said number of vessels is on the decrease so, for instance, the number of fishing boats has fallen from 940 to 784 and the number of fishing ships from 73 to 67 in just two years. In general, taking into consideration the fishing season, the area of Kvarner and Rijeka Bay can be seen as an area of relatively high number of fishing ships, especially purse seiners. Small blue fish usually swim in schools so it is not uncommon for a large number of ships to group and fish in the area of approximately 4 to 5 M in diameter, however given the number of fishing ships that gravitate towards the northern Adriatic (over 50), this can pose a problem and threat to the main waterways because of the possibility of collision.

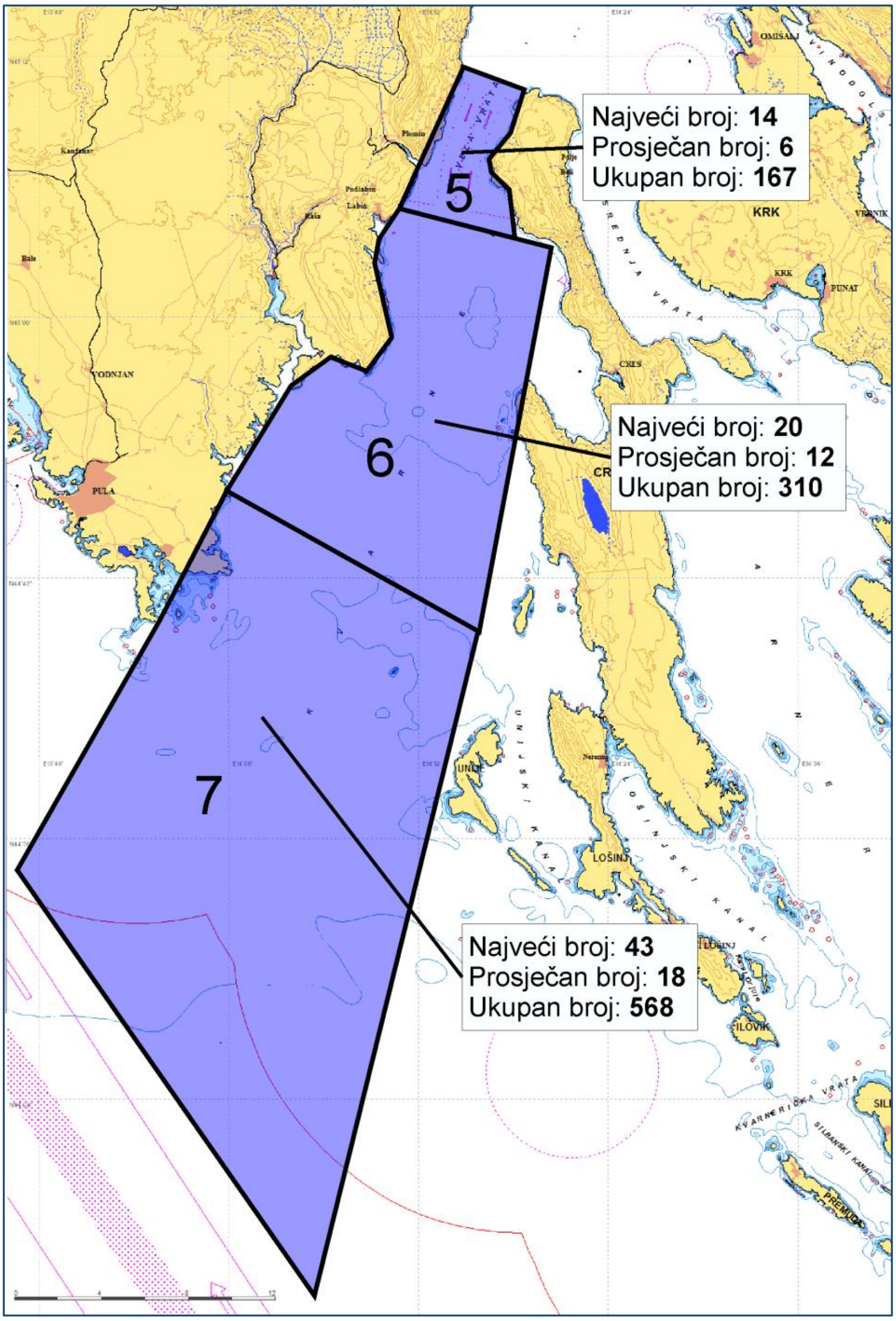

Image 7 Fishing boat overload of the access waterway (according to data collected by the Ministry of Agriculture)

The image shows the daily and total number of fishing boats in August 2016, in the sectors east and southeast of Istria that represent the main access waterway of the LNG carrier. The total number of fishing ships is not noteworthy in respect to the size of the observed sector. However, seeing as how fishing in the said navigation area is mostly done by purse seiners, which usually fish in a restricted navigation area and in groups, they can cause the need for added caution by the LNG carrier using that waterway.

2.5 MARITIME SAFETY

The waterway stretching from the open part of the Adriatic to the LNG FSRU terminal is an area of various hydro meteorological and navigational conditions and diverse maritime traffic in which vessels of significantly different characteristics sail side by side.

Srednja Vrata and Tihi Channel are approaching waterways for the ports in Rijeka Bay for cargo and passenger ships of smaller sizes sailing nationally as well as vessels used in nautical tourism. During the summer months, there is heavy traffic of vessels used in nautical tourism which leads to a higher risk of collision. Tihi Channel poses a particular threat, for ships that use it must significantly change their course and sail through a passage with a minimum width of 0,25 M. Sailing through these passages is not the subject matter of this study because it is used very rarely, and the usual ship sizes are such that they pose an insignificant safety threat to the LNG carriers.

Vela Vrata. This waterway is the main waterway leading to and from Rijeka and all of its terminals in the area of Rijeka Bay towards the open sea, i.e. the territorial and international waters. It is the waterway which will be used by all LNG carriers entering or leaving the terminal. The passage is 2,3 to 2,8 M wide and 5,5 M long, a traffic separation scheme has been placed in the middle part. The waterway from Rijeka to the border of the internal waters is around 42 M long. This waterway is the most frequently used waterway leading to Rijeka.

A traffic separation scheme has been placed in the waterway. The traffic of ro-ro passenger ships on the Brestova-Porozina route intersects with the traffic separation scheme, i.e. the main waterway, at a right angle and in that way renders the area an area of common maritime route intercrossing. The ships that follow the main waterway do not have to significantly change their courses. During the summer season, maritime traffic is intensified by smaller excursion ships, boats and yachts that mostly sail in the coastal area.

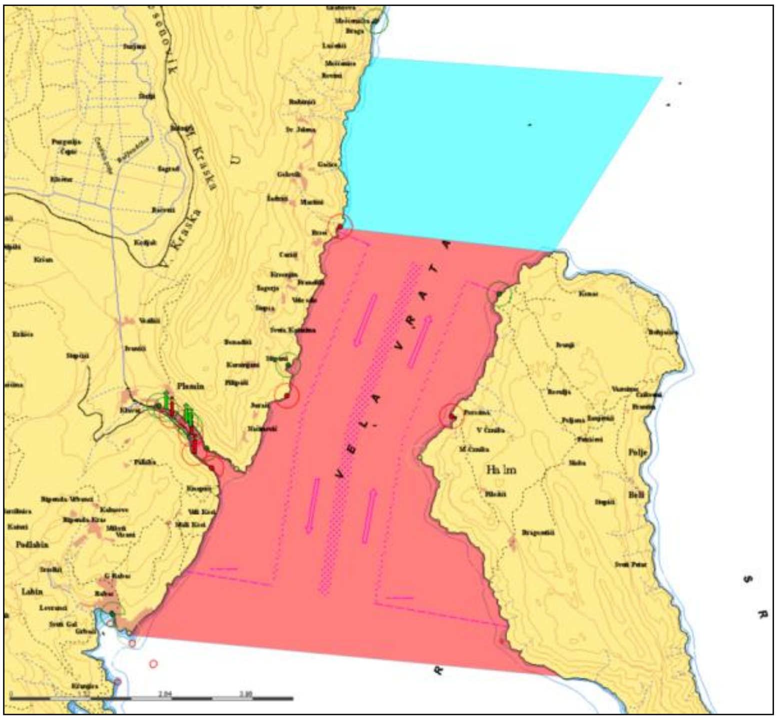

Image 8 The Vela Vrata Strait

Pursuant to the "Regulation on the navigation..." navigation through Vela Vrata has been organised in the following way: [9]

9 Regulation on the navigation and passage of the nearby Port of Šibenik, Pašman Strait, Vela Vrata, Rivers Neretva and Zrmanja, and prohibiting the navigation through Unije Channel and Channel Krušija, parts of the Srednji Channel, the Murter Sea and Žirje Channel (Official Gazette of the Republic of Croatia 09/2007 and with amendments 57/2015 and 104/16).

1. *Navigation through the passage of Vela Vrata is carried out according to the rule 10 of the International Rules for Preventing Collisions at Sea and Article 10 of the Regulations for Preventing Collisions at Sea (»Official Gazette«, No. 17/96);*[10]
2. *A traffic separation scheme is to be placed in the waterway.*
3. *The area of the traffic separation has been defined by a central line that joins the points to the geographic coordinates: 45º 05' 00" N 014º 14' 30" E, 45º 07' 45" N 014 15' 10" E, 45º 10' 24" N, 014º 16' 36" E. The area of separation is 1 cable lengths (0,1 miles) wide on each side of the central separation line. The navigation area for ships and yachts that use the separation scheme continues to the area of separation at each side at a width of 7 cable lengths (0,7 miles), whereas toward the mainland coast, i.e. the coast of the island of Cres, a zone of coastal navigation continues.*
4. *Ships and yachts, over 20 m in length, must use the eastern side of the navigation area when sailing northeast, i.e. when entering Rijeka Bay, and the western side of the navigation area when sailing southwest, i.e. leaving Rijeka Bay (general course of navigation).*
5. *Ships and yachts may be used in the zone of coastal navigation in cases when it is possible to navigate safely through the waterway within the neighbouring scheme of separated traffic. However, ships and yachts up to 20 m in length, as well as sailing vessels and fishing boats, may be used in the zone of coastal navigation.*
6. *Fishing boats may operate the area of the passage of Vela Vrata, however they must step aside and give way to any boat sailing in the general course of navigation.*

This access waterway is used by:

- merchant and passenger ships sailing nationally (throughout the year),
- smaller passenger ships for multi-day cruises and trips, especially those coming from domestic ports of the northern Adriatic (during the summer months);
- regular ro-ro passenger liners that link the island of Cres with the mainland (Brestova – Porozina);
- regular high-speed passenger crafts that link the nearby islands with the mainland (Mali Lošinj - Ilovik - Susak - Unije - Martinšćica - Cres -Rijeka);
- fishing boats;
- yachts and boats of various sizes (mostly during the summer months).

Due to favourable navigation coverage of the passage, sufficient depths, clear radar visibility and the right width of the navigation route with a traffic separation scheme, the safety of navigation in this passage, considering the existing traffic, has been deemed satisfactory.

It is necessary to stress that the mentioned fishing permission in the passage goes against the rules of navigation in traffic separation schemes that say that fishing boats should not obstruct the passage of a single boat travelling on the navigation route and the rule that says that, in normal circumstances, ships should not cross the line of separation except when fishing within the zone of separation.[11]

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[10] Regulations for Preventing Collisions at Sea (Official Gazette 17/96) pursuant to Article 78 of the Regulations on Safety of Maritime Navigation in Internal Waters and Territorial Waters of the Republic of Croatia and the Manner and Conditions of Control and Management of Maritime Traffic (Official Gazette 79/2013, as amended 140/2014 and 57/2015) is no longer in force.

[11] Regulations on Safety of Maritime Navigation in Internal Waters and Territorial Waters of the Republic of Croatia and the Manner and Conditions of Control and Management of Maritime Traffic (Official Gazette 79/2013, as amended 140/2014 and 57/2015).

Access to terminals in the area of Rijeka Bay is carried out in a way that causes intersection of waterways. The area just in front of the northern approach to the traffic separation scheme represents the area of the biggest course change of ships and the area of course intersection (marked in blue in the given image). Also, the other area where waterways intersect is located in the middle part of Rijeka Bay at the intersection of navigation routes of ships from Vela Vrata sailing for Bakar Bay or Omišalj oil terminal and ships from Srednja Vrata sailing for the ports of Rijeka and Opatija.

The entire access way and the passage of Vela Vrata are navigationally well marked. Ships arriving from the open sea usually pass between Istria and the rock of Galijola (8 M wide) with an access course of 013°. Smaller ships arriving from the south also pass between the rock of Galijola and the island of Unije (4,5 M wide) with an access course of 004°. Navigation through the access way towards Vela Vrata is not demanding due to the fact that almost no course change is needed. The navigation area for ships obligated to use the TSS is 0,7 M wide at both sides, and the separation zone is 0,1 M wide. In the middle part of the zone of separated traffic (athwart from the Cape Prestenice on the island of Cres) the change in course is 019°. Almost in the same area, there is traffic of ro-ro passenger ferries between the island of Cres and the coast of Istria (regular route Brestova - Porozina) that intersects the main waterway used by ships sailing from and to Rijeka almost at a right angle. Those types of navigation situations are not uncommon in maritime traffic and are usually resolved by respecting the International Rules for Preventing Collisions at Sea.

In the area at around 2 M after exiting the traffic separation scheme, there is a change of course toward the final destination in the area of Rijeka Bay. The new courses range from 005° towards the Port of Opatija to 067° towards Omišalj oil terminal, i.e. Krk LNG FSRU terminal.

Merchant and passenger ships sailing internationally mostly sail at an unchanged course and usually pass side by side when travelling in opposite courses in the area of Kvarner and Rijeka Bay, i.e. before or after the zone of separated traffic, with minor changes of course. All vessels longer than 20 m are required to use the TSS and as a result no ships, in the passage of Vela Vrata, pass side by side with ships travelling in opposite courses; however instances of overtaking are possible. Other ships, boats and yachts up to 20 m in length, may use the inshore traffic zone. It is not uncommon, in the passage of Vela Vrata, for unexperienced navigators operating boats up to 20 m in length, to obstruct the navigation of larger ships sailing in the TSS.

According to the simulation drafted in a recent research on the most significant threat when sailing through Vela Vrata and Rijeka Bay, passenger ships are at risk the most, followed by other cargo ships. In the simulation model, the waterway consists of four parts: south access, Vela Vrata and the west and east waterway in Rijeka Bay. Each of the parts has a separate waterway of entering and leaving, according to the traffic separation scheme in Vela Vrata. Numerically, the results show the following:

Type of accident:	Annual frequency	Frequency (ann.)
Running aground while sailing	0,2047	4,885
Running aground - loss of power	0,3034	3,296
TOTAL running aground	**0,5081**	**1,968**
Collision during overtaking	0,0008047	1.243
Collision from opposite directions	0,0005396	1.853
Collision when intersecting	0,001778	562,4
Collision when entering the waterway	0,0002218	4.509
TOTAL collisions	**0,003344**	**299**

Table 4 Likelihood of running aground and collision as well as a time interval between the events[12]

In the observed area, accidents of running aground should be expected every 4,8 years. Running aground in case of loss of power should be expected every 3,2 years. If viewed together, the probability of running aground regardless of the state of power in the moment of running aground, totals at 0,5081, i.e. once every 1,9 years. Numerically, the areas with the highest danger of running aground are the coastal areas of Istria and the island of Cres in the passage of Vela Vrata and the Rijeka basin (coastal edge marked with a bright red and purple on the image showing graphical results).

It is important to notice that the probability of running aground does not depend on the intensity of traffic through the year. The probability of running aground depends on statistical parameters related to technological characteristics of the ship and the waterway (proximity to the land and shallows), whilst the impact on the surrounding traffic is not significant.

12 The simulation supports the conservative presumption that the intensity of traffic during the summer period equals the intensity of traffic throughout the whole year, which gives a more unfavourable result than what can be expected.

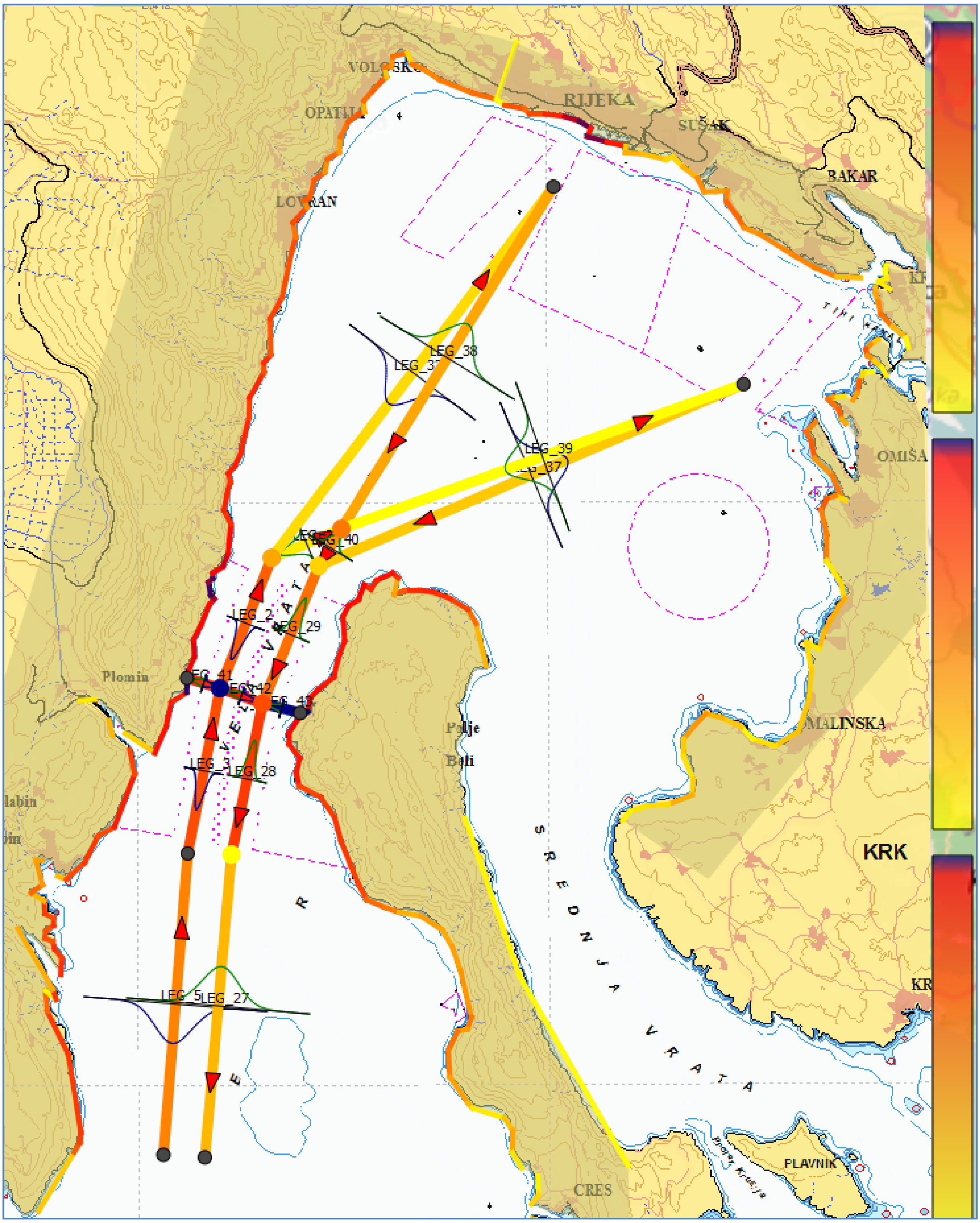

Image 9 Graphical results of the simulation model showing the access to the Port of Rijeka with an estimated danger of running aground and collision in each area of the waterway (taken from the Sea Traffic and Navigation Study..., 2015)[13]

[13] For each charted waterway, there is possibility of input statistics for traffic data for both directions. For direction that data were input, distribution of traffic is graphically shown, while for the direction that dana were not input (eg no

Contrary to the previously mentioned, the intensity of traffic directly affects the likelihood of a collision. In that respect, the model has been set in a way that the number of ships on an annual level has been raised so that it matches the number of ships sailing the area during the summer period. The annual increase is around 50%. The estimation of the number of ships does not include ships shorter than 20 m due to the fact that those vessels, under Article 20 of the Regulation on safety..., should not obstruct traffic of other ships that can sail safely only within the narrow channel or the waterway. In other words, the shown probability matches that which would exist if the intensity of traffic during the summer period represented the intensity of traffic throughout the whole year.

According to estimates, the expected probability of collision when intersecting is 0,001778, i.e. once every 562 years, whilst the likelihood of collision of ships coming from opposite directions, collision during overtaking or entering the waterway is smaller still. In total, the likelihood of all types of collisions is 0,003344, i.e. once every 299 years. One should keep in mind that vessels shorter than 20 m have been taken out of the estimation. In respect to the configuration of the access waterway, the areas with the highest threat of collision when intersecting is when travelling from and to the Rijeka basin with regular ro-ro passenger liners in the zone of separated navigation (the point of turning/intersecting is marked with a bright red and purple on the image showing graphical results). The highest possibility of collision during overtaking is when travelling the waterway at the passage of Vela Vrata on both sides, i.e. almost the same likelihood for ships travelling from and to Rijeka Bay, whilst the highest possibility of collision of ships coming from opposite directions is in the area of Kvarner, i.e. south of the passage of Vela Vrata (waterways marked in orange and bright red on the image showing graphical results).

In the navigation area of Rijeka Bay, pilotage is carried out at the access ways to passenger and cargo ports and terminals

In the area of Rijeka Bay, pilot stations are located at access ways to certain port terminals:

- for Rijeka and Susak basins and for Brajdica terminal at 45°18,0' N, 014°23,5' E,
- for Port Opatija at 45°19,0' N, 014°20,0' E
- for Omišalj oil terminal and Bakar basin (bigger ships) at 45°15,0' N, 014°27,0' E,
- for Sršćica LPG terminal at 45°11,8' N, 014°29,4' E.

The pilot who operates the route through Tihi Channel boards at the pilot station for smaller ships in the access area of the Bakar basin. The pilots berthing LPG ships boards at the pilot station for Sršćica LPG terminal.

Ships also use pilot stations when entering:

- Viktor Lenac shipyard at 45°17,0' N, 014°27,0' E,
- Omišalj oil terminal and Bakar basin (smaller ships) at 45°15,0' N, 014°31,0' E,

Port pilotage is also required if a ship is moves from one part of the shore to the other or if it moves along the shore using its own power engine.

There are no special pilotage requirements in the navigating area except those prescribed by general legal provisions.

The existing organisation of the pilotage service, with the existing traffic intensity, in general meets the requirements of safe navigation.

traffic), the red arrow is presented as the initial program setting. The red arrows do not indicate the assumed traffic direction.

Anchorages. In the observed navigation area, there is a number of marked anchorages in front of the Port of Rijeka and its terminals, as well as in front of Opatija Port. Ship anchoring in other areas is common in front of local ports.

Anchorages in front of the Port of Rijeka include the following areas:

- east and west anchorage for merchant ships in the area of Port Rijeka, as marked on the given image and official maritime maps,
- anchorage for tankers is limited by the following geographical points:
  - A. 45º17.75' N, 014º 28.30' E,
  - B. 45º15.15' N, 014º 27.10' E,
  - C. 45º14.10' N, 014º 29.40' E,
  - D. 45º16.10' N, 014º 31.80' E,
- anchorage for ships transporting liquefied gas in a circular shape of an approximately 3 M diameter with the centre at 45° 11,1' N, 014° 28,3' E; the position of the anchorage is located at approximately 1,5 M from the shores of the island of Krk close to Njivice,
- anchorage in front of Opatija Port is limited by the following geographical points:[14]
  - A. (45º20´43´´N, 14º19´44´´E)
  - B. (45º20´20´´N, 14º20´22´´E)
  - C. (45º19´45´´N, 14º19´42´´E)
  - D. (45º19´59´´N, 14º19´11´´E)
  - E. (45º20´17´´N, 14º19´14´´E).

East and west anchorages of Rijeka Port are used for cargo and passenger ships that enter the terminals in the area of Rijeka Bay in Rijeka, Sušak and Bakar basins, Brajdica container terminal and shipyards Viktor Lenac, 3. Maj and Kraljevica. Anchorage for tankers is used by ships entering the JANAF terminal and Bakar tanker port, whilst the anchorage for ships transporting liquefied gas is intended for use only to anchor ships transporting liquefied gas.

In general, cruisers anchor at the anchorage in front of Opatija Port. At the port anchorage, two ships with a length not exceeding 200 m can be anchored and harboured at the same time, as well as several smaller ships and yachts, provided that their swing circles don't intersect.

[14] Regulations on the maintenance of port order and terms of using ports in the area of the port authority of Opatija-Lovran-Mošćenička Draga.

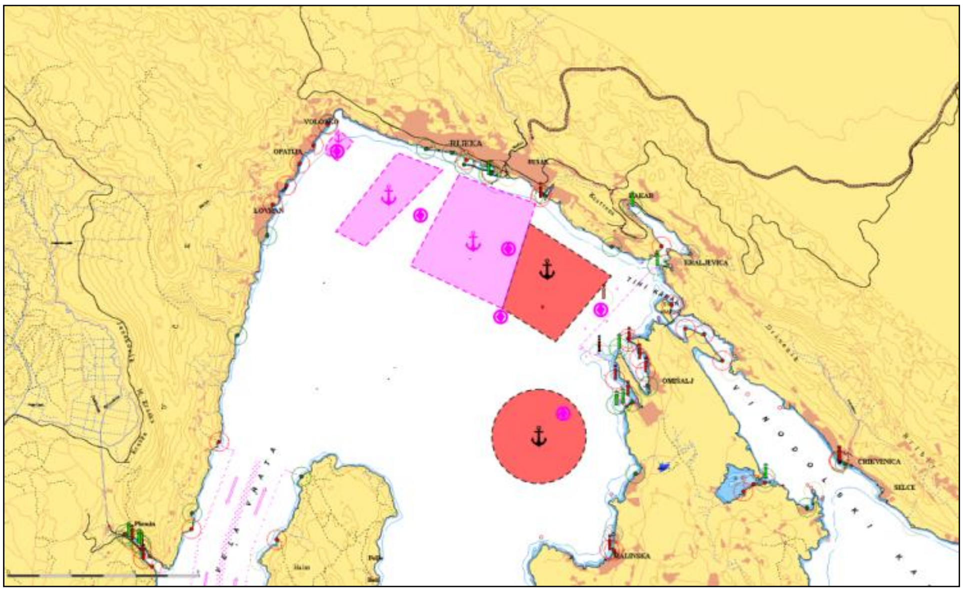

Image 10 Anchorages and pilot stations in Rijeka Bay

Existing anchorages meet the requirements for a safe ship anchoring and their sizes agree with the existing number and type of ships that enter the area of Rijeka Bay and request anchoring.

Towing. All ports under the supervision of Rijeka's harbourmaster's office offer towing services. However, the number of tugboats is not prescribed, except in Omišalj oil terminal.

During towing in Omišalj oil terminal the following should be used:

- 2 tugboats for ships up to 180 m upon arrival, and 1 tugboat at departure,
- 3 tugboats for ships between 180 - 240 m upon arrival, and 2 tugboats at departure,
- 4 tugboats for ships between 240 - 280 m upon arrival, and 2 tugboats at departure,
- 5-6 tugboats for ships over 280 m upon arrival, and 3 tugboats at departure.

In addition, for a safe arrival at a berth, it is advised for the sum of the total power of the tugboats used for berthing to be approximately one third of the power of the ship, i.e. each of the tugboats to have a bollard pull of at least 30 tonnes.[15]

In other ports, the number of tugboats is determined by the pilot in agreement with the ship master depending on the technical and technological characteristics of the ship and on the weather conditions.

A special provision applies for tankers in Omišalj oil terminal where one tugboat is requested to be standby. In this regard, it is requested that the tanker is equipped with emergency towlines of adequate thickness and length, tightly tied to the bollards on the bow and stern of the ship, lowered 1 m above the water's surface so that the towline could, in case of emergency, be fastened to the tugboat and tow the ship from the dangerous location.[16]

Prior notice is needed in order to use tugboats in other ports in the wider navigation area, as the requested number of tugboats arrives from the Port of Rijeka. In the Port of Rijeka, at the moment there is a total of 8 tugboats of relevant dimensions and technical and technological characteristics. Two new tugs are planned to be engaged in the Rijeka bay from October 2017.

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15 Port order regulations and terms of using a part of the Omišalj basin port facilities, in the area under the jurisdiction of the port of Rijeka authority.

16 A similar rule is valid for a tanker's stay in a quarter mooring in the industrial port of Bakar where the tugboat must stay connected to the tanker for the whole duration of its stay at the port.

Tug name	Loa (m)	B (m)	T (m)	Propulsion power (kW)	Bollard pull (kN)
ARIES	29,85	8,05	3,60	1.595	340
BAKAR	29,80	9,50	5,00	2 * 1.370	420
BELI KAMIK	31,65	9,30	6,25	2 * 912	340
CHAMPION	32,00	11,60	4,56	2 * 1920	680
DAVID PRVI	32,50	10,60	4,16	2 * 1.830	570
LUKAS	26,09	7,94	3,20	2 * 1.305	500
MAK	22,57	7,84	3,74	2 * 1.014	390
OMIŠALJ	29,41	9,50	5,00	2 * 1.370	420
PLUTON	27,50	8,25	4,00	1.029	205
POLLUX	29,85	8,00	3,55	2.200	340
RIJEVEC	31,65	9,30	6,25	2 * 912	340
VENUS	29,85	8,00	3,55	2.200	340

Table 5 Basic dimensions and characteristics of the tugboats in the Port of Rijeka in the ownership of JPS company (2018)

Characteristics of the mentioned tugboats meet the requirements of most of the ships entering the ports of Rijeka Bay. However, their technical and technological characteristics and available pull force are questionable, especially for a safe towing of the largest ships (VLCC tankers with deadweight of a total of 330,000 tonnes for which at least 5 tugboats must be used as well as for the ships in Viktor Lenac shipyard roughly up to 270 m in length).

It should be stressed that the tugboats from the Port of Rijeka are also used for berthing ships sailing internationally in the ports of Raša and Plomin. The use of tugboats in the Port of Raša (which is under the authority of the port of Rijeka) and the industrial port of Plomin (coal terminal) has a significant impact for the safety of navigation in the ports of Rijeka Bay because these terminals are far away and it takes quite some time for the tugboats to be back on standby in the terminals of Port Rijeka.

Conclusion:

(1) The waterway stretching from the open part of the Adriatic to the LNG FSRU terminal allows for a safe navigation of LNG carriers of a specified size and does not require implementation of any special measures of safe navigation due to the anticipated increase in traffic.

(2) Orientation points and waterway markings of the waterway stretching from the open part of the Adriatic to the LNG FSRU terminal allow for a safe navigation of LNG carriers. There is no need to introduce new markings of the waterway.

(3) The existing navigational and communication support ensures a safe access to the LNG FSRU terminal for the LNG carriers. The measures for navigation management (VTS) are adequate for the existing traffic.

(4) The total existing traffic of ships in the Rijeka Bay, i.e. towards the ports in Rijeka Bay, is of small or average intensity and does not call for additional safety measures for navigation.

(5) The area of the access waterway that does ask for special attention is the area of Vela Vrata.

(6) The probability of running aground of any type and size of vessel at the access waterway comes down to approximately 0,50 instances a year. The highest probability is in the area of Vela Vrata. Running aground due to a loss of power is more probable than running aground due to an error in making navigational decisions. Accoridng to statistical data, the grounding of tanker was not recorded at the approaching waterway.

(7) The probability of collision at the access waterway is at the point of being insignificant. Passenger ships are at risk the most.

3 METEOROLOGICAL AND OCEANOGRAPHIC FEATURES OF THE NAVIGATIONAL AREA

3.1 WIND

The prevailing wind in Kvarner is the bura. It blows from a wide range of directions: along the island of Cres from a direction close to north and along the Istrian coast from a direction close to east. It generally occurs in autumn and winter, from November to March. Warning signs of bura are crown like whitish clouds over Velebit. It usually blows for 3-4 days, but can also last a whole week. In this area, bura is also the strongest wind. It is strongest in winter and early spring and generally in the colder months of the year. Maximum gusts also occur when bura blows. It blows intermittently and can reach a high hourly value of up to 30 m/s. The maximum speed of the gusts can significantly exceed the mean hourly values and reach up to 60 m/s. Calming down and end of bura occurs after the clouds from the top of Velebit dissipate. The probability of the occurrence of bura in the winter period is around 40% whilst in summer around 20%.[17]

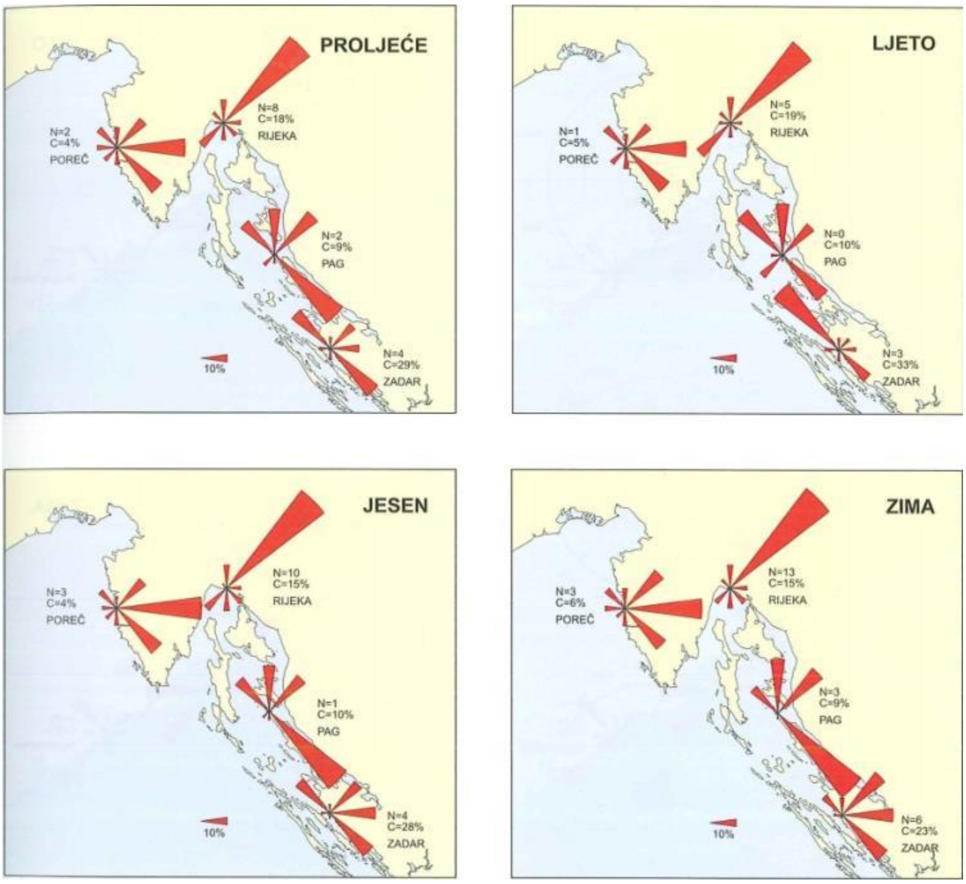

Image 11 Seasonal wind roses, the number of days with the intensity of the wind higher than 8 Beaufort (N) and the frequency of silence (C), for certain places in the northern Adriatic[18]

17 A significant information comes from the Omišalj weather station on Krk where strong bura blew the longest for 59 hours (29/11- 01/12/1980).

18 According to Peljar I, HHI, 2012

Number of days with strong wind (6 or more Bf)													
Year	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**Σ**
1996.	15.	11	22	13	14	18	18	2	-	7	18	11	149
1997.	15.	14	20	17	12	9	10	17	8	18	20	19	179
1998.	17	15.	21	16	13	11	14	17	10	19	25	12	190
1999.	11	17	19	15.	14	18	18	16	15.	20	22	25	210
2000.	14	14	14	15.	12	12	15.	13	19	18	20	11	177
2001.	3	22	22	19	23	17	13	22	20	13	22	28	224
2002.	18	14	19	21	12	11	22	17	21	17	16	23	211
2003.	25	25	14	19	14	14	21	18	17	24	17	21	229
2004.	25	17	19	15.	15.	8	17	-	22	11	17	18	184
2005.	19	22	16	15.	16	18	14	20	17	13	17	22	209
2006.	22	20	24	10	18	17	22	19	13	22	17	18	222
2007.	13	15.	24	16	19	18	11	13	16	24	18	23	210
2008.	15.	15.	21	19	17	16	20	16	22	18	19	25	223
2009.	20	21	21	16	14	21	14	15.	20	24	17	25	228
in total	232	242	276	226	213	208	229	205	220	248	265	281	2845
avg.	16,6	17,3	19,7	16,1	15,2	14,9	16,4	14,6	16,9	17,7	18.9	20,1	203,2
std.	5,8	4	3,2	2,8	3,1	4	4	4,9	4,5	5,2	2,6	5,5	23,9
max	25	25	24	21	23	21	22	22	22	24	25	28	229
min	3	11	14	10	12	8	10	2	8	7	16	11	149
ampl	22	14	10	11	11	13	12	20	14	17	9	17	80

Number of days with gale winds (8 or more Bf)													
Year	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**Σ**
1996.	6	11	14	7	4	13	5	0	-	0	0	6	66
1997.	10	7	16	12	7	I	0	0	1	10	13	15.	92
1998.	11	11	14	10	8	1	7	10	8	10	18	7	115
1999.	7	12	11	5	7	8	12	9	7	10	15.	18	121
2000.	10	6	8	4	3	0	0	0	10	11	13	7	72
2001.	3	15.	10	9	11	8	4	11	12	6	18	20	127
2002.	10	7	10	16	5	8	12	4	17	9	9	13	120
2003.	20	20	12	12	7	6	9	7	12	16	12	16	149
2004.	12	10	14	8	8	5	10	-	12	4	11	11	105
2005.	12	18	10	9	8	7	IO	8	11	10	11	13	127
2006.	17	14	15.	6	6	13	9	7	6	11	8	12	124
2007.	6	6	19	8	8	5	4	4	9	19	14	17	119
2008.	5	14	15.	8	8	9	10	7	13	9	12	15.	125
2009.	13	13	14	8	9	9	10	11	12	17	6	21	143
in total	142	164	182	122	99	93	I02	78	130	142	160	191	1605
avg.	10,1	11,7	13	8,7	7,1	6,6	7,3	6	10	10,1	11,4	13,6	114,6
std.	4,7	4,3	3	3,1	2,1	4	4	4,1	3,9	5	4,7	4,7	23,8
max	20	20	19	16	11	13	12	11	17	19	18	21	149
min	3	6	8	4	3	0	0	0	1	0	0	6	66
ampl	17	14	11	12	8	13	12	11	16	19	18	15.	83

Table 6 Average number of days with strong and gale wind per month and per year, with standard deviation, for Krk Bridge in the period of 1996 – 2009.[19]

19 Study on wind climate…, DHMZ, Split, 2010.

The direction and speed (intensity) of wind heavily depend on the terrain. Therefore, for example in the area of Kvarner, in the same or similar conditions, there is a different wind mostly due to the effect of channels between the mainland and the island as well as between islands, whether it be bura or jugo, so the wind in the middle of the channel is usually somewhat more powerful. In spite of this, from a number of data obtained in a wider area, a regularity should be noticed that shows that the intensity of bura decreases travelling from Rijeka towards Pula whilst jugo somewhat decreases travelling from Kvarner towards Rijeka Bay.

In the observed area, immediately after bura in significance (considering the top speeds and frequencies), is jugo which mostly blows in the direction from ESE to S and in most part in the winter months from October to March. In the observed area, during jugo, the biggest waves occur due to the fact that Kvarner is open to the winds from the southeast. They usually blow for 2-3 days but can last an entire week. A warning sign of jugo is a dark cloud cap over Mt. Učka and fog over Osoršćica and Velebit.

According to data from the study drafted by the Meteorological and Hydrological Service, for the observed area, based on the measurements at the station on Krk Bridge, the number of days registered with strong winds (6 or more Bf) totals at approximately 203,2 days a year (period of 1996 – 2009.). On average the highest number of days was registered in the months of December and March.[20]

In the observed period, the number of days with gale wind totalled at approximately 114,6 days a year, and the registered days a year ranged from 66 to 149 which shows high levels of the standard deviation. The highest number of days with gale winds was also registered in the months of December and March. Strong and gale winds are the most uncommon in the summer months.

The lebić is also a noteworthy wind in this geographical area, it usually blows from the SW and can also be of a high intensity. In summer, winds from the northwest prevail.

During the summer months there can be a sudden appearance of local storms (nevera). These result from local atmospheric disturbance and are difficult to predict. They are mostly short-lived sudden gusts of south-westerly winds sometimes of a storm intensity, with speeds over 40 knots and are accompanied by heavy rain.

Apart from bura, jugo and lebić, during the summer months during stable weather conditions, from noon to night, the maestral from the NW is also common, however it is of a lesser intensity and will in general not trouble vessels. Also, during summer evenings and at night, immediately by the coast, there is possibility of the burin, a mild wind blowing from the land that occurs during temperature differences between land and sea.

Highest average hourly wind speeds													
Month	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**year**
Speed (m/s)	29,7	29,2	29,3	31,7	21,8	22,3	19.4	24	25,8	31,6	32,1	33,1	**33,1**
Direction	NNE	ENE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	ENE	ENE
Strongest wind gusts													
Month	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**	**year**
Speed (m/s)	57	50,8	57,3	54,6	39,6	40,9	37,3	43,6	42,3	57,1	57,9	58,9	**58,9**
Direction	NNE	ENE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	ENE	ENE

[20] Study on wind climate for Bakarac, Port Kraljevica, including Carevo Cove, as well as part of Bakar Bay along Bakar, DHMZ, Split, 2010.

Table 7 Highest recorded average hourly wind speed per month and per year and the strongest gusts of wind recorded on the Krk Bridge in the period of 1996 to 2009. year[21]

Highest average hourly speed was 33,1 m/s and was registered from the ENE, whilst the strongest gust of wind was 58,9 m/s and was registered from the NE. Both levels were recorded in December 1996.

The area of the planned Krk LNG FSRU terminal is prone to strong and very strong northerly winds. The strongest winds come from the land and will not cause waves, however they could significantly affect the safety of the ship during its stay at the berth, especially during manoeuvres of berthing and unberthing.

The strongest gusts of wind are short, shorter than the time of response of the vessel, as such they do not cause significant impact for the larger ships. Instead of wind gusts, the average wind intensity should be taken into consideration in the time of the response. For large ships, the time of response is usually 30 seconds.

The following table shows expected levels of wind characteristics (maximum average hourly speed and strongest gust) for the return periods of 2 to 100 years measured by a method of maximum values from a sample of annual maximum average hourly speeds of wind and annual maximum gusts of wind, for each direction and respective possibility of the accuracy of the estimation. Higher levels of wind characteristics are expected for northerly winds, i.e. bura (gusts of up to 58,7 m/s for the return period of 50 years), whilst somewhat lower values are expected for southerly winds.

If we take into consideration the average values for all directions with the return period of 50 years and the 98% occurrence rate, maximum average hourly speeds of wind up to 33 m/s and maximum gusts of wind up to 58,8 m/s can be expected in the wider area by the terminal.

Bura									
T (year)	**P (%)**	**W avg. (ms-1)**	**W gust (ms-1)**	**P (%)**	**W avg. (ms-1)**	**W gust (ms-1)**	**P (%)**	**W avg. (ms-1)**	**W gust (ms-1)**
	N			**NE**			**ENE**		
2	50	6,6	47,9	50	20	51,3	50	9,5	51,2
5	80	11,5	52,0	80	24	55,6	80	16,8	55,2
10	90	16,6	53	90	25,4	57,1	90	22,8	56,2
20	95	23,4	53,3	95	26,1	58	95	29,6	56,7
25	96	26,1	53,4	96	26,3	58,3	96	32	56,8
50	98	36,5	53,6	98	26,6	58,7	98	40,2	56,9
100	99	50,8	53,6	99	26,8	59	99	49,8	57
Jugo									
T (year)	**P (%)**	**W avg. (ms-1)**	**W gust (ms-1)**	**P (%)**	**W avg. (ms-1)**	**W gust (ms-1)**	**P (%)**	**W avg. (ms-1)**	**W gust (ms-1)**
	S			**SSE**			**ESE**		
2	50	13,8	26,8	50	15.	27,2	50	11.8	36,8
5	80	16,3	29,8	80	17,7	30,8	80	13,8	42,7
10	90	17,1	31,1	90	18.9	33,5	90	14,9	46,3
20	95	17.6	32,1	95	19.8	36,4	95	15,9	49,4
25	96	17.6	32,4	96	20	37,4	96	16,2	50,3
50	98	17.8	33,1	98	20,6	40,8	98	17,1	53,1
100	99	18	33,6	99	21,1	44,5	99	17,9	55,6

Table 8 Expected wind characteristics in different return periods (Source: Study on wind climate..., DHMZ, Split, 2010)

[21] Study on wind climate…, DHMZ, Split, 2010.

It should be stressed that milder gusts of wind due to a partial cover from the NNE winds are expected in the area of the planned LNG FSRU terminal.

According to the FEED data, the strongest gusts of wind are expected from the NE direction at 40,4 m/s.[22]

Direction	Direction [° w.r.t. North]	T100 10' wind speed Rijeka	T100 10'- wind speed LNG-terminal	T100 hourly wind speed LNG-terminal	T100 30"- wind speed LNG-terminal
N	0	15.5	23.3	20.9	35.1
NNE	22.5	21.4	32.1	29.0	48.5
NE	45	22.2	33.3	30.1	50.3
ENE	67.5	21	31.5	28.4	47.6
E	90	12.1	18.2	17.0	27.4
ESE	112.5	11.2	16.8	15.7	25.4
SE	135	14.5	21.8	20.5	32.8
SSE	157.5	17.8	26.7	25.2	40.3
S	180	17.7	26.6	24.2	40.1
SSW	202.5	12.4	18.6	16.9	28.1
SW	225	11.6	17.4	15.8	26.3
WSW	247.5	12.6	18.9	17.2	28.5
W	270	10.1	15.2	14.1	22.9
WNW	292.5	13.4	20.1	18.8	30.4
NW	315	12.8	19.2	17.9	29.0
NNW	337.5	13.6	20.4	19.1	30.8
omnidirectional		**25.4**	**38.1**	**34.5**	**57.5**

Table 9 Characteristics of wind in a 100-year return period - 50% reliability[23]

Direction	Direction [° w.r.t. North]	T100 CI 10' wind speed Rijeka	T100 CI 10' wind speed LNG-terminal	T100 CI hourly wind speed LNG-terminal	T100 CI 30" wind speed LNG-terminal
N	0	17.9	26.9	24.2	40.5
NNE	22.5	25.9	38.9	35.1	58.7
NE	45	26.9	40.4	36.5	60.9
ENE	67.5	25.4	38.1	34.5	57.5
E	90	13.7	20.6	19.3	31.0
ESE	112.5	13.2	19.8	18.6	29.9
SE	135	17.4	26.1	24.6	39.4
SSE	157.5	21.8	32.7	30.9	49.4
S	180	21.3	32.0	29.1	48.2
SSW	202.5	14.7	22.1	20.0	33.3
SW	225	14.2	21.3	19.4	32.2
WSW	247.5	15	22.5	20.5	34.0
W	270	11.9	17.9	16.7	27.0
WNW	292.5	16.1	24.2	22.6	36.5
NW	315	15.7	23.6	22.1	35.6
NNW	337.5	16.2	24.3	22.8	36.7
omnidirectional		**30.9**	**46.4**	**42.0**	**70.0**

22 Tractebel Engineering S.A..

23 *FEED, Tractebel Enginereeing S.A.*

Table 10 Characteristics of winds in a 100-year return period - 95% reliability2[24]

3.2 WAVES

In a wider area of Kvarner, waves from southern directions 7 – 9,1 m in height may occur.[25]

The length of those waves in Kvarner ranges from 20 to 30 m, depending on the direction and intensity of the wind. The longest waves come from the SW direction. After the wind stops, the waves in Kvarner and Rijeka Bay slowly calm down due to the spacious fetch length and the steep and high coastline, and for a long time the waves of the swell are felt.

The biggest waves in the Adriatic can be expected in the area of Kvarner, due to the long term stormy jugo or oštro winds. Partially limited fetch length affects the waves in Kvarner, especially waves coming from the east. Bura and levant can develop waves up to 2,9 m. Waves of lebić are not expected at heights above 3,2 m.

The highest waves in Rijeka Bay are the waves coming from the SE. The fetch length toward S and SW (Mala and Vela Vrata) is open. The waves coming from the south in Rijeka Bay change direction from SE to SW and can be expected at heights up to 3,5 m. For example, the wave measuring buoy moored in front of Port Rijeka has registered waves higher than expected (3,7 m) in a short period of time.

Due to the position of the Krk LNG FSRU terminal on the western side of the island of Krk, i.e. due to a short fetch length, the winds caused by bura and jugo are not significant. Only smaller waves of a swell occur, made by diffraction of wind waves, which enter the area of the berth. Those types of waves are not expected to have a negative impact on LNG carriers during their stay at the LNG FSRU terminal.

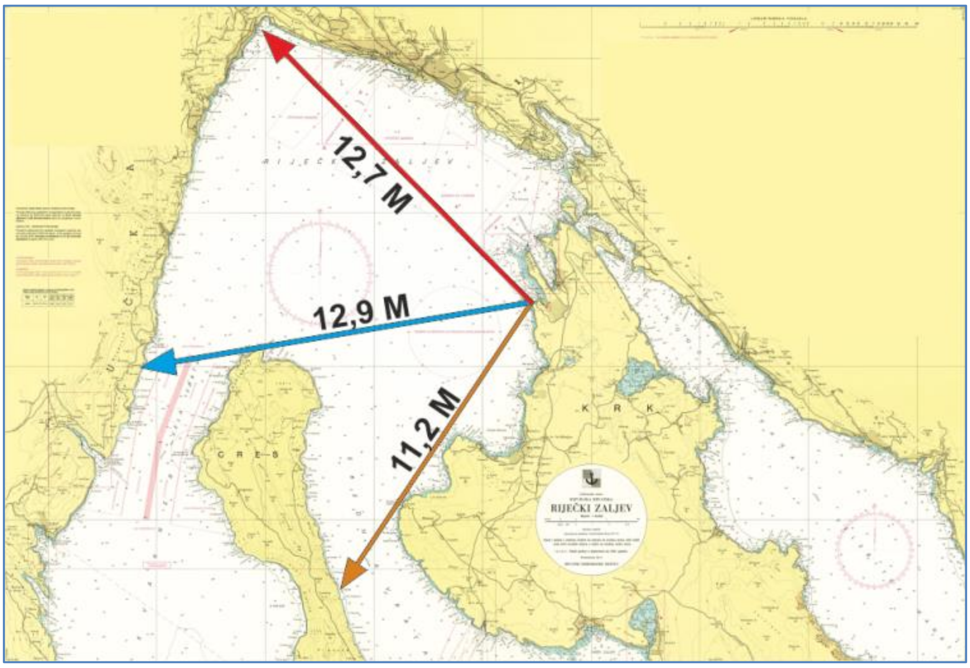

Image 12 Fetch lengths for main directions

The waves of tramontana, ponente and maestral can be as high as 1 m. These types of winds are mild in the northern Adriatic so the waves that they cause can't reach a more significant height. The biggest

24 *FEED, Tractebel Enginereeing S.A.*

25 Nearby, south of Kvarner, Panon wave measuring station measured a wave 10,8 m in height.

waves in the area of the berth can be expected from the lebić, during long-lasting winds or summer nevera. It is not probable for these waves to reach a height above 2,2 m due to short fetch lengths. These types of winds can hinder the arrival and departure manoeuvres or even make them impossible, especially because of their impact on tugboats. For a berthed ship, these types of waves shouldn't pose any serious difficulties.

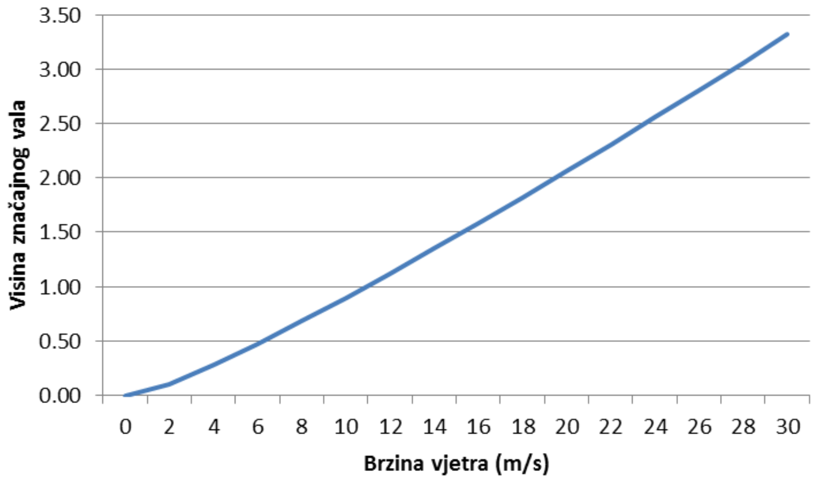

Image 13 Theoretic height of developed waves for a fetch length of 12,8 m

It should be stressed that the results of the wave model show a possible wave height of 4,47 m with a 95% reliability for a 100-year return period, i.e. significant wave height of 2,85 m during winds blowing from the NNE direction, i.e. 4,17 m and 2,37 m for the WNW direction. The authors of this study deem the wave model results questionable. Experience gained during the use of the DINA berth, does not determined waves of such heights nor the need for significantly smaller ships to leave the berth as a consequence.[26][27]

Waves in general should not have an effect on the possibility of stay of an FSRU ship and/or LNG carriers at the terminal.

[26] *FEED, Tractebel Enginereeing S.A.*

[27] The height relates to the average maximum height of 1/250 waves.

WIND INPUTS			WAVE RESULTS				
Wind Direction	Wind direction [° North]	Wind speed [m/s]	H_{m0} [m]	$H_{1/250}$ [m]	T_p [s]	T_{m02} [s]	Dir [°N]
N	0	20.9	1.75	2.73	5.3	4.0	322
NNE	22.5	29.0	2.16	3.38	5.8	4.2	335
NE	45	30.1	1.51	2.37	4.5	3.5	357
ENE	67.5	31.5	1.07	1.68	3.2	1.9	35
E	90	18.2	0.38	0.60	2.0	1.3	53
ESE	112.5	16.8	0.27	0.43	1.4	1.0	91
SE	135	21.8	0.40	0.63	4.0	1.4	186
SSE	157.5	25.2	1.01	1.57	5.4	4.4	227
S	180	24.2	1.57	2.45	5.9	4.6	238
SSW	202.5	16.9	1.19	1.86	4.9	4.0	241
SW	225	15.8	1.26	1.98	4.7	4.0	251
WSW	247.5	17.2	1.65	2.58	5.0	4.2	265
W	270	14.1	1.38	2.15	4.5	3.8	277
WNW	292.5	18.8	2.08	3.26	5.4	4.4	294
NW	315	17.9	1.90	2.97	5.3	4.2	305
NNW	337.5	19.1	1.87	2.93	5.3	4.2	312

Table 11 Characteristics of waves for winds in a 100-year return period - 50% reliability[28]

WIND INPUTS			WAVE RESULTS				
Wind Direction	Wind direction [° w.r.t. North]	Wind speed [m/s]	H_{m0} [m]	$H_{1/250}$ [m]	T_p [s]	T_{m02} [s]	Dir [°N]
N	0	24.2	2.14	3.34	5.8	4.3	321
NNE	22.5	35.1	2.85	4.47	6.6	4.6	334
NE	45	36.5	1.98	3.10	5.1	3.8	357
ENE	67.5	38.1	1.41	2.20	3.6	2.2	35
E	90	20.6	0.46	0.72	2.2	1.3	54
ESE	112.5	19.8	0.31	0.49	1.6	1.1	90
SE	135	26.1	0.53	0.84	4.6	1.5	186
SSE	157.5	30.9	1.40	2.19	6.1	4.8	231
S	180	29.1	2.06	3.22	6.6	5.1	241
SSW	202.5	20.0	1.49	2.33	5.4	4.3	242
SW	225	19.4	1.66	2.60	5.3	4.3	252
WSW	247.5	20.5	2.07	3.23	5.6	4.5	266
W	270	16.7	1.73	2.70	5.0	4.1	277
WNW	292.5	22.6	2.67	4.17	6.1	4.7	294
NW	315	22.1	2.52	3.94	6.0	4.7	305
NNW	337.5	22.8	2.37	3.70	5.9	4.6	312

Table 12 Characteristics of waves for winds in a 100-year return period - 95% reliability[29]

28 *FEED, Tractebel Enginereeing S.A.*

29 *FEED, Tractebel Enginereeing S.A.*

3.3 CURRENTS

Currents, alongside wind and waves, significantly affect the movement of a ship without power and the movement of oil after an oil spill.

Currents in Kvarner and Rijeka Bay follow the flows of general circulation and do not exceed 0,5 knots. In most part, they flow in a counter-clockwise direction.

The main Adriatic current in the area of Rijeka Bay mostly enters between the islands of Sv. Marko and the land and a bit less between the islands of Krk and Sv. Marko and between the islands of Cres and Krk. The current exits through Vela Vrata, faster from the side of the Istrian peninsula. Rječina may have an effect on the characteristics of sea currents immediately along its mouth, so it somewhat changes the general circulation in Rijeka Bay. Also, during long periods of rainfall, a stronger current may be expected in the same area.

DEPTH (m)	2	25	50
Maximum speed (cm/s)	73	14	13
Average speed (cm/s)	31	6,1	2,5
Minimum speed (cm/s)	5	2	1
Resultant vector (cm/s/°)	30,8/291	3,2/78	2,0/360
STABILITY FACTOR	99	53	78

Table 13 Characteristics of sea currents in Rijeka Bay[30]

It should be noted that the speed of the current at berth during nice weather will not exceed 0,5 knots and even during the strongest winds it should not exceed 1,5 knots. In depths over 2 m currents will already not exceed 0,5 knots.

3.4 TIDES

Tides in Kvarner are very similar to those in the open sea of the Adriatic. Only during intensive and long-lasting jugo, the water levels rise somewhat more than in the open sea. Also, during intensive and long-lasting bura, the water levels fall somewhat more than in the open sea of the Adriatic. Tides will in no way affect the maritime traffic in Kvarner or Rijeka Bay.

In Rijeka Bay, these conditions can cause an average rise of 1,4 m, and a fall up to 0,3 m in relation to the hydrographic zero.

At the location of the planned LNG FSRU terminal, the most important are changes to the sea levels caused by the gravitational forces of the Moon and the Sun, as well as the atmospheric pressure and wind. All of them can change the water levels in the winter months in relation to the hydrographic zero (average level of lower low waters of spring tides) ranging from approximately 1,7 m above to 0,6 m below the level of the map.

30 The measurings of the HHI in a time period of December 1-13, 1993 during the laying of the Cape Tenka Punta - Cape Škrkovac underwater oil pipeline.

	Speed of jugo (in knots)						
Duration of jugo (in days)	**10**	**15.**	**20**	**25**	**30**	**35**	**40**
1	42	52	62	72	82	92	102
2	44	54	64	74	84	94	104
3	46	56	66	76	86	96	106
4	48	58	68	78	88	98	108
5	50	60	70	80	90	100	110

Table 14 Estimation of the change in water levels (in cm) relative to the speed and duration of jugo

Duration of bura (in days)	Speed of bura (in knots)						
	10	**15.**	**20**	**25**	**30**	**35**	**40**
1	6,6	9,6	12.6	15,6	18.6	21,6	24,6
2	7,2	10,2	13,2	16,2	19.2	22,2	25,2
3	7,8	10,8	13,8	16,8	19.8	22,8	25,8
4	8,4	11,4	14,4	17.4	20,4	23,4	26,4
5	9,0	12,0	15,0	18.0	21,0	24,0	27,0

Table 15 Estimation of the change in water levels (in cm) relative to the speed and duration of bura

In the tide tables, the height of the tidal wave is given for the pressure of 1013 hPa. The water level due to changes in pressure can be approximately measured in a way that lower each pressure hPa above the average water level by 1 cm, and increase each hPa below the average water level by 1 cm. This correction is valid only if such a pressure lasts several days.

Tides in the area of the planned terminal may be delayed in relation to the time estimated in the tide tables due to the blowing of bura. The delay is not expected to be more than 10 minutes.

According to estimates based on the measurements and model (FEED), the estimated heights are as follows:

Return period	High Water Level		Low Water Level	
Year	Relative to Mean Sea Level [m]	Relative to Chart Datum [m]	Relative to Mean Sea Level [m]	Relative to Chart Datum [m]
1	0.65	0.98	-0.41	-0.08
10	1.01	1.34	-0.71	-0.38
20	1.08	1.41	-0.75	-0.42
50	1.17	1.50	-0.78	-0.45
100	1.24	1.57	-0.81	-0.48

Table 16 Extreme water levels based on measurements[31]

Altogether, according to FEED, the highest water level in a 100-year return period is expected to be 2,07 m (southern directions) and the lowest -0,44 m (south-eastern directions). These estimates are deemed consistent with experiences to date.

31 *FEED Tractebel, S.A.*

3.5 VISIBILITY

Horizontal visibility is affected by the time of day, rainfall and fog. Good visibility can be significantly reduced by heavy rain, hail or snow.

Fog in the Kvarner region can reduce visibility on an average of 8 days per year. It can be localized, such as around Port Plomin. In Rijeka Bay, it can be expected on average 6 days a year.

Biggest amounts of rainfall a day (mm)													
Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	MAX
1981	29,5	17,7	46,6	6,4	41,7	23,7	38,6	58,3	50,3	109,2	14,3	35,3	109,2
1982	26,2	7,3	45,1	7,2	51,2	49,1	2,4	27,2	19,3	40,3	51,0	41,2	51,2
1983	44,6	26,6	43,4	17,9	21,3	17.2	19.8	8,8	27,9	35,6	13.7	31,8	44,6
1984	43,4	28,7	25,6	35,3	26,5	31,6	37,7	54,4	55,1	145,0	24,7	19.6	145,0
1985	25,7	47,9	91,6	20,4	21,6	18.6	5,4	40,2	36,2	26,4	37,6	11,0	91,6
1986	25,1	28,3	35,6	16.5	32,9	44,6	26,1	46,8	28,2	24,9	27,8	41,2	46,8
1987	21,1	31,3	17.4	24,4	29,0	25,9	25,1	16.0	55,6	55,6	43,0	31,6	55,6
1988	15.8	28,4	44,6	26,0	28,8	67,7	10,5	28,3	50,0	17.2	9,4	48,7	67,7
1989	0,3	16,3	10,0	31,3	7,2	37,2	17.8	63,6	13,2	23,5	40,9	59,1	63,6
1990	9,0	21,9	28,6	21,0	17.6	29,4	29,9	59,9	76,9	113,1	29,5	31,9	113,1
1991	46,2	32,1	6,5	13,6	19.6	34,4	7,2	13,3	****	****	***	****	46,2
1992	****	****	50,0	16.0	18.0	21,9	42,9	41,3	25,7	79,7	52,4	35,0	79,7
1993	2,5	7.5	20,7	26,1	0,8	35,0	5,1	42,5	87,1	111,6	35,5	46,0	111,6
1994	12,7	29,2	7,8	31,5	15,7	56,8	8,6	53,2	33,8	63,4	46,9	40,3	63,4
1995	31,7	24,3	32,8	9,6	59,0	32,5	34,9	20,3	38,9	23,5	67,2	48,8	67,2
1996	57,0	32,9	2,1	23,6	33,5	35,3	22,5	26,5	45,9	64,6	46,1	33,6	64,6
1997	50,4	12,1	45,4	18,7	19.8	36,6	92,7	33,6	90,2	7,1	58,6	26,6	92,7
1998	31,3	8,2	5,4	24,7	13,1	17.2	60,0	20,5	88,7	71,2	38,4	36,5	88,7
1999	21,6	36,3	29,9	39,7	78,7	10,1	37,2	13,0	22,1	67,0	37,6	91,7	91,7
2000	12,3	32,6	52,0	16.0	9,0	27,0	31,8	3,5	74,0	71,8	40,4	50,3	74,0
2001	25,2	22,5	41,1	44,4	4,3	25,3	22,4	1,0	39,1	10,7	31,1	27,6	44,4

Monthly and annual amounts of rainfall (mm)													
Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Σ
1981	89	46	121	21	133	92	71	76	255	224	27	248	1402
1982	49	8	132	15.	153	132	5	61	72	268	169	156	1219
1983	65	130	114	59	87	43	36	31	87	57	31	109	849
1984	185	172	48	77	98	77	76	147	254	281	121	48	1584
1985	66	86	222	63	63	92	12	85	41	44	148	40	960
1986	109	101	99	95	72	158	50	120	71	54	78	75	1081
1987	88	96	25	64	109	73	46	35	158	227	191	51	1164
1988	68	117	133	70	68	124	18	68	69	64	16	78	893
1989	1	41	36	114	31	179	33	138	31	44	125	74	846
1990	24	43	36	115	49	101	52	75	179	256	104	140	1174
1991	95	91	20	31	81	68	15.	23	****	****	****	****	****
1992	****	****	141	64	37	145	129	64	99	408	240	69	****
1993	4	12	32	58	2	89	13	105	287	364	186	114	1263
1994	53	51	18	131	50	118	16	87	135	116	111	132	1017
1995	105	140	143	35	201	140	44	58	170	36	127	130	1330
1996	117	109	5	53	100	103	59	90	155	239	249	159	1438
1997	216	35	65	51	62	85	148	84	99	38	206	152	1240
1998	52	9	15.	139	40	47	86	46	424	273	111	50	1292
1999	76	50	66	151	127	31	82	14	67	133	106	204	1108
2000	14	76	132	47	26	33	83	6	143	255	349	186	1350
2001	143	26	202	101	14	79	40	1	198	26	95	47	972

Table 17 Rainfall in the observed area (*missing data)

In general, rainfall in the area of the LNG FSRU terminal, i.e. its berth, is of a small intensity and will hinder the arrival and departure manoeuvres only in rare cases. These cases will occur only during short-lived squalls (neverin).

The occurrence of fog can be somewhat predicted based on the relative air humidity. In the area of the planned terminal, fog occurs 5 days a year on average, mostly in autumn and winter.

Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Avg.
1981	47	53	69	59	70	65	56	59	73	76	65	69	63
1982	54	50	52	50	59	62	52	53	62	66	64	61	57
1983	64	56	56	65	63	50	46	53	55	56	51	57	56
1984	63	56	50	49	70	59	54	55	74	70	69	58	61
1985	55	53	66	55	58	56	49	51	60	64	74	83	60
1986	65	60	67	70	68	65	57	62	62	63	72	63	65
1987	64	70	49	57	70	67	58	63	69	74	74	76	66
1988	78	67	61	72	71	71	54	53	69	71	60	63	66
1989	64	70	60	73	61	67	65	65	68	73	58	64	66
1990	62	69	48	64	57	66	46	49	65	69	66	59	60
1991	53	48	57	54	62	60	47	51	****	****	****	****	54
1992	****	****	60	****	57	67	64	61	67	79	77	63	66
1993	72	51	61	64	59	58	54	50	72	****	****	75	62
1994	67	64	68	63	64	62	50	60	72	64	74	68	65
1995	62	69	60	63	66	68	56	61	74	66	67	71	65
1996	64	56	54	59	71	57	55	62	68	71	73	69	63
1997	72	65	50	57	63	68	64	62	59	63	70	64	63
1998	66	47	47	66	51	56	49	42	59	64	47	63	55
1999	66	55	64	65	62	54	53	52	59	63	64	62	60
2000	57	59	63	63	56	51	56	50	63	75	74	76	62
2001	72	61	78	61	60	58	57	52	73	77	62	56	64

Table 18 Average relative air humidity (%) (*missing data)

Just looking at the relative humidity, it can be concluded that fog, in the area of the LNG FSRU terminal as well is the entire Rijeka Bay, will be rare and of a short duration, consequently, the delay of the arrival and departure manoeuvres due to fog will be brief.

Conclusion:

(8) Weather conditions do not significantly hinder the navigation of larger ships in the access waterway.

(9) The heights of waves and gusts of wind during the strongest storms may delay the mooring of LNG carriers, i.e. delay the handling of cargo. The highest waves should be expected during winds coming from the northwest and west directions and they should not affect a safe stay of the ships at the terminal, however they can hinder the ship manoeuvring.

(10) The LNG FSRU terminal is protected from winds coming from the north, northeast, south and southeast.

(11) The likelihood of more significant wave heights of over 1,5 m in the area of the terminal is very small, especially as a result of westerly winds.

(12) A delay upon mooring of LNG carrier or a halt in cargo handling can be expected during strong winds from the NE quadrant. Those types of unfavourable weather conditions are significantly more likely during the winter period.

(13) Local storms may have an effect on deciding to halt cargo handling throughout the year.

4 TECHNICAL AND TECHNOLOGICAL CHARACTERISTICS OF SHIPS USED FOR TRANSPORT OF LNG

4.1 BASIC CHARACTERISTICS OF LNG CARRIERS

Ships used for transport of liquefied gas are ships that carry cargo in pressurized tanks in which the pressure is greater than the atmospheric pressure in order to prevent the cargo getting mixed with air. Because of that, the tanks only carry cargo (in its liquid and gas state) which prevents the formation of an explosive atmosphere. In general, ships used for transport of liquefied gas are divided into:

- ships used for transport of liquefied natural gas – LNG carriers,
- ships used for transport of liquefied natural gas and chemical gases – (Liquefied Petroleum Gas) LPG carriers.

At the LNG FSRU terminal on Krk the handled cargo will be liquefied natural gas so the rest of this study will only discuss ships used for transport of liquefied natural gas – LNG carriers.

LNG carriers are used to transport liquefied gas to the market, where the liquefied gas gets regasified and delivered by pipeline to the costumers. The density of the LNG is approximately 0,41 to 0,5 kg/dm³, depending on the temperature, pressure and content. In general, due to the way in which LNG carriers are constructed, liquefied gas with a density greater than 0,5 kg/dm³ (500 kg/m³) should not be loaded.

During loading and unloading of cargo carried on ships used to transport liquefied gas, no gas gets released into the atmosphere. At LNG terminals, there should be a vapour return pipes.

Ships used for transport of liquefied gas must meet the regulations prescribed by the International Maritime Organisation (IMO), as well as all safety measures and measures against environmental pollution that are common for other ships as well. Ships discussed in this study must meet very strict construction demands. This primarily concerns the ability of the ship to sustain a certain degree of damage during collision, impact or running aground, whilst not sustaining any damage of the cargo tanks. Ships built after January 1, 1996, in terms of construction and equipment, must abide by the International code for Construction and Equipment of Ships Carrying Liquefied Gases that form a mandatory part of the Chapter VII of the SOLAS convention. Older ships are built in accordance with the Code for Construction and Equipment of Ships Carrying Liquefied Gases, i.e. regulations for existing ships. Also, ships usually must meet the standards prescribed by the Oil Companies Marine International Forum – OCIMF and are also subject to continuous examinations specified by the Ship Inspection Report Programme, i.e. the internal rules of the Forum.[32][33][34]

In general, LNG carriers must meet the safety standards and measures protecting maritime environment that exclusively apply to maritime transport of LNG and which are as a rule at a higher level than in other industry sectors, including maritime transport of crude oil, derivatives and chemicals. LNG carriers must have a double hull, custom-built tanks, pumps, vents and pipelines able to handle the requested conditions of storing LNG. Transport of liquefied gas requires high expertise, special equipment and technology in order to reduce the risk to the lowest possible level, or danger of any kind.

Mandatory equipment of this type of ships includes the control of temperature and pressure, gas detection and equipment for measuring the levels of liquid in tanks, as well as a highly complex alarm system, accompanied by a number of auxiliary devices. The variety of equipment of these ships can

32 *International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk – IGC Code.*
33 *Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk – GC Code.*
34 *Code for Existing Ships Carrying Liquefied Gases in Bulk – Existing Ships Code.*

make them into highly complex vessels that require a very high degree of expertise and attention. LNG carriers primarily differ in respect to power and construction of tanks used to transport cargo.

Taking into account that every LNG project represents significant financial expense for all of those involved in transport, LNG carriers are generally built for specific lines, although, in the last 10 years or so, ships used in the free market are also being built. A ships' service life is estimated at 25 years, however, in reality, it may exceed 40 years.

LNG carriers transport liquefied natural gas that, in its liquefied state, occupies about 600 times less space than in its gaseous state at atmospheric pressure. The highest pressure during transport totals at around 25 kPa, i.e. 250 mbar, whereas the temperature is around -160°C. The reduction in volume makes it much more efficient for long-distance transport where there are no pipelines. Liquefaction of natural gas is performed at export LNG terminals and it also includes the removal of unwanted impurities such as dust, acid gases, helium, water and heavy hydrocarbons.

In general, LNG carriers can be divided according to:

- size,
- system of built-in tank on ship,
- type of propulsion.

Size of LNG carriers. Given the size of the LNG carriers, they can generally be divided into five groups, depending on the carrying capacity in cubic metres, as follows:

- small LNG carriers,
- conventional LNG carriers (small and large),
- Q-Flex ships, and
- Q-Max ships.

Carrier class of LNG carriers	Capacity (x1.000 m3)	L(m)	B(m)	T(m)
Q-Max	< 260	345	53-55	12,0
Q-Flex	200 – 220	315	50.0	12,0
Large conventional LNG carrier	150 - 180	285 - 295	43 - 46	12,0
Small conventional LNG carriers	120 - 150	270 - 298	41 - 49	< 12,0
Small LNG carriers	< 90	< 250	< 40	< 12,0

Table 19 Classification of LNG carriers according to their size

Approximately by 2008, the usual capacity of LNG carriers ranged from 120.000 m³ to 150.000 m³. Until 2008, over 80% of the world fleet was made up of small conventional LNG carriers, around 15% of small LNG carriers and less than 5% of large conventional LNG carriers. From 2008 to 2010, the world fleet was enlarged by the arrival of ships whose capacity extended over 200.000 m³, they were Q-Flex and Q-Max ships whose capacity ranged from 210.000 to 217.000 m3, i.e. from 261.700 to 266.000 m3. They represent ships of the new generation and are also the largest ships sailing the world seas. These ships have been in service for several years and by 2016, a total of 31 Q-Flex and 14 Q-Max ships have been built.

Also, in the last several years, the number of conventional ships with a capacity exceeding 150.000 m³ has risen significantly, although their capacity is still much lower than that of Q-Flex or Q-Max ships. For example, in 2014, the average capacity of delivered ships totalled at 161.000 m³ (an increase of 12.200 m³ in relation to 2012). Just in 2014, as much as 80% of ships from the total number of contracted new builds (a total of 68 ships) had a carrying capacity ranging between 170.000 and 174.000 m³, whilst not one ship had a capacity exceeding 200.000 m³.

Small LNG carriers can be divided into two classes: smaller LNG carriers that are similar to conventional ships in regards to their technical and technological characteristics and have a capacity smaller than 90.000 m^3, but larger than 45.000 m^3; and LNG carriers with a capacity smaller than 45.000 m^3.

Smaller LNG carriers are very rare nowadays (less than 10 ships in the world fleet) and according to data from 2014, the smallest ship belonging to this class had a capacity of approximately 64.000 m^3. It should be stressed that almost all new builds are larger than 150.000 m^3 (by the end of 2014 only one new build had a capacity smaller than 150.000 m^3).[35]

On the other hand, the group with the smallest LNG carriers is gaining importance and is on the rise. The smallest LNG carriers include ships of relatively small capacities: from those smallest of 1.000 m^3 to those largest of 30.000 m^3 (LNG Feeder Ships). Those ships are intended for transport of smaller amounts of LNG at short distances, i.e. within one region.

Approximate dimensions of LNG carriers with a capacity of 30.000 m^3 are as follows:

- length – 185 m
- breadth – 28 m
- draft – 7,0 m
- deadweight – 16.500 tonnes

Also, technological development and strict ecological requests had an impact on merchant ships that will be LNG-fuelled, and as such, an impact on the need to build LNG bunker vessels that usually sail within certain port areas. Approximate dimensions of LNG bunker vessels with a capacity of 5.000 m^3 are as follows:

- length – 110 m
- breadth – 18 m
- draft – 5,9 m
- deadweight – 2.700 tonnes

In general, the world fleet of the smallest LNG carriers is relatively small with a global number of 44 ships in 2017. However, since 2015, there has been a sudden rise in order of such ships and so, at the moment, the world fleet includes approximately 80 of them, including the ships currently being built. The ships include:

- LNG carriers,
- CNG carriers (Compressed Natural Gas), i.e. ships transporting high-pressure cargo in gaseous state,
- multifunctional LNG/LPG/Ethylene carriers with double propulsion, as well as
- LNG bunker vessels.

In the next short term, a rapid development and construction of the smallest LNG carriers intended for supply of other LNG-fuelled merchant ships is expected. LNG bunker vessels are usually of smaller capacities (up to 5.000 m^3) and can also be built as barges. Also, a rise in the number of larger ships of capacities up to 30.000 m^3 is expected as well, seeing as how they allow their owners flexibility in supplying smaller terminals.

[35] The specified data relates to LNG carriers larger than 30.000 m^3 and does not include smaller LNG carriers and LNG bunker vessels.

Image 14 LNG barge (left) and smaller LNG supply carriers (right)

Image 15 The „ENGIE ZEEBRUGGE"- first purpose-specific LNG bunker vessel (in service since April 2017)

Seeing as how the loading of LNG is planned on the LNG FSRU terminal on Krk, loading of smaller LNG carriers, i.e. LNG feeder vessels, is also to be expected.

The system used for storing gas in ships during transport (Containment system) consists of a primary barrier (the cargo tank), secondary barrier (if fitted), associated thermal insulation, any intervening spaces, and adjacent structure, if necessary, for the support of these elements. In general, according to the IGC Code, the LNG tank systems can be divided into:

- membrane-type systems (semi-membrane and membrane tanks-integrated tanks),
- self-supporting systems (independent tanks of type A, B and C),

Self-supporting tanks do not form a part of the ship's hull (independent tanks) and do not affect its firmness. According to their shape they can be prismical (type A or B), cylindrical (type C) or spherical (type B). Membrane-type tanks are not self-supporting and consist of a thin layer (membrane) supported through insulation by the adjacent hull structure; they can be membrane and semi-membrane as well as internal isolation tanks. Other types of systems were not used in LNG carriers. The primary visual characteristic of membrane-type tanks are great heights which more often than not exceed 20 m. On the other hand, self-supporting tanks are usually of a spherical shape whose protective cover significantly protrudes beyond the deck of the ship.

The basic designs of tanks used today on LNG vessels are:

- Technigaz Mark III membrane system,
- Gaz Transport No 96 membrane system,
- GTT Mark III Flex membrane system with pressures up to 700 mbar (developed exclusively for operations on FSRU ships),
- GTT No 96 Max,
- GTT CS1 membrane system,
- GTT Mark V membrane system,
- Kvaerner Moss system with self-supporting spherical type B tanks,
- MHI Moss Sayaendo class,
- IHI SPB system with self-supporting prismatic type B tanks,
- Esso system with self-supporting prismatic type A tanks.

Membrane system. The system consists of primary and secondary barrier and insulation.

The primary barrier makes a very thin (0.7 - 1.2 mm) invar or stainless steel membrane that is in direct contact with the load. The secondary barrier must be installed along the entire rim of the membrane tank to prevent further leakage and lowering of the ship's temperature in the event of a primary barrier damage. The insulation is located behind the membranes; it protects the coating from low temperatures and transmits static and dynamic loading on the shell plating.[36]

The membrane system Tehnigaz Mark III has a primary barrier made of corrugated stainless steel (18% nickel and 10% chrome) 1.2 mm thick. Corrugation allows the mitigation of thermal stresses of materials at cryogenic conditions. The first insulating area consists of a layer of polyurethane foam covered with wooden plates that serve as a carrier of the first membrane. The second barrier is made of a triple layer, an aluminium foil between two layers of fiberglass. The second insulating area consists of another layer of polyurethane foam, leaning against the wooden plates attached to the double formwork by screws. Nitrogen is injected into the insulating space as an inert gas. The older version of this system, Mark I, had balsa wood as an insulating material and wooden maple plates instead of a triple layer. The advantage of the newer Mark III system compared to Mark I is that insulation materials have lower thermal conductivity and better sealability by using aluminium foil.

It is important to mention one of the new versions of the Technigaz system of tanks, Mark III flex, which represents the system or technology that, with the reduction of daily rate of vaporisation (Boil-off Rate (BOR), allows pressures within the system up to 700 millibars compared to the classic Mark III system (up to 250 mbar). The system was developed for the simultaneous transhipment of liquid cargo on the FSRU ship and regasification from the FSRU on the mainland, that is, flexibility during the operations, by which it was named after.

Gaz Transport No 96 membrane system consists of a primary and secondary barrier and the insulation area. Primary and secondary barrier membranes are of the same material, 0.7 mm thick invar. The first insulating area is the insulation layer between the first and second membranes, and the second insulating area is from the second membrane to the double formwork. Insulation areas consist of wooden boxes reinforced with longitudinal and transverse barriers filled with perlite, granular insulating material of silicon oxide and aluminium that does not pass water and moisture. Also, nitrogen (N2) is injected into the insulating space as an inert gas.

[36] Invar is a stainless steel alloy with 36% nickel and 0.2% carbon. It has a very low heat expansion coefficient.

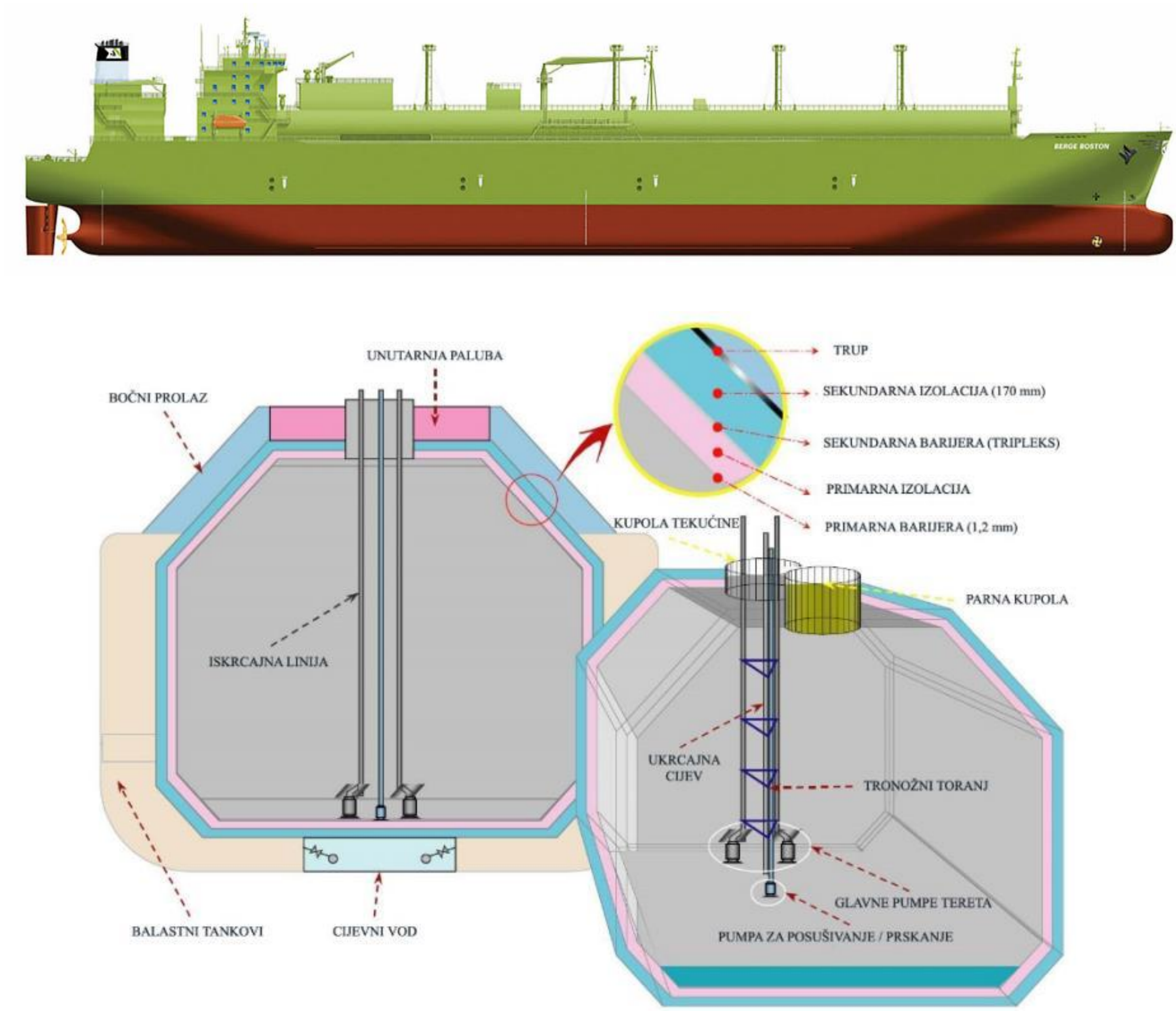

Figure 16 LNG vessel with membrane tanks Technigaz Mark III type

By joining these two membrane tank construction companies, GazTransport & Technigaz company (GTT) was founded and they have developed a membrane system called GTT CS1 (Combined System 1). CS1 is a combination of Mark III and No 96 systems. The insulation and the second barrier is the same as in Mark III system (polyurethane foam and triplex), and primary membrane is made of invar as in No 96 system. By doing so, the benefits of each design have been utilized and, as the company claims, this saved 15% on the price. This system design is still not often used in practice.

The latest GTT system called Mark V is based on the Technigaz Mark III system, but with the difference that the secondary triple barrier (0.7 mm thick) is replaced by an invar membrane that is identical to the primary membrane in Gaztransport System No 96. The system offers qualitative improvements that are primarily reflected in better insulation (400 mm thicker polyurethane foam) and reduced daily evaporation (from 0.15% to 0.085% per day).

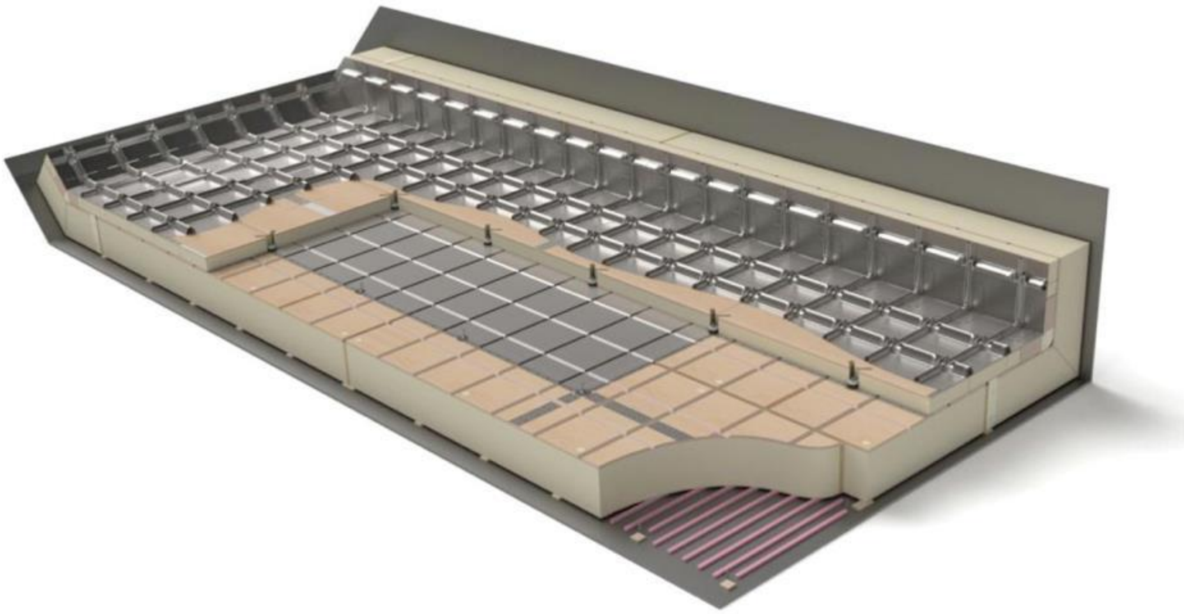

Figure 17 Cross section of the tank in GTT Mark V membrane system

In addition to Mark V system, a new GTT No 96 Max system has been developed, which offers improvements in the form of original perlite insulation being replaced by glass wool insulation, and in general, it has improved insulating properties and a lower mass than the No 96 system.

System with self-supporting spherical type B tanks. This system consists of a self-supporting spherical tank fixed on the equatorial sphere by means of an equatorial ring and cylindrical vertical shell, which is welded to the hull with its lower part. Tanks can be made of aluminium or 9% nickel steel. They are leaned along equatorial ring on a cylindrical shell that transfers the load to a double formwork. Thermal dilatation of tank due to low temperatures is taken over by deformation of the upper part of the shell. In order to reduce heat losses through cylindrical shell of the tank, the newer versions have a stainless steel heat bridge.

Insulation consists of several different layers of insulators, reinforcements, dilatation joints and protective layers, it is self-supported and fastened to the tank with screws. Insulating materials are most commonly panels of various expansion foams (polyurethane foam, polystyrene foam, phenolic resin foam, etc.), which are reinforced with a built-in fiberglass or wire mesh, while aluminium foil or combined coatings of polyurethane and butyl rubber make a protective insulation formwork. An integral part of insulation are also dilatation joints which must enable the shrinkage of panels in horizontal and vertical directions. Since the insulation is not directly related to the tank's surface, it allows detection of possible gas leaks in the interspace as well as its unhindered flow to the lower part of the system.

Due to the tank design, this type of system does not require a second barrier on the upper part of the tank. The secondary barrier is limited to the lower part of the tank beneath which there is a heat-insulated vessel in which possible leaks occur. The most famous version of this type of system is the Kvaerner Moss system.

The IHI SPB (Self-supporting prismatic IMO type B) system consists of self-supporting prismatic type B tanks made of aluminium. They have longitudinal and transverse barriers inside the tank, which allows loading at any height. On the outside, they are freely leaned to the double formwork and hull over the carrier, thus enabling unhindered thermal expansion. Insulation consists of polyurethane foam panels that are directly connected to the outer surface of the tank. On the bottom side of the tank there is a drying vessel.

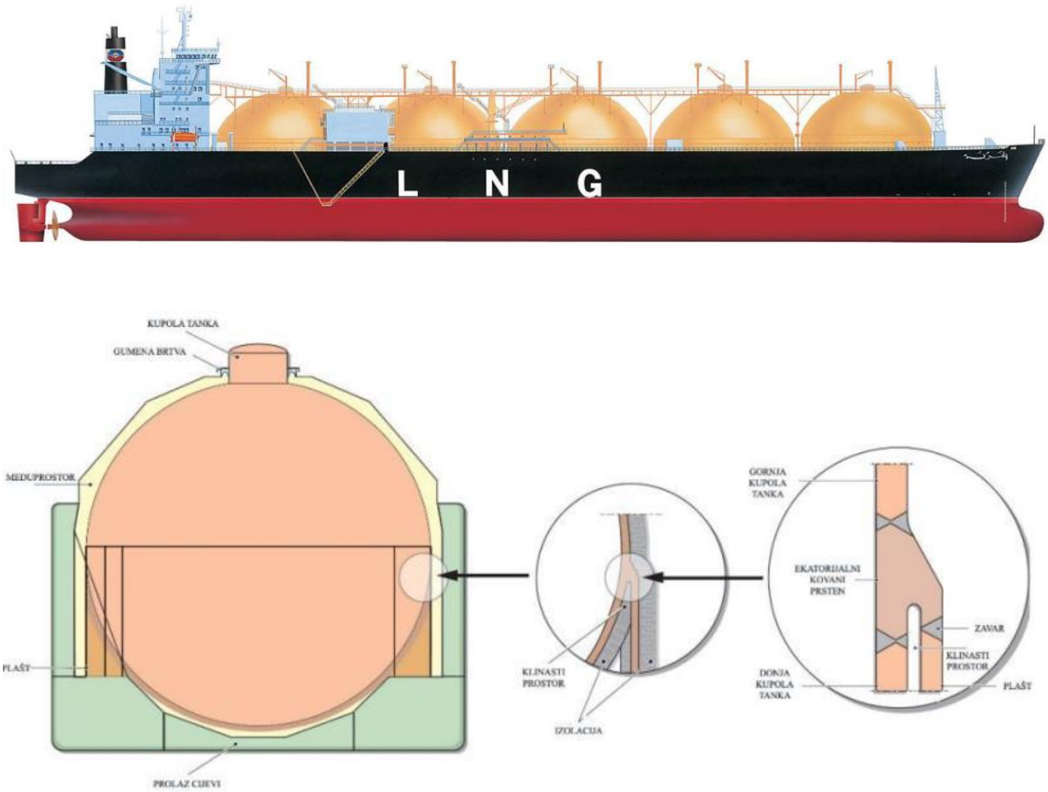

Figure 18 LNG vessel with spherical self-supporting tanks of Kvaerner Moss type

Esso system with self-supporting prismatic type A tanks was used only on two ships built in Italy in 1969 and 1970 that were in navigation until 2012. The system consists of aluminium tanks that must have a complete secondary barrier, which makes the design more expensive. This led to the abandonment of this type of system.

LNG vessels typically have 5 tanks while the usual capacity of individual tank is greater than 25,000 m³. The largest Q-Max ships have the capacity of the largest tanks of approximately 59,000 m³.

Some tank designs have certain advantages, but also disadvantages compared to other designs. The choice of the type of system depends on the wishes and needs of the ship-owner or market needs.

The advantages of membrane tank systems are:

- smaller dimensions for equal capacity,
- smaller ship displacement,
- less power required and therefore lower fuel consumption,
- smaller freeboard, better visibility from the bridge (except on Q-Flex and Q-Max ships where the liquefaction plant significantly disturbs visibility on the right side of the ship),
- secondary barrier around the tank (advantage and disadvantage),
- higher capacity compared to the spherical tank,
- the tank shape allows the construction of large capacity ships,
- cheaper construction in relation to the Kvaerner Moss system.

Disadvantages of membrane systems are:

- only 98.5% of the volume can be charged,
- free surfaces (possible splashing of cargo against tank walls - Sloshing),

- thin primary barrier, greater cargo evaporation,
- greater risk of damage and breakage of tanks during collision or grounding.

The advantages of Kvaerner Moss system are:

- smaller amount of insulating material,
- greater safety when damaging the tank during collision or grounding,
- faster construction, i.e. reduced shipping time,
- improved quality control during construction,
- a simpler inspection of the insulation and space between the tank and the hull,
- the ability to fill the tanks to any level, up to 99.4% capacity,
- better loading and unloading capabilities,
- higher gas pressures (better possibility of collecting evaporated gas),
- the possibility of using partial secondary barriers.

Disadvantages of Kvaerner Moss system are:

- larger freeboard, lower visibility from the bridge compared to other ships,
- higher total weight of the tanks (together with cylindrical shell),
- poor manoeuvre ability,
- relatively high centre of gravity (small metacentric height),
- poor utilization of hull,
- large mass of the equatorial ring requires greater attention when changing the tank temperature.

The biggest shortage of independent prismatic systems IHI SPB lies in the fact that they are much more expensive compared to other variants.

Currently, around 75% of ships in the world are equipped with a membrane tank system, which is also prevalent in newbuildings. Vessels with self-supporting tanks are usually remodelled in the FSRU units, i.e. in the floating terminals for storing and gasification of natural gas. In addition, the largest ships (Q-Flex and Q-Max) are built with membrane tank system.

All of these tank construction systems meet stringent safety standards of LNG transport by sea, and so far there were no LNG vessel accidents with serious consequences. The LNG FSRU terminal Krk is expected to accept LNG vessels with all these tank systems.

Figure 19 LNG vessel with membrane tanks (left) and self-supporting tanks (right)2

Figure 20 Q-Max LNG vessel during manoeuvring

Propulsion. The type of propulsion used by LNG vessels largely depends on the cargo carried by the vessels. Given the fact that during the navigation with cargo, gas evaporation occurs that must in some way be stored or spent, from the very beginning of the occurrence, the LNG vessels used a steam turbine as a main propulsion machine. This system is reliable and enables easy and safe combustion of gas (0.1 - 0.3% per day) and liquid fuel in steam generators. On conventional LNG vessels with steam turbines, the surplus of evaporated cargo is solved by combustion of gas in vessel steam generators for the production of superheated steam, which is used for the propulsion of vessel and auxiliary devices. On vessels with diesel engines, the so-called GCU (Gas Combustion Unit) is installed to burn the evaporated part of the cargo.

As technological solutions for gas liquefaction and gas fuel combustion in diesel engines are constantly being improved, alternative solutions for the propulsion system of these vessels have been developed. Today, as propulsion systems on LNG vessels, beside steam systems, can also be installed:

- slow-speed diesel engine propulsion system with reliquefaction plant (DRL - Diesel Engine with ReLiquefaction Plant or SSD - Slow Speed Diesel),
- Diesel-electric plant with engines working on gaseous and liquid fuel and electromotor drive (DFDE- Dual Fuel Diesel Electric plant),
- Diesel-electric plant with engines working on heavy, diesel and gaseous fuel and electromotor drive (TFDE – Tri-fuel Diesel Electric plant),
- slow-speed diesel-engine high-pressure gas injection system (ME-GI - M-Type electronically Controlled Gas Injection).

Type of LNG vessel	Displacement (t)	Capacity (m3)	Height (m)	Freeboard (m)	Power of machines (kW)	Bow thruster (kW)	Approximate freeboard / underwater lateral surfaces (m2)
Q Max (SSD)	179.000	265.940	34.7	15.0	2 x 21.770	N/A	7.700-4.000
Q Flex (SSD)	149.000	217.000	34.7	15.0	2 x 18.881	N/A	7.000-3.600
Conventional GTT Mark 3	105.846	145.000	38.0	14.0	29.455	2.500	6.100-3.000
Conventional - Moss	104.998	147.598	47,0	15,0	26.900	N/A	9.000-3.200
Conventional vessels	105.000	138.000-180.000	34 – 50	14-15	-	N/A	6.000-9.000 3.000-4.000

Table 20 Basic characteristics of different LNG vessels

The share of steam turbine plants compared to other alternative plants are decreasing. Although over the past few years the largest number of LNG vessels have been delivered per year, a traditional steam-turbine plant slowly loses against new drive solutions. From 2008 ordering of vessels with DRL plant, followed by vessels with DFDE plant has increased. Although as the first alternative solution a vessel with DFDE plant was delivered, in the following years it was believed that system with main diesel engine and natural gas reliquefaction plant was better, since by then the electric propulsion of larger vessels was only used on passenger ships. As time passes, ordering of vessels with DFDE plant increases, and the biggest increase in the world's fleet of these vessels was in 2010 . In 2011 the number of new vessels with DRL and DFDE plants equalized, however, by the end of the year there were more DFDE plants. Gennerally, at the LNG FSRU terminal in Omišalj, berth of LNG ships without steam turbine plants are expected.

In case of DFDE engine, the propulsion power and the vessel's electric power supply is provided by a double diesel engine (two electrical motors are used for propulsion while four to five auxiliary motors are used for power generation). Such engine operation provides flexibility and reduction of working hours, and beside that the propulsion is reliable. The engine also achieves 30% more thermal efficiency compared to steam turbines. Apart from lower fuel consumption compared to steam turbines, cost-effectiveness is also reflected in lower vessel mass due to smaller fuel tanks. This has increased the vessel's capacity for 4,000 m^3 more than the previous. In addition, emissions of harmful carbon dioxide are smaller than in turbine vessels. Nitrate release is also 1/10 smaller than in equivalent diesel engines, which also reduces maintenance costs.

Currently, the largest number of vessels in the world uses a steam turbine plant, which is represented approximately by 58% in the global fleet, followed by TFDE and SSD propulsion. It should be emphasized that DRL propulsion is currently used only by Q-Max and Q-Flex vessels. The basic feature of these vessels is that they have a Reliquefaction plant, two diesel engines, two screws and two rudders. The building cost of these vessels is approximately USD 250 million (Q-Max). In general, these are vessels with membrane type tanks (GTT No. 96 or Mark III).

The latest trend points to an increased number of LNG vessels using ME-GI and TFDE plants. According to the order book, 40% of vessels are planned to be built with TFDE propulsion plant and 30% of vessels with ME-GI propulsion.

The usual steam turbine power plant is seldom planned for newbuildings, except for Japanese ship-owners. There are currently 7 LNG tankers of MHI Moss class (Sayaendo class) with capacity of 155,000 m3. The vessels were developed in 2011 and they represent an improved version of the Kvaerner Moss tanks of the Japanese name Sayaendo (pea-shaped). and Sayaringo STaGE (apple-like shape) as the next generation of LNG tankers.

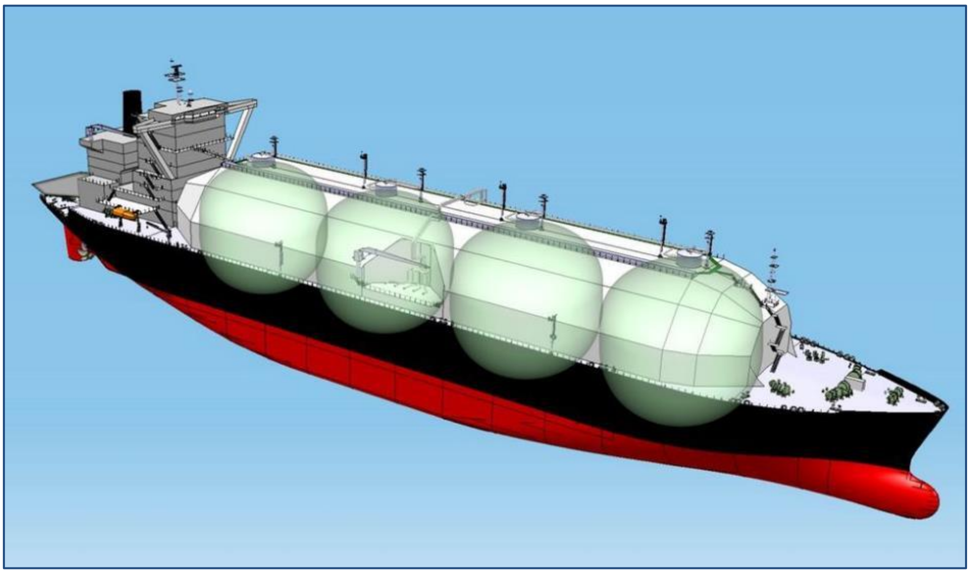

Figure 21 LNG vessel of MHI Moss Sayaendo Class

In addition, the latest version of MHI Moss Sayaringo tanker uses two propulsion screws. The vessels have capacity of 180,000 m3, and will be built in the beginning of 2018.

In terms of maritime features, LNG vessels are significantly different from all other types of vessels. Given that the conventional LNG vessels have steam turbine as propulsion engine, during manoeuvring it is necessary to take into account the following:[37]

- when navigating with a stern, up to 70% of the power is available compared to the power when navigating forward;
- the start or stop time of the main machine is somewhat longer;
- the time to reach larger axle power needed in emergency is also longer.

The main difference between LNG vessels and oil tankers of approximately same length is in displacement due to the considerable difference in the specific load density and due to the exceptional volume of primary or secondary tank protection of LNG vessels. Because of the above reasons, the displacement of loaded LNG vessel is approximately 2.5 - 3 times smaller than the displacement of tanker of approximately same length. Different features of load tanks result in different proportions of the freeboard and underwater side surfaces. While in case of tankers this ratio is considerably smaller than 1 (approx. 0.3), in LNG vessels this ratio is considerably above 1 (approx. 3). From a maritime point of view, and as a result of the above mentioned constructive features, special attention should be paid to:

- a large freeboard of the LNG vessel has a highly negative impact on manoeuvring at strong side winds;
- a smaller draft of the vessel creates a relatively small resistance to lateral movement of the ship at side wind, thus further affecting manoeuvring characteristics of the vessel;
- due to the high freeboard, high cargo space (regardless of the technology used for the construction of tanks) and due to the large length of the vessel, the visibility range from the command bridge is relatively limited;
- when using a steam turbine drive, the propulsion speed during manoeuvring is considerably slower compared to vessels with diesel engines;

37 It can be assumed that, at the time of the LNG terminal in Krk commissioning, approximately 50% of the world's LNG vessel fleet will be powered by a steam turbine.

– the size i.e. the width of the vessel, despite a relatively small displacement, does not permit manoeuvring of the vessel without the use of a sufficient number of tugs.

It is significant that, according to past experiences, LNG vessels exhibit relatively good manoeuvrability at low speeds.

For these reasons, the procedure of mooring and unmooring of an LNG vessel as well as shipboard procedures in the event of an accident or danger are significantly different from the procedures applicable to other types of vessels entering the terminals in Rijeka port basin.

4.2 LNG CARRIERS SAFETY REGULATIONS

LNG transportation safety factor is reliant on the quality of vessel hull, containment system, equipment and personnel competence.

For LNG transportation in the tank ships it is required:

– to prevent LNG contact with any material that becomes friable at the low temperature of LNG,
– to prevent formation of explosive or flammable mixture where gas may contact with air and would create an explosive atmospheric condition.

The first requirement imposes the design of containment system using the materials resistant to the very low temperatures and the provision of the secondary barrier (membrane). The secondary barrier is an inner barrier capable of containing the cargo without any risk to the vessel hull in case of partial or complete cargo leakage from any tank.

The second requirement imposes the use of leakless double-wall piping, inert gas and atmosphere control in the areas close to the cargo as well as determination of the risk zones where Intrinsically Safe Equipment should be installed.

To minimize level of negative implications in case of vessel accident LNG carriers are provided with the double hull spaces used for storage of ballast water tanks and to lessen the damages in case of collision, impact or running aground. Besides, beam grid structure reduces bending of the ship structure and any possible damages to the membranes in the membrane type cargo containment systems or torsion stress in the self-supporting tanks type cargo containment systems.

During normal operation heat transfer through insulation may decrease the temperature of a double-wall hull from 5º to 10º C in comparison to the ambient temperature. The absolute temperature for LNG carriers is specified at -18º C as the ambient temperature, therefore the double hull should resist the temperature of -28º C. This requires use of alloyed steel and imposes heating of the barrier walls for the operations in the cold seas. To avoid the risks of LNG contact with the double-hull a tank should have the so called secondary barrier that would storage the cargo in case of the primary barrier leakage.

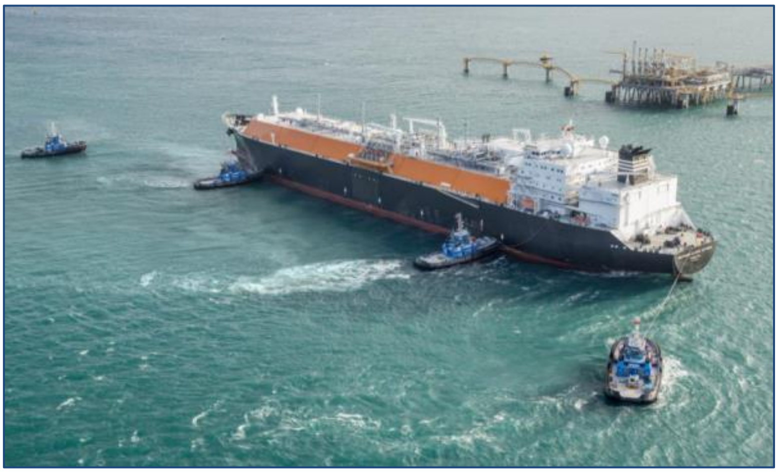

Image 22 Typical use of tag for LNG carriers mooring3

One of the safety risks detected during LNG transportation is cargo (LNG) synchronous motion that may cause impacts on the tank walls. Such cargo sloshing is dangerous since may cause damages to the tanks and pumps in the membrane type cargo containment systems. This problem is generally solved in a constructive way by minimizing of liquid free surface at the top and bottom of a tank, which has been achieved by increasing the height of “chamfer” at the topside and bottom side of a membrane-type tank, by increasing of the number of tanks and reinforced bottom area of one or two tanks containing the amount of liquid gas sufficient for the ballast voyage to prevent the cargo motion due to its low level in the other tanks.

To reduce the effect of cargo sloshing and consequent impact on the membrane-type tanks walls it is required to maintain the level of the tanks within the required limits. Therefore, tanks should be operated in a fully laden condition or with a minimum of cargo (LNG) during the ballast voyage to maintain low temperature in the tanks. As a rule, the so called sloshing limits are 10% to 80% of the tanks filling level, therefore LNG carrier should not operate in a condition when the tanks are loaded with cargo from 10% to 80% of their capacity. For the self-supporting type cargo containment systems arrangement the above problem is solved by installation of the barriers inside the tanks. For the spherical B type LNG tanks arrangement this problem does not exist due to their shape.

LNG carriers berthing and mooring in the discharge port is performed by using of at least 4 tugboats, where 1 tugboat is attached at the bow and stern and 2 tugboats are positioned on the port quarter of the ship. Tugboat at the stern should be moored first, since it slows the ship down, and the other tugboats are moored after it. They are usually moored with steel spring lines. Tugboats should be fitted with the fire-fighting system and equipped with the antistatic protection as well as with protected net and spark arrester on the exhaust gas piping and funnels.

To ensure safe manoeuvring and ship's stay at the berth the typical limit conditions are specified. The basic limit conditions for manoeuvring, emergency shutdown, release of a loading arm and leaving the berth are as follows: wind speed, wave height and limited visibility (usually no less than 0,5 M) . .

Wind speed (knots)	Significant wave height (m)	Procedure
> 25	1,20	the berthing is banned
>30 (or considerable motion of the ship at the berth)	1,50	emergency shut down and release of a loading arm
> 35	1,75	to consider abandoning the berth

Table 21 Typical limit values for manoeuvring and LNG carrier's stay at the berth

In addition, the other limit condition is the minimum under keel clearance that is usually no less that 20% of the static draught (manoeuvring), which is respectively less when a ship stays at the berth.

One of the most important manoeuvres during mooring is positioning of a ship. The required position is the one where loading arms and ship vapour return system are levelled with the terminal. In addition, earthing has to be arranged either through a ground cable or through the fixed type loading arms or cryogenic flexible cargo transfer hoses. In addition, LNG carrier and FSRU terminal should be cabled to enable Emergency Shut Down and telephone communication with the terminal.

4.3 LOADING SYSTEMS

Piping system for LNG carrier comprises of liquid manifolds for cargo loading and auxiliary piping installed on the main deck. Auxiliary piping consists of: cryogenic line, nitrogen supply lines, draining system and air supply lines. Cargo (un)loading is handled via liquid manifolds installed along the centre-line of the vessel, on the left and right sides. The liquid manifolds are equipped with safety stop valves which enable only low flow at the open position. Large-diameter lines (700 mm) are those connecting LNG collector with the gas unloading manifold on the vessel lateral side. Operating pressure in the liquid manifolds is 7 bar at maximum. The liquid manifolds are subject to hydraulic proof test under pressure of 20 bar. Upon installation they should be tested with cold liquid nitrogen under pressure of 10 bar. Maximum gas flow speed in the liquid manifolds is 30 m/s, providing that they are thermally insulated. Piping hangers are installed to enable transverse movement of the lines, and all lines are equipped with expansion joints.

Generation of boil-off gas increase the pressure in the tanks, therefore it is required to release the excess boil-off gas to atmosphere in order to decrease the pressure and to prevent damages to the tank walls. Release of gas in the air is generally used in emergency cases only. The amount of boil-off gas released to atmosphere should maintain the tank rated pressure, whilst it should be as small as possible due to gas loss and for safety reasons. Due to this pressure safety valves should:

– be closed and sealed prior to the open pressure,
– safely open regardless of the temperature from -162º C to +40º C
– open completely to enable maximum discharge and to stop increase of the tank pressure,
– close at the pressure that is slightly lower that the open pressure,
– safely operate in case of ice generation (where cold gas and air are in contact),
– open in case of vacuum inside the tanks to prevent possible pressure variation between the isolated areas and the tank.

Valves that meet the above requirements should have a membrane and be operated with the help of pilot valves controlling the pressure. Each tank on LNG carrier is fitted with two safety valves that maintain the membrane-type tank pressure of 0,225 bar and vacuum of 0,010 bar. Valves are made of stainless steel and a membrane - of synthetic rubber.

In case of tank pressure increase, pilot valve discharge gas from the header above the membrane. Valve's membrane lifts and discharge the gas from the tank. In case of vacuum in the tank, pilot valve discharges into it gas from the header above the membrane, this way enables the valve to open and take in the air.

LNG carriers have submerged centrifugal pumps which are used in cargo loading operations. Inside each tank there are two main cargo pumps. They are usually installed into the storage tank in a vertical position, fixed to the bottom and electrically driven. LNG inlet is located at the bottom side of a pump, and its power cable insulated with minerals goes through copper cables connected with the pump distribution board. Typical capacity of the cargo pump is 1.200 – 1.700 m³/h. In the event both main cargo pumps fail in one tank, an emergency cargo pump can be lowered down to the bottom of the emergency pump tower.

Compressors are the major part of the cargo containment system. There are gas compressors on the carrier (typically installed by the right board) that aim:

- to return LNG to shore (in the event there is no compressor on the terminal) and to warm up the cargo tanks (1 to 2 compressors),
- to feed boilers with gas for steam-turbine propulsion ships (two low duty compressors).

Q-Flex and Q-Max carriers also use two low compressors to feed the regasification unit, whereas DFDE, TFDE and ME-GI with diesel motors use two low duty compressors for compressing LNG vapour to be used in the motor engine as fuel.

Compressors on modern LNG carriers are centrifugal and driven by electric motors to ensure better fire and explosion protection. Electric motors are installed in a special room and the drive shafts starts the compressors installed in the compressor room. To prevent any contact of the ignition source with the flammable mixture compressor electric motor drive shaft is insulated with a gas (nitrogen) tight shaft seal.

In general, all cargo containment systems should be resistant to the low temperatures of LNG processing, transportation and (un)loading.

Conclusion:

(14) On LNG FSRU terminal can be expected LNG carriers having capacity greater of 3.500 m^3, i.e. LNG Feeder ships.

(15) The estimation shows that the most frequent vessels to be accommodated are those with the capacity from 140.000 to 180.000 m^3. Probability of acceptance of the biggest LNG carriers (260.000 m^3) is relatively small.

(16) At LNG FSRU terminal shall be expected acceptance of LNG carriers equipped with all existing technologies of ship tanks for liquefied gas.

(17) At LNG FSRU terminal shall be expected LNG carriers equipped with all recently known driving systems. In this regard, manoeuvrability of the LNG carriers to be accommodated will be considerably various.

(18) Manoeuvrability characteristics depend on the following characteristics of LNG carriers: large freeboard lateral surface exposed to the wind, low draught of a ship, i.e. low lateral resistance, low visibility from the command bridge, and extremely slow engine start-up for some propulsion system configurations.

(19) To ensure safe operations on board of LNG carriers all safety regulations should be observed.

5 TECHNICAL AND TECHNOLOGICAL CHARACTERISTICS OF LNG TERMINALS

LNG terminal comprises of the facilities for liquefaction or regasification of natural gas. At the export terminal natural gas is liquefied under the temperature of -160°C when the volume of natural gas is decreased approximately 600 times. Cold LNG is transported by carriers to the import terminals (shore terminals or FSRU terminal) for regasification and further distribution.

5.1 TECHNOLOGICAL PROCESSES ON THE LNG FSRU TERMINAL

LNG FSRU terminals serve for mooring of LNG carriers, storage, regasification and further delivery of natural gas into the gas distribution grid.

FSRU terminal comprises of the shore facilities and FSRU vessel that can be equipped as a gas carrier converted into an independent unit or a new unit build as FSRU. FSRU vessel is moored at the constructed jetty and serves for mooring LNG ships. Given its characteristics FSRU terminal may serve as a bunkering terminal for small ships such as tugboats, small ro-ro passenger car ferries, barges or other transport means that use LNG as fuel.

FSRU vessel should meet the requirements of the recognized authorities (classification societies) of the flag state, in compliance with the international convention dealing with LNG vessels under the temperature of -163°C. FSRU vessel should have all the necessary certificates updated annually or every 5-year. It is necessary to highlight the possibility of the extended dry dock period, when the period between dry docks can be extended for 7,5 or 10 years and with special modifications upto 20 years.

Since FSRU terminal comprises of the shore facility and FSRU vessel, typically FSRU vessel supply electric power to the shore facility in compliance with the operating conditions specified for the project.

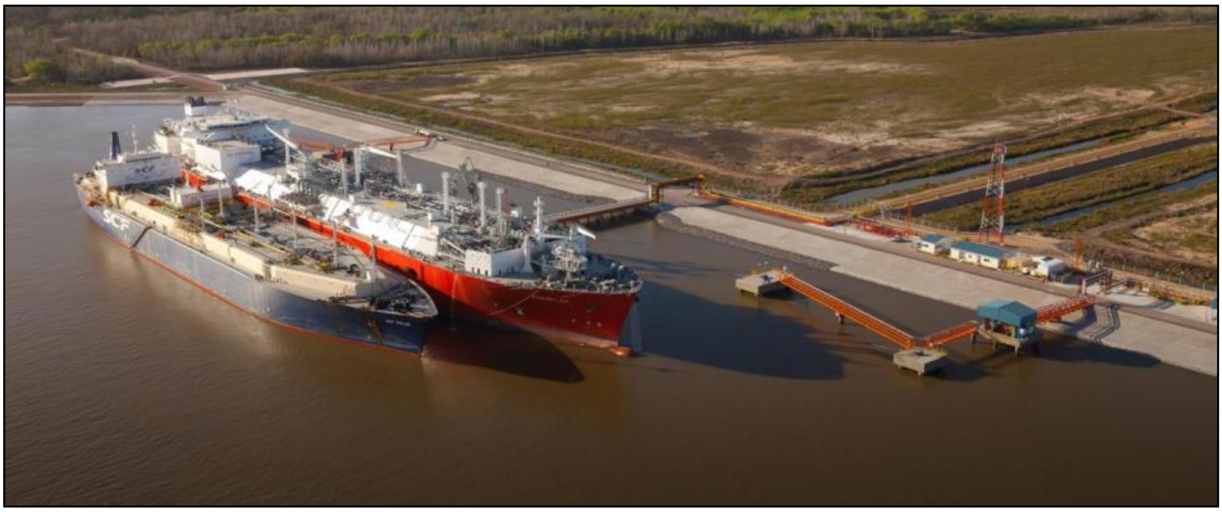

Image 23 FSRU terminal/vessel

FSRU vessel engine shall follow the same philosophy as for the other LNG vessels. In terms of energy efficiency the most effective are those that have electrical power generators rather than those having steam turbines and boilers or other older technology.

(Un) loading equipment. Operating procedure for LNG transfer from LNG carrier to FSRU vessel consists of a number of the associated operating processes. LNG is transferred to FSRU vessel from the other LNG carriers via:

- Flexible cryogenic cargo transfer hoses and
- Fixed type loading arms.

The above is the major equipment on FSRU terminal.

Typical characteristics of flexible cryogenic cargo transfer hoses are:

- diameter 10"
- length: 18.50 m
- operating temperature: -196°C to +50°C
- operating pressure: 10 bar
- electrical resistance: 4.2 Ω
- weight: 23.9 kg/m.

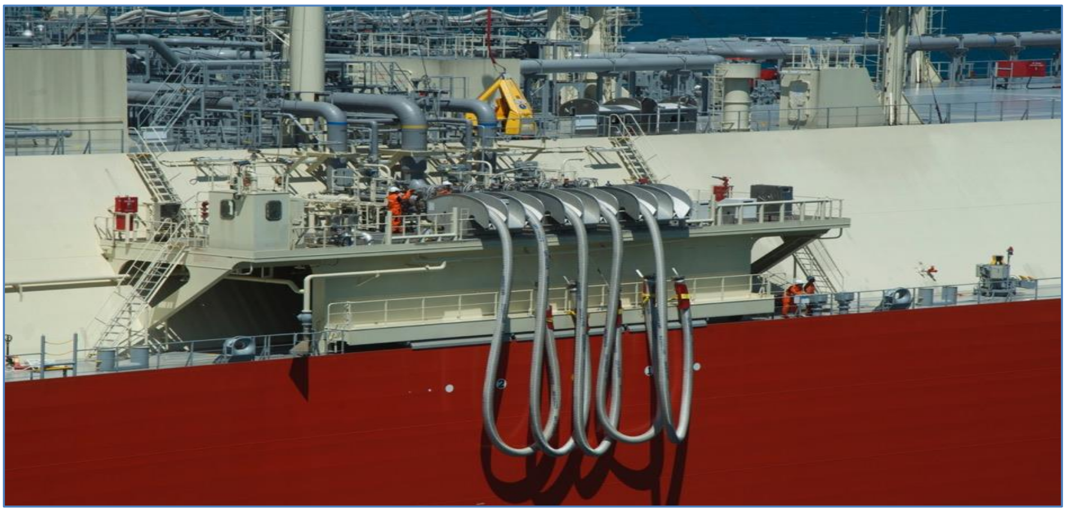

Image 24 Flexible cryogenic cargo transfer hoses on FSRU vessel

Flexible cryogenic cargo transfer hoses are used due to their simple technology and easier maintenance in comparison with the fixed type loading arms.

Furthermore, flexible cryogenic cargo transfer hoses is the only equipment for LNG transfer from vessel to vessel in offshore conditions in case of emergency (cargo transfer due to running aground, cargo tank leakage or risk of hull damage under low temperatures).

In addition, because of their low expansion coefficient flexible hoses enable higher rate of LNG flow and low gas vaporisation. Besides, flexible cryogenic cargo transfer hoses are easier for handling in comparison with the fixed type loading arms, which prevents any possible damages to the liquid manifold of LNG vessel. Flexible hoses are pulled to the LNG vessel with the help of handling equipment and are tied up in the saddles. In the course of cargo operations, due to the gas low temperature ice is regularly formed on the cover of flexible hoses.


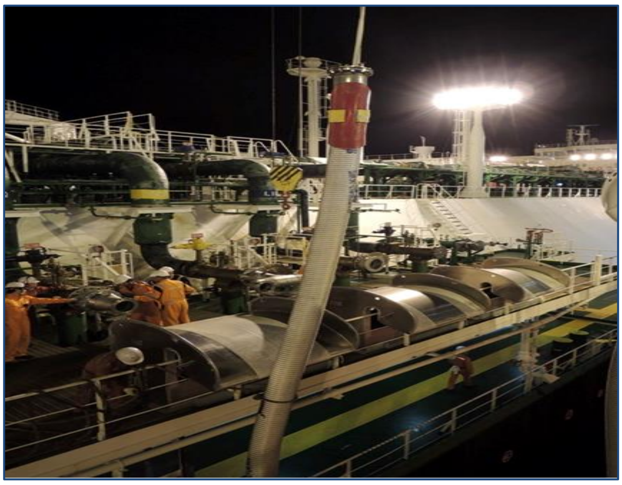

Image 25 Flexible cryogenic cargo transfer hoses handling and tie-up in the saddles.4

For LNG transfer via flexible hoses the following configuration with 3 or 4 main liquid manifolds and one vapour return manifold is used:

- L1 main liquid manifold,
- L2 main liquid manifold,
- V cargo vapour return manifold,
- L3 main liquid manifold,
- L4 main liquid manifold.

Two flexible hoses are tied up to each manifold, liquid and cargo vapour return, to the previously installed Y-piece reducers. Therefore, total number of flexible cryogenic cargo transfer hoses used is 6 and 2 cargo vapour return hoses.

Maximum flow rate while using flexible cryogenic cargo transfer hoses depends on their number and configuration of reducers, therefore ranges from 6000 m to 9000 m3/h, subject to the operating pressure.


Image 26 Installation of Y-piece reducers

Insulation kit installed between the reducers and the main liquid manifold flange towards LNG vessel prevents electric stress.

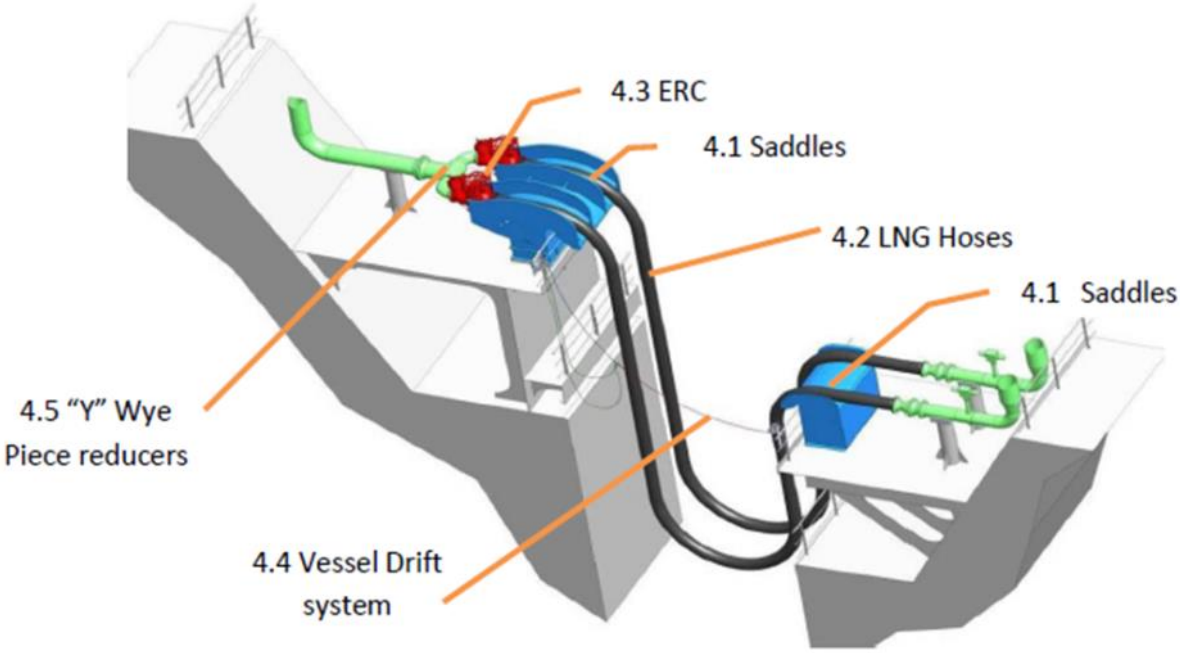

Image 27 Insulation kit between LNG and FSRU vessel

Image 28 Cargo operations through flexible cryogenic cargo transfer hoses

Estimated time to tie up cryogenic flexible hoses for LNG cargo operations is 3 hours, while estimated tine to disconnect hoses upon completion of the operations including time for force evaporation of boil off gas and inerting with nitrogen is longer, around 6-8 hours. Therefore, for LNG cargo operations through the cryogenic flexible hoses the time of LNG vessel stay at berth is longer in comparison with LNG cargo operation through fixed type loading arms.

Fixed type loading arms provide an easier and more ergonomic handling (connection and disconnection), does not require any additional equipment as it is in the case of the cryogenic flexible cargo transfer hoses application. In addition, they are significantly resistant to the harsh weather conditions and mechanical damages.

Image 29 Use of fixed type loading arms for offshore cargo operations 5

As a rule, fixed type loading arms are manufactured as per OCIMF Design and Construction Specification for Marine Loading Arms (Third Edition-1999).Two configurations are provided by the design for cargo operations from LNG carrier to FSRU vessel taking into consideration the capacity from 125.000 m3 to Q flex ships of a capacity from 217.000m3. Two configurations are provided by the design for cargo operations from LNG carrier to FSRU vessel taking into consideration the capacity from 125.000 m3 to Q flex ships of a capacity from 217.000m3. There are usually two arms for LNG cargo operations and one for cargo vapour return.

Typical technical characteristic of fixed type loading arms for LNG cargo operations and cargo vapour return are as follows:

– rated diameter	16"
– design operating pressure	19 bar
– test pressure	28 bar
– operating temperatures	-196°C to +93 °C
– LNG flow rate	5.000 m3/h
– operating pressure	4 bar – 8 bar
– cargo operations temperature range	-163°C to -100°C
– gas flow rate	25.000 m3
– design vapour pressure	13,4 bar
– vapour temperature	-60°C
vapour return temperature range	-196°C to +93°C

Use of fixed type loading arms may be difficult for LNG cargo operations from FSRU vessel to the small scale LNG takers.

Cargo operations. Cargo operations will start when LNG carrier is moored and include as follows: LNG transfer to FSRU and its regasification prior to delivery onshore. Regasification process is carried out in the regasification unit through LNG vaporizers (heat exchangers). Natural gas is delivered to the final destination through the onshore export pipeline that is connected to the FSRU terminal.

LNG flow rate from LNG carrier to FSRU vessel depends on a number of factors, the most important are as follows:

- LNG vessel capacity,
- cargo composition Liquefied Natural Gas Analysing
- total volume of LNG to be transferred,
- LNG carrier water ballast capacity and management,
- LNG cargo management (stability, „sloshing", cargo vapour return)
- FSRU vessel capacity,
- FSRU vessel tanks reserve space to enable continuous regasification and cooling down of cargo tanks,
- regasification capacity.

In the event the net volume of LNG to be transferred from LNG carrier to FSRU vessel is below the total volume available on FSRU, LNG flow rate is defined by the loading equipment largest capacity.

In the event the net volume of LNG to be transferred from LNG carrier to FSRU vessel is above the total volume available on FSRU, LNG flow rate is defined by the regasification rate at the FSRU vessel.

To enable admission and storage on FSRU vessel in the event of the excess amount of LNG fed, regasification volume on FSRU vessel should be equal to the volume of the excess LNG to transfer.

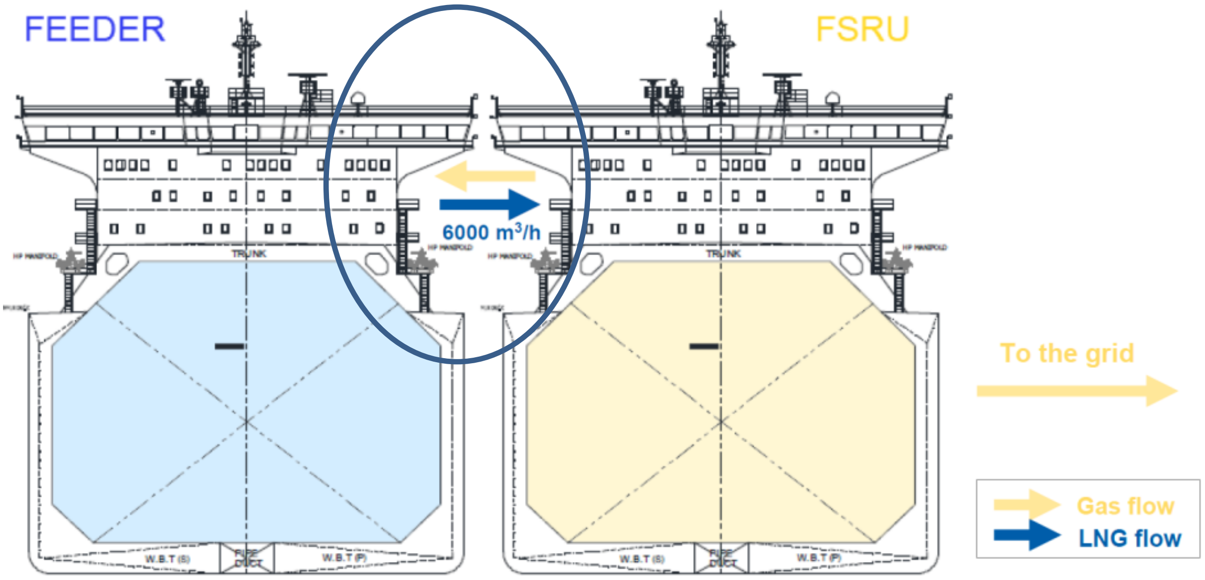

Image 30 LNG cargo operations from LNG carrier to FSRU vessel6

Total capacity of FSRU vessel and regasification unit (i.e. FSRU terminal capacity) depends on the capacity of gas transport network and annual demands of the consumers directly connected to the gas distribution grid.

FSRU with regasification capacity of 750 mmscf/d is a terminal of larger capacity and flexibility. There are two solutions for regasification:

- Open loop mode,
- Closed loop mode,

– Combined loop mode.

Choice of the mode depends on the intermediate medium and the seawater temperature. At present there are glicol-based and propane-based systems for regasification of LNG. In both cases seawater is used for LNG heating, so the systems are based on:

– seawater-propane technology and[38]
– steam-glicol technology
– direct seawater.

The most sophisticated technology at present is seawater-glycol-based.

LNG transfer time and speed range for FSRU vessel capacity of 170.000 m3												
LNG carrier capacity of 140.000 m3												
Regasification speed mmscf/day	100		200		300		400		500		600	
LNG vaporization m3/h	194		388		582		776		970		1164	
Excess cargo on LNG feeder	Excess cargo regasification time (h)	Transfer speed m3/h	Excess cargo regasification time (h)	Transfer speed m3/h	Excess cargo regasification time (h)	Transfer speed m3/h	Excess cargo regasification time (h)	Transfer speed m3/h	Excess cargo regasification time (h)	Transfer speed m3/h	Excess cargo regasification time (h)	Transfer speed m3/h
1.000	5	5.000	3	5.000	2	5.000	1	5.000	1	5.000	1	5.000
10.000	52	2.716	26	5.000	17	5.000	13	5.000	10	5.000	9	5.000
20.000	103	1.358	52	2.716	34	4.074	26	5.000	21	5.000	17	5.000
30.000	155	905	77	1.811	52	2.716	39	3.621	31	4.527	26	5.000
40.000	206	679	103	1.358	69	2.037	52	2.716	41	3.395	34	4.074
50.000	258	543	129	1.086	86	1.630	64	2.173	52	2.716	43	3.259
60.000	309	453	155	905	103	1.358	77	1.811	62	2.263	52	2.716
70.000	361	388	180	776	120	1.164	90	1.552	72	1.940	60	2.328
80.000	412	340	206	679	137	1.019	103	1.358	82	1.698	69	2.037
90.000	464	302	232	604	155	905	116	1.207	93	1.509	77	1.811
100,000	515	272	258	543	172	815	129	1.086	103	1.358	86	1.630
110.000	567	247	284	494	189	741	142	988	113	1.235	95	1.481
120.000	619	226	309	453	206	679	155	905	124	1.132	103	1.358
130.000	670	209	335	418	223	627	168	836	134	1.045	112	1.254
140.000	722	194	361	388	241	582	180	776	144	970	120	1.164
150.000	773	181	387	362	258	543	193	724	155	905	129	1.086
160.000	825	170	412	340	275	509	206	679	165	849	137	1,019

Table 22 Typical average transfer time vs regasification rate (FSRU capacity 170.000 m3)3

There is another solution for regasification, so called “Combine loop“. This technology implies to maintain the seawater temperature at the location of FSRU terminal within permissible limits (based on empirical data) during certain months of the year, providing sufficient heat exchange in the vaporizers between the media (e.g. propane) with the use of heaters. In general, in terms of energy efficiency this solution for LNG regasification has disadvantages due to the large consumption of energy required for heating in the vaporizers.

38 Seawater is an agent for heating propane that is used for the heat exchange in vaporizers.

Open loop mode does not require the media (seawater) heating, the direct seawater from FSRU terminal location is used. Closed loop mode, on the other hand, does require pre-heating of the seawater.

The lowest seawater temperature used in the open loop mode to ensure regasification process within the limits specified at the site is +10°C. Open loop mode inevitably cool the water at FSRU terminal location down, with calculated dispersion model in the range of 200 m the difference in the temperature is less than 0.5 C. To considerably protect coolant liquid (seawater) lines from fouling, water could be chlorated or treated by the other chemical reagents. In terms of energy efficiency open loop mode is the most favourable solution due to the low rate of energy consumption.

In closed loop mode seawater should be pre-heated to provide proper thermal exchange in the heaters. It is done in cases when the send-in seawater temperature is below +13°C. Steam is used for heating. The whole system is under automatic control and effects the HP NG send out temperature to the gas distribution grid.

Closed loop mode requires the high rate of energy consumption for the seawater preheating, therefore CO_2 emissions are considerable.

Depending on their configuration some regasification units have one or two booster pumps on each unit. As a rule, regasification units comprise of 3 to 4 units with 3 to 8 booster pumps.

Booster pumps send out pressures are typically lower than the maximum design pressure in the gas export pipeline outlet.

HIPPS system (High Integrity Pressure Protection) is foreseen on the FSRU portside on the HP NG send out line to the HP gas export manifold to the final consumers. HIPPS system aims to protect gas pipeline in the event of pressure jump in the send out line above the rate of the gas export pipeline design pressure.

In conclusion, FSRU is interfaced to the gas distribution grid through the fixed HP gas export manifolds. The typical configuration is with two export manifolds, where one is operating and the other is used in emergency situations or during planned maintenance of the operating manifold.

Image 31 Firefighting tower and HP gas export pipeline – HP gas export manifolds

Gas metering station is installed on the NG send out line to the HP gas export manifold. It meters the total production rate that is regasification rate for 24 hours. Metering station should be certified by the competent authorities and meter gas in KWh or MWh.

The standard equipment for metering and NG quality control is as follows:

- Gas Chromatograph,
- Densimeter.

FSRU terminals are typically fed from the previously agreed loading terminals. In this case the gas quality is usually set. When FSRU terminal is fed from the spot market, the gas is mixed in the cargo tanks, therefore its composition may vary. In any case, the FSRU terminal prescribes the range of gas quality that can be accepted, in compliance with the TSO Network Rules where the regasified LNG enters.

5.2 TECHNICAL AND TECHNOLOGICAL CHARACTERISTICS OF THE FSRU TERMINAL IN OMIŠALJ

The Krk LNG FSRU terminal will be located in the north-west part of the Island of Krk at the Zaglav Cape. The area is in the Omišalj municipality located in the Primorsko-goranska County. Location is about 1,5 km to the south-west from Omišalj city and about 2 km to the north from Njivice city.

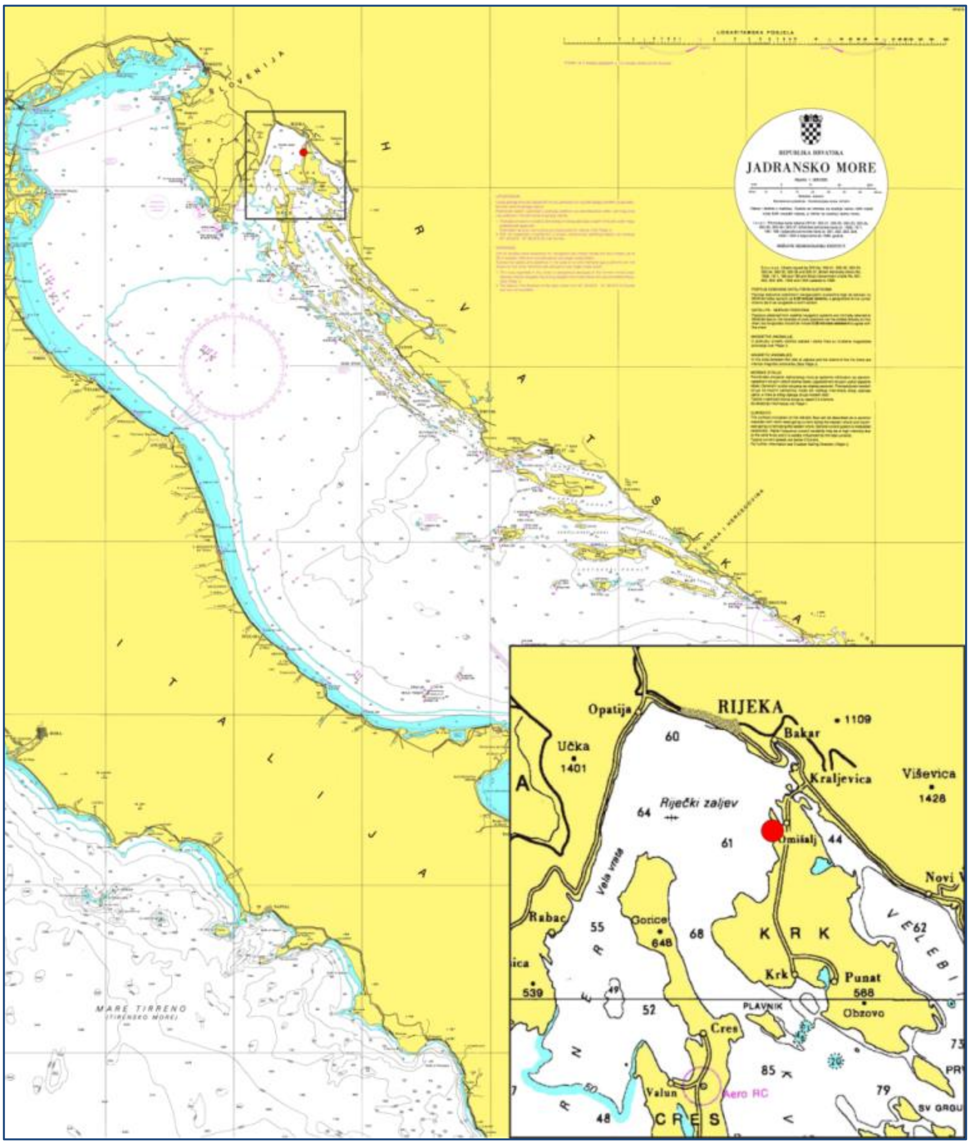

Image 32 Location of LNG FSRU terminal on the Island of Krk

The plan is to construct a new terminal for FSRU vessel, jetty and gas export pipeline interfaced to the gas transmission grid.

It is initially planned to use FSRU terminal as an export regasification system for further delivery of NG through the onshore gas transmission grid to the final consumers, providing that LNG shall be fed from LNG ships.

FSRU terminal shall consist of:

- FSRU vessel,
- Jetty,
- shore facilities to interface FSRU vessel to the gas transmission grid

FSRU terminal capacity is planned to be at the range from 160.000 m3 to 265.000 m^3 (QMax FSRU), where the potential capacity is from 170.000 m^3 with annual regasification capacity from 2,6 up to 3,5 billion m^3. Maximal installed capacity that could be expected at the FSRU ships is 8,3 billion m^3 (BCM) per year (890.000 Nm3/h) with the maximum operating pressure of 100 bar.[39]

Following the FSRU terminal design capacity, the envisaged annual traffic shall be from 25 to 70 LNG carriers.

FSRU terminal main specifications are as follows:

- Jetty for FSRU vessel of a capacity from 160.000 m3 to 265.000 m3,
- FSRU vessel to receive LNG carriers of a capacity from 125.000 m3 to 265.000 m3.

It is planned to use FSRU vessels with the following characteristics:

FSRU vessel	Capacity (m3)	LOA (m)	Breadth (m)	Draft (m)
QMax	263.000	345	55	12,2
Conventional LNG vessel	170.000	294	46	10,2

Table 23 Dimensions of typical types of FSRU vessels

FSRU vessel is planned to be „permanently "docked at the jetty. Terminal operating hours are 24 hours per day all year.

It is planned to construct the onshore terminal management office and auxiliary facilities with a restricted entry. A security office shall be enclosed. Management office, auxiliary facilities and electrical substation shall be located on shore area of the terminal.

Image 33 Layout drawing of the terminal with the location of FSRU vessel docking place

39 The capacity is approximately equivalent to the annual consumption of natural gas in the Republic of Croatia.

One part of the terminal shore area borders with the DINA Petrokemija area and the other part abuts local public road intersecting to the island highway, i.e. state highway D102.

In general, jetty comprises as follows:

- loading platform with the manifold, (47*25) 7 m CD
- breasting and mooring dolphins,
- shore gangway,
- gas export pipeline interfaced to the gas transmission grid.

The jetty head dimensions are 47 x 25 meters. The jetty head height is 7 meters over the sea level. The specified depth of the waterway alongside the terminal is 15 meter, and the depth alongside the jetty is 16,5 meters. The jetty consists of the caissons connected into the platform of 45 meter length. The platform shall be sliding resistant.

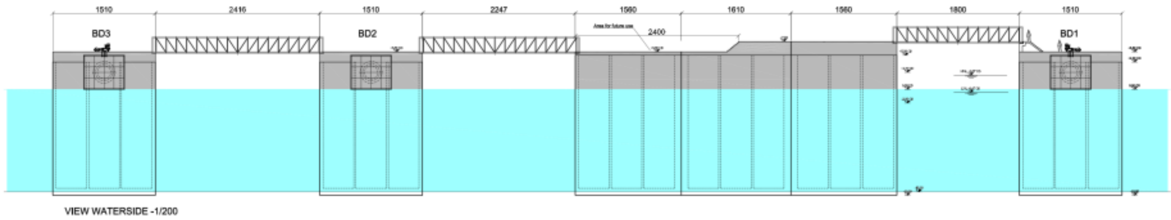

Image 34 Jetty central area (platform) with breasting dolphins installed on it

A trestle of 52 meters length and 8 meters width shall connect the platform to shore. A trestle shall accommodate piping, cables and a roadway for personnel access and vehicles to the platform.

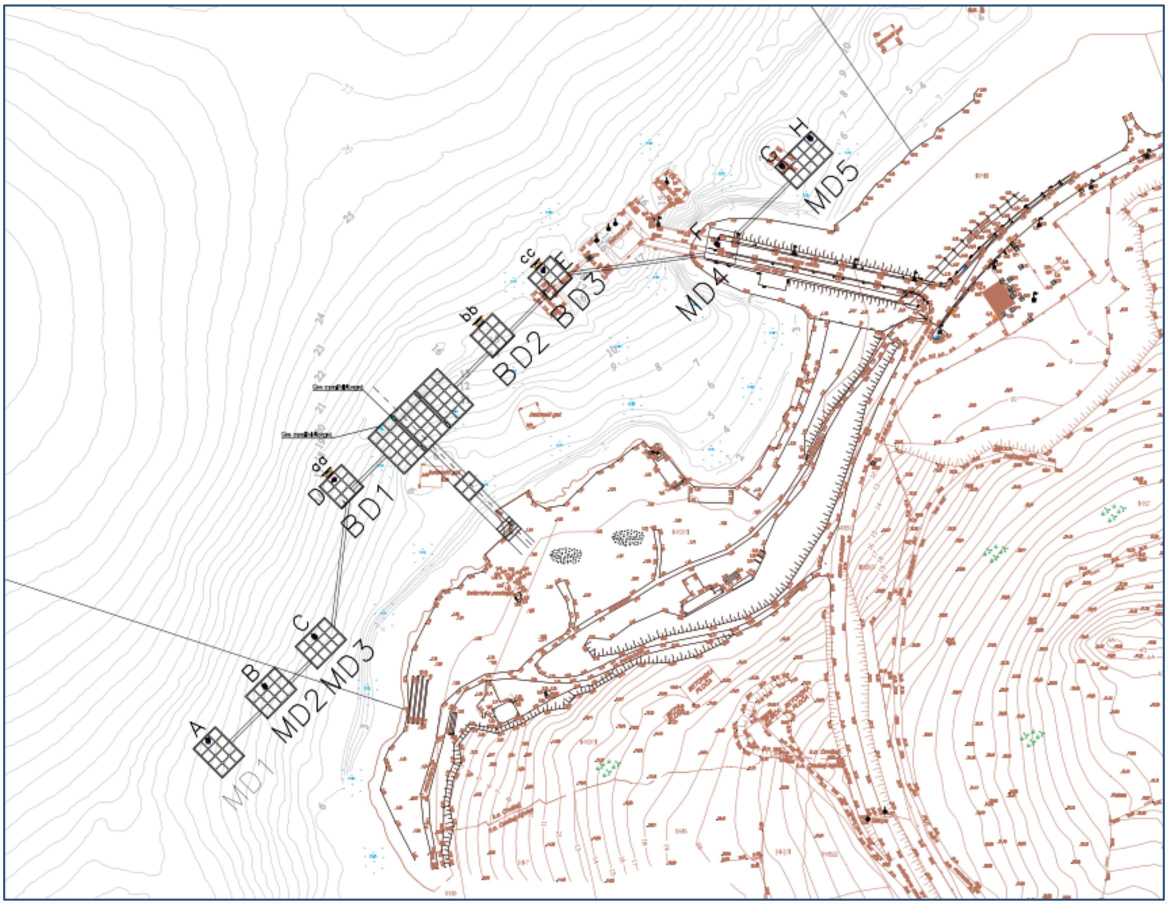

Image 35 Future jetty

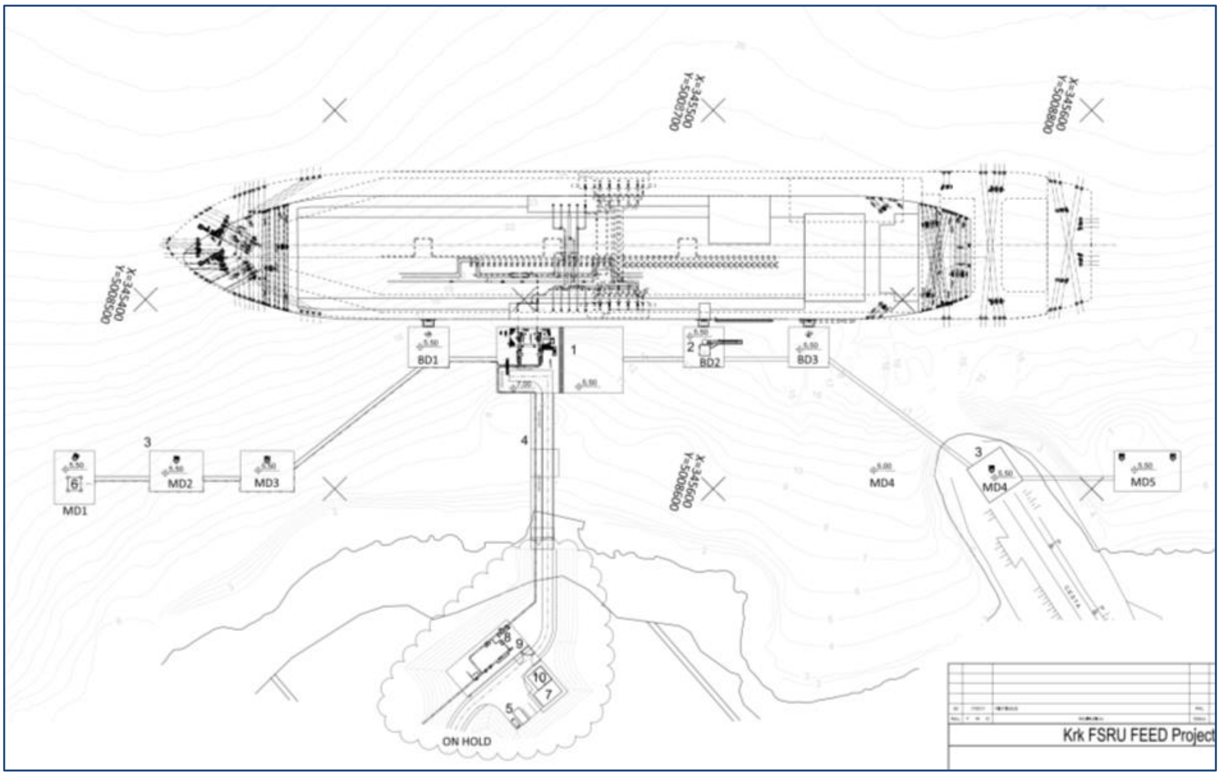

Image 36 Position of FSRU vessel berthing against the jetty 7

The platform shall accommodate process and service equipment such as two fixed type loading arms (2 x 12" HP NG) and gas export pipeline to connect FSRU vessel with the gas transmission grid. It is planned to use flexible cryogenic hoses for LNG cargo operations from LNG carrier to the FSRU vessel.

Mooring dolphins (MD) and breasting dolphins (BD) shall be manufactured of concrete. The plan is to install 8 dolphins in total: three of them shall be installed immediately at the mooring pontoons (BD 1-3) and the other 5 (MD1-5) shall be distributed on the farther ends of the jetty, 3 in the south part of the jetty and 2 in the north. Dolphins shall be connected by the steel footbridges of 1,5 meters width with the walking clearance of 1,5 meters. Dolphins shall be connected by the steel footbridges of 1,5 meters width with the walking clearance of 1,5 meters. Spacing between the dolphins vary from 18 meters (breasting dolphin located at the jetty head BD1) to 24 meters (breasting dolphin in the south part of the jetty BD3). Dolphin's approximate dimensions are as follows:

- MD1, MD2, MD3 20 x 15 m,
- *MD4 15 x 15 m,*
- MD5 25 x 15 m,
- BD1, BD2, BD3 15 x 15 m

Dolphin's height above the sea level is 5,5 meters. All dolphins shall be lightened and equipped with railing, life ring and coping.

Each of 3 breasting dolphins shall be equipped with fenders to absorb the maximum energy of FSRU vessel and LNG carrier berthing against the jetty. It is planned to install a fender panel with high energy absorption to ensure sufficient load on the hull (recommended type SCN2000 Super Cone Fender or any other with similar specifications).

All mooring lines on the jetty shall be connected to the Quick Release Hooks.

Dolphin	Quick Release Hooks	Fenders
MD1	4 x 150 tone	-
MD2		-
MD3		-
MD4		-
MD5	4 x 150 tone (2)	-
BD1	2 x 150 tone	1 x SCN2000
BD2	-	
BD3	2 x 150 tone	
Platform	-	-

Table 24 Distribution of equipment on the dolphins provided for QMax FSRU4

According to the design, 6 sets fitted with 4 quick release hooks each shall be installed for FSRU QMax vessel, and 5 sets fitted with 3 quick release hooks each plus one set fitted with 4 quick release hooks - for the FSRU vessel of a capacity of 170.000 m3 2 sets fitted with 2 quick release hooks each shall be installed on the breasting dolphins in the centre. All hooks shall resist the load of at least 1.500 kN (150 tons).

An electric capstan to haul the lines up to 1,5 tons at the speed of 20 m/min shall be integrated into the system.

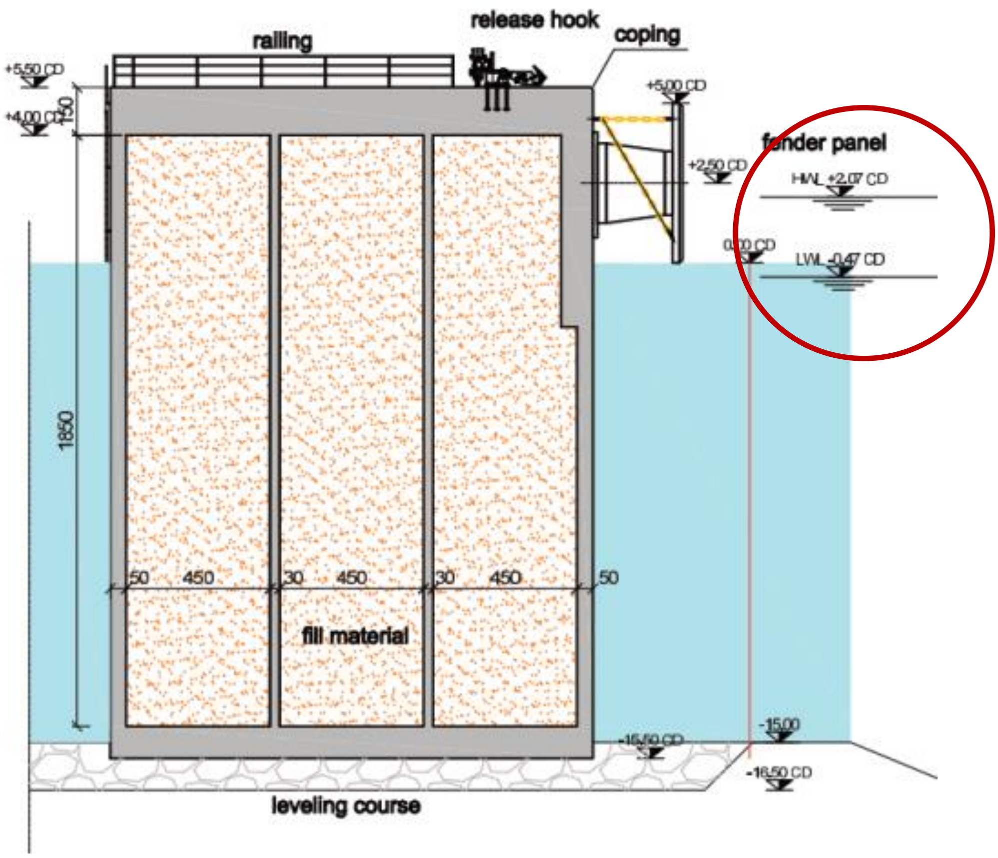

Image 37 Breasting dolphin cross section

Breasting dolphins located alongside the platform (BD1 and BD3) aim to pull FSRU vessel spring lines, whereas the other dolphins will serve to pull the other mooring lines (bow, stern and breast).

The jetty is planned to be constructed in the approximate direction NE-SW (45°-225°), with the total length of 400 m. FSRU vessel is anticipated to bow on the south-west. This position will facilitate the fastest sailaway in case of emergency and the vessel will be less effected by the most frequent winds from NE and SSE directions.

The following safety solutions shall be provided on the FSRU terminal:

- water monitors,
- cargo transfer emergency shutdown system (ESD),
- fire detection system (use of smoke, fire and heat detectors),
- process shut down system (PSD),
- installation of HIPPS (High Integrity Pressure Protection Systems) on FSRU vessel to prevent increase of pressure in the shore gas export pipeline,
- earthing system for all units at the terminal,
- Integrated Control and Safety System (ICSS) to control equipment at the terminal,
- control over the terminal with CCTV cameras, motion detectors, unauthorized access detection systems,
- security check at the entrance to the terminal.

Main specifications of the future FSRU terminal:	
Maximum regasification capacity of FSRU vessel	Max. 8,3 billion m3 (BCM) per year, or 750 mmscf/d[40]
Average capacity of NG delivery	up to 2.6 billion m^3/year Regasification rate from 350,000 Nm3/h
FSRU vessel capacity	Min. 160.000 m3 Max. 265.000 m3
LNG unloading ships capacity:	125.000 – 265.000 m^3
LNG loading ships capacity	Min. 3,500 m^3 - Max. 35.000 m^3 (LNG feeder ships)
Regasification mode	depends on FSRU vessel (open loop or combine loop)
FSRU vessel engine	DFDE, TFDE or MEGI
Pipeline pressure and temperature	Max. 100 bar Min. 0°C
FSRU terminal send out gas temperature	Max. 15 °C Min. 2°C
FSRU vessel send out gas pressures	Max 130 bar (extraordinary conditions)
Depth alongside the terminal	Min. 15 m
Terminal traffic capacity	25 – 70 LNG unloading ships
Transfer equipment	Gas transfer on shore - 2 x 12" fixed type loading arms LNG transfer from LNG carrier to FSRU vessel - cryogenic flexible hoses
(Un)loading capacity	Depends on technical and technological characteristics of LNG carrier and FSRU vessel
Additional specifications	LNG loading from FSRU vessel to future onshore LNG truck loading station tanks

Table 25 Main specifications of the future FSRU terminal

Electrical power to the terminal shall be provided from FSRU vessel and emergency diesel generator shall be used in case of emergency. FSRU vessel is foreseen to be self-reliant in terms of services provided and the whole terminal shall be operated from FSRU vessel (through Basic Process Control System - BPCS) with the use of onshore emergency system located in the terminal management office.

Gas flow metering station shall be installed on the FSRU vessel to control gas flow to the gas distribution grid.

40 mmscf/d (Million Standard Cubic Feet per Day) and Nm3/h (Normal Cubic Meters per Hour) represent the units of measure for the transported gas quantity (gaseous state)- 1 mmscf/d = 1.244 Nm3/h(gaseous state).

Sea ladders and life rings shall be provided in the terminal shore facilities. The whole area shall be provided with shadow lights not to affect ships manoeuvring. In addition, the whole area shall be fenced with the safety barrier providing sufficient lightning.

Conclusion:

(20) LNG FSRU terminal shall be located in the north-west part of the Island of Krk at the Zaglav Cape, at about 1,5 km to the south-west from Omišalj city and about 2 km to the north from Njivice city.

(21) Basic components of LNG FSRU terminal are shore berth (includes a platform, solid structure berths for docking and mooring) for acceptance FSRU ship capacity 160.000 m3 to 265.000 m3 and FSRU ship enabling mooring of LNG carrier capacity 125.000 m^3 to 265.000 m^3.

(22) The biggest planned annual capacity of terminal amounts to 8.3 billion cubic meters gas i.e. an average in the first years of terminal work amounts to 2.6 billion m^3 gas, with further increase depending on development of gas network capacity.

(23) Anticipated annual traffic of LNG carriers delivering gas in first years of work is estimated from 15 to 30 ships for cargo unloading. LNG carriers' traffic for the biggest capacity of FSRU ship is estimated from 50 to 70 LNG carriers annually for gas unloading.

(24) It is envisaged the LNG loading to feeder ships of a capacity from 3.500 m^3 to 35.000 m^3. It is impossible to estimate the number of LNG feeder ships since it depends on further development of the onshore gas transmission grid.

(25) Anticipated unloading time LNG carriers in delivering is estimated to 24 hours depending on instant cargo quantity on FSRU ship and on capacity of gasification and consumption of the natural gas by end users. The estimated total time of LNG carriers stay at berth is up to 50 hours.

(26) Terminal transhipment equipment on shore includes loading/unloading arms (12") for delivery of gas from FSRU ship to shore and its dispatching to gas network. LNG shall be transferred from LNG carrier to the FSRU ship via cryogenic flexible hoses.

(27) The design provides for the depth of 15 meters alongside the waterway at the terminal.

6 CONDITIONS AND MANOEUVRING AN LNG CARRIER

The procedures during the manoeuvres of mooring and unmooring and the stay of LNG carrier and FSRU vessel at the berth must provide an adequate level of safety for the ships and other floating units and port buildings. To assess the safety of manoeuvring and stay of ships at the berth it is required to assess the impact of external forced acting on the ship, terminal and to estimate the minimum number of tugs required and their capacity.

6.1 EVALUATION OF EXTERNAL FORCES AND DYNAMICS OF REFERENT SHIPS

To test the meteorological and oceanographic impact to the safety level during manoeuvring and stay of the ship at the berth two types of LNG carries, i.e. Q-Max membrane tank carrier and conventional Kvaerner-Moss spherical tank carrier are considered, with the following characteristics:

Type	D (t)	Capacity (m3)	L (m)	B (m)	T (m)	Approximate surfaces of the vessel (m2)[41]	
						freeboard surface part of the vessel horizontal/vertical	submerged part of the vessel horizontal/vertical
Q-Max	179.000	265.940	345	53.8	12,0	7.700 / 1.800	4.000 / 645
K-M	104.998	147.598	290	49,0	11,4	9.000 / 1.500	3.200 / 560

Table 26 Main characteristics of the vessels reviewed5

Assessment of the impact is based on the following predictions:

- the highest values of forces at the adverse angles of the wind's action are considered during manoeuvres;
- only most significant winds are considered: the bura (NNE), the maestral and local squalls from the west (WNW) and the lebić (SW); the other winds are not taken into consideration due their considerably less speed, frequency or less action on a ship providing for the terminal location and land configuration;
- the referent ships are the objects with high inertia; it is assumed that short-time wind gusts will not have an immediate response that may apply relevant force on the mooring point; therefore 30-seconds wind speeds and forces of their action are considered;
- load values are those calculated for LNG carriers with spherical and prismatic tanks; [42]
- total wind force is composed of longitudinal and lateral force coefficients;
- effect of waves is not considered for the assessment of the bura impact; effect of waves is considered for the assessment of the westerly's and the jugo impact; effect of waves is estimated for the adverse weather conditions (waves, multi-day waves, hurricane waves).

6.1.1 Effects of wind

Longitudinal and lateral wind force Fv acting on LNG carrier is estimated based on the following formula:

$$Fv = Cv(\alpha) \cdot \rho v 7600 \cdot Vv2 \cdot A \qquad \left(— \right)$$

[41] These areas are estimated using simplified ship profiles in a way that the actual sizes are approximately 5-10% smaller than mentioned.

[42] See OCIMF Predictions of Wind & Current Loads on VLCC's, 1994 and SIGTTO Prediction of Wind Loads on Large Liquefied Gas Carriers 2007.

where:

- *Fv* – wind force [t],[43]
- *Cv()$_\alpha$* – coefficient of air resistance on the body exposed to wind (individuals values are specified for carriers with spherical and prismatic tanks at various angles of the wind's action),
- ρ_z – air density [kg·sec2/m4],[44]
- *Vv* – wind speed [m/s],[45]
- *A* – freeboard surface part of the vessel [m²].

LNG carrier yaw moment is estimated based on the following formula:

$$Mz = Cvz(\alpha) \cdot \rho v 7600 \cdot Vv2 \cdot A \cdot LPB \qquad \left(— \right)$$

where:

- *Mz* – ship yaw moment [tm],
- *Cvz()$_\alpha$* – coefficient of yaw moment caused by the wind (individual values are specified for the carriers with spherical and prismatic tanks),
- *LPB* – length between perpendiculars [m],

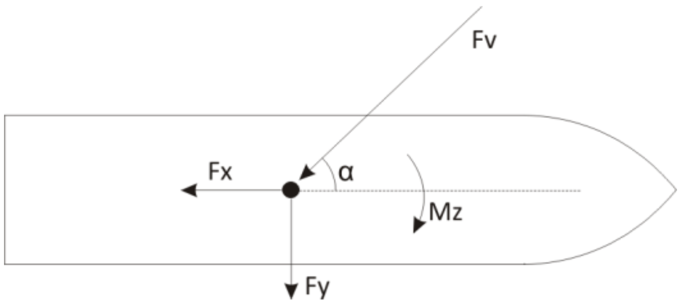

Image 38 Longitudinal (Fx) and lateral (Fy) coefficients of the wind force acting on a ship and yaw moment (Mz)

Calculation of forces and of the yaw moment are performed based on the wind force of 25 knots (≈13 m/s) that is supposed to be the strongest wind when berthing and mooring is allowed.

	Conventional carrier with spherical tanks				Q-Max carrier with prismatic tanks			
Angle	**Fx [t]**	**Fy [t]**	**Fv [t]**	**Mz [tm]**	**Fx [t]**	**Fy [t]**	**Fv [t]**	**Mz [tm]**
0˚	**-12,9**	**0,3**	**12.9**	**26,8**	**-18,0**	**0,2**	**18.0**	**27,3**
30˚	**-10,9**	**38,9**	**40,4**	**-1178,6**	**-15,3**	**40,1**	**42,9**	**-1199,6**
60˚	**-3,6**	**79,3**	**79,4**	**-1125,0**	**-6,2**	**78,6**	**78,8**	**-872,5**
90˚	**-0,2**	**83,4**	**83,4**	**750,0**	**-1,9**	**86,9**	**87,0**	**1472,3**
120˚	**8,3**	**68,1**	**68,6**	**2651,9**	**8,4**	**75,2**	**75,7**	**4171,4**
150˚	**14.8**	**35,9**	**38,9**	**2651,9**	**17.2**	**40,1**	**43,6**	**3926,0**

[43] The wind force is expressed in tones in order to maintain sequence regarding the used sources.
[44] The air density is 0.1248 kg · sec2/m4 at a temperature of 20 ° C.
[45] The value of wind speed measured at a height of 10 m above the sea level is entered in the formula and 10-minute average velocity is assumed.

180˚	**12,8**	**0,0**	**12,8**	**0,0**	**17.0**	**0,2**	**17.0**	**0,0**

Table 27 Wind forces and yaw moment at various angles of the wind's action

The enclosed graphs show the values of the wind force and yaw moment for the conventional carrier with spherical tanks (in blue) and Q-Max carrier (in red).

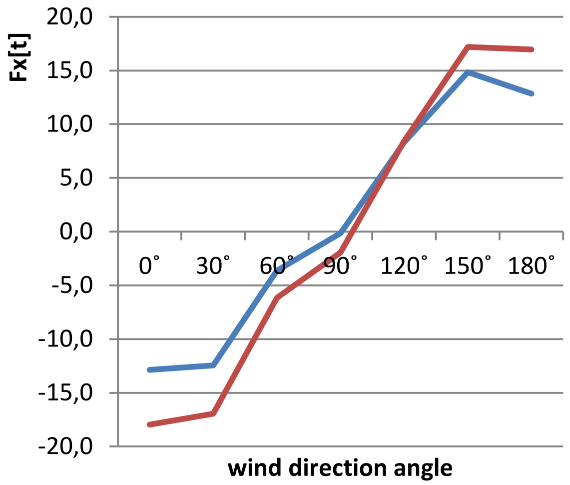

Image >39 Longitudinal force coefficient

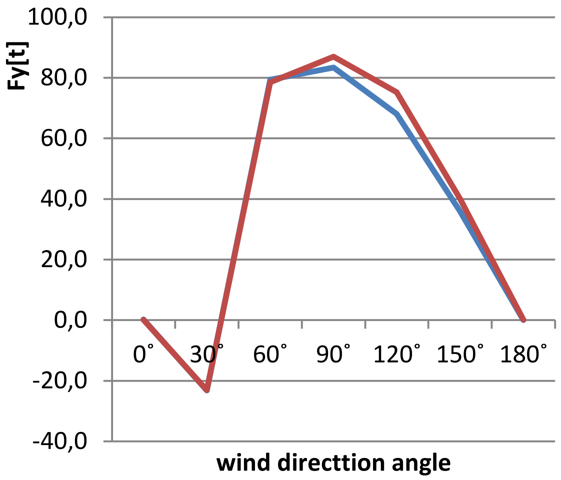

Image 40 Lateral force coefficient

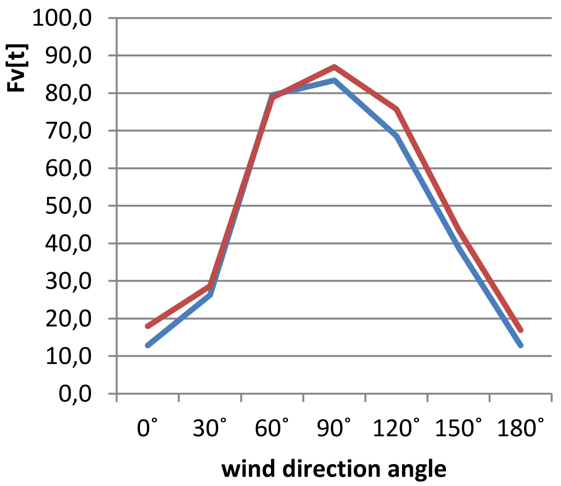

Image 41 Total wind force

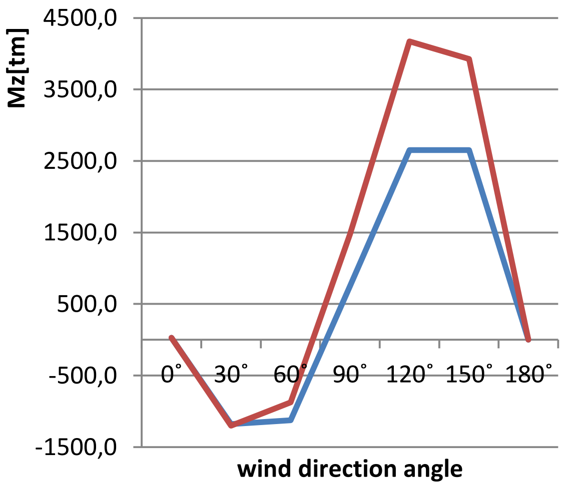

Image 42 Yaw moment

In compliance with the estimated values the total wind load for a conventional LNG carrier is 83,4 t and for Q-Max is 87 t and that applies in case of the lateral wind acting on the largest surface area of the vessel. Longitudinal force for a conventional LNG carrier is the highest for the angle of the wind's action of about 150˚ effecting the bow quarter and approximately is 15 t, whereas for Q-Max carriers for the angle of the wind's action of 0˚ effecting the stern is 18 t. As a result, the values are almost similar, since a conventional LNG carrier being smaller in length for almost 50 m, has 4 to 5 high spherical tanks, which increase the total surface effected by wind.

On the other hand, the yaw moment of Q-Max carriers is much higher and is about 4.100 tm, in comparison with 2.600 tm for a conventional carrier, which is based on the fact that the exposed surface of a conventional LNG carrier is the evenly distributed alongside the vessel length.

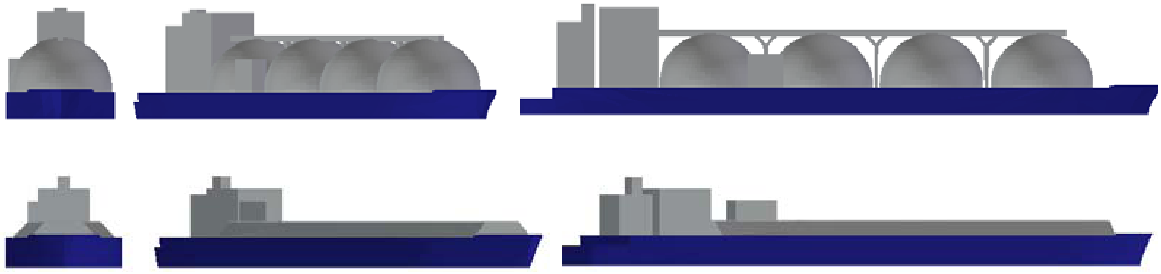

Figure 43 Cross-section of a conventional LNG carrier (above) and Q-Max carrier (below) at different wind angles of attack[46]

During the manoeuvre when the carrier is near and parallel to the terminal and during the stay at the terminal the carrier's port side will be set up at course of 225˚. In this case, the estimated forces for significant winds are as follows:

- In the case of bora from the NNE direction, the wind angle of attack on the ship is about 160°; For the conventional LNG carrier, the total wind force is 25.7 tons (of which 15.2 t longitudinal and 20.8 t transverse component), while for the Q-Max carrier the total wind force is 30.6 t (of which 18 t longitudinal, and 24.7 t transverse component).
- For the westerly wind from WNW direction the angle of the wind's action on the vessel is around 70˚; for conventional LNG carrier the total wind force is 83 t (parallel force of 2,7 and vertical force of 82,9 t) where for Q-Max vessel the total wind force is 84 t (parallel force of 3,9 t and vertical force of 83,9 t).
- For the lebić from SW direction the angle of the wind's action on the vessel is about 0˚ on the bow; in this case the total wind force is equal to the parallel force and for conventional LNG carrier is 12,9 t, where for Q-Max vessel is18 t.

Direction and angle of the wind's action	Conventional LNG carrier L=290m	Q-Max LNG L=345m
NNE 160˚	**25,7 t**	**30,6 t**
WNW 70˚	**83 t**	**84 t**
SW 0˚	**12,9 t**	**18 t**

Table 28 Estimated forces for wind moving at 25 knots from significant directions

In the case of a wind stronger than 6 Beaufort (>13,8 m/s), exceptional circumstances set in at the terminal and no manoeuvring is allowed. However, in the case of moored carrier, it is necessary to take into account the wind forces affecting the mooring and the terminal itself. Table below displays estimations of wind force on reference ships for winds from significant directions of force greater than 6 Beaufort.

46 Source: SIGTTO, Prediction of Wind Loads on Large Liquefied Gas Carriers, 2007

Direction and angle of the wind's action	Conventional LNG carrier L=290m					
	30 knots (15m/s)	**40 knots (20m/s)**	**50 knots (25m/s)**	**58 knots (30m/s)**	**68 knots (35m/s)**	**78 knots (40m/s)**
NNE 160˚	**37 t**	**65,8 t**	**102,8 t**	**138,3 t**	**190,2 t**	**250,1 t**
WNW 70˚	**119,5 t**	**212,5 t**	**332 t**	**446,5 t**	**614,2 t**	**817,3 t**
SW 0˚	**18,6 t**	**33 t**	**51,6 t**	**69,4 t**	**95,5 t**	**125,5 t**

Table 29 Estimated forces for winds stronger than 6 Beaufort from significant directions for the conventional LNG carriers

Direction and angle of the wind's action	Q-Max LNG L=345m					
	30 knots (15m/s)	**40 knots (20m/s)**	**50 knots (25m/s)**	**58 knots (30m/s)**	**68 knots (35m/s)**	**78 knots (40m/s)**
NNE 160˚	**44 t**	**178,3 t**	**122,4 t**	**164,6 t**	**226,4 t**	**297,7 t**
WNW 70˚	**121 t**	**215 t**	**336 t**	**451,9 t**	**621,6 t**	**817,32 t**
SW 0˚	**26 t**	**46,1 t**	**72 t**	**96,8 t**	**133,2 t**	**175,1 t**

Table 30 Estimated forces for winds stronger than 6 Beaufort from significant directions for the Q-Max LNG carriers

Wind forces for the largest FSRU terminals (Q-Max FSRU) can be considered equivalent to the above displayed for Q-Max LNG carriers. Their main features are almost identical, and small differences, which are considered negligible for the purpose of this study, can be in the surfaces of vessels that are above water due to the exposed additional equipment for regasification and manipulation with the cargo on the deck of FSRU. Therefore, in cases when the FSRU is moored alone, wind forces calculated for the Q-Max LNG carrier can be considered reliable and can be applied to the FSRU terminal.

In cases when one of the reference ships is moored at the FSRU terminal, it is necessary to take into account the total force affecting the interface of the FSRU terminal - berth. The total force affecting both vessels depends primarily on the wind angle of attack, that is, to what extent is FSRU sheltered from the direct impact of the wind.

In the case of predominantly side winds, such as the significant wind from WNW, the FSRU is almost completely sheltered by the LNG carrier. In that case the total force on both vessels can be considered equal to the wind force that affects only the exposed LNG carrier. Side wind can, to a lesser extent, directly affect the FSRU if the moored vessel is significantly smaller than the FSRU, but that force is not considered to be greater than that the one the FSRU vessel alone is exposed to (when LNG carrier is not present).

In the case of winds with the angle of attack directed into the bow or stern quadrant, such as wind from NNE, the FSRU vessel is, to a lesser extent, exposed to the direct impact of the wind. However, the circumstances are very similar to the ones in the previous case so it is estimated that the total force is not greater than the one generated when the FSRU vessel alone is exposed to the wind.

In the case of winds angled directly at the bow or stern, such as the significant wind from SW, the terminal is fully exposed and the total force that amounts to the sum of the wind forces affecting the LNG carrier and the FSRU. In such circumstances if, for example, the conventional LNG carrier (L = 290 m) is moored at the Q-Max FSRU (L = 345 m), the total force, in the case of a wind moving at 25 knots from SW, is 30,9 t (12.9 t + 18 t).

During winds that are angled directly at the bow or stern, and, to a lesser extent, at the bow or stern quadrant, it is important to keep in mind the balance in ropes as a result of currents between the LNG carrier and the FSRU. Such longitudinal flow can cause separation of one and the attraction of the other side of the vessel, depending on the wind direction. Possible movements can be prevented by timely checking the state of the mooring lines or by balancing the forces in the mooring lines.

6.1.2 The influence of sea current

The force caused by the sea current that affects the moored vessel is calculated by the formula:

$$F_{ms} = C_{ms(\alpha)} \cdot \tfrac{1}{2} \cdot \rho_v \cdot v_{ms}^2 \cdot A_{ms}$$

where:

Fms – force of the sea current that affects the vessel [N],

Cms()$_\alpha$ – water resistance coefficient of a body exposed to the impact of the sea current,

ρ_v – the density of seawater in which the vessel floats [kg/m³],

vms – speed of sea current [m/s],

Ams – surface of the underwater part of the vessel [m2].

The following is valid for reference boats:

- The exposed surface of the conventional LNG carrier ranges from 560 m² (longitudinal centreline) to 3.200 m² (transverse centreline), while the surface of Q-Max ranges from 645 m² (longitudinal centreline) to 4,000 m² (transversal centreline); given that vessels, when at berth, are located next to the FSRU terminal, i.e. the coastline, and are exposed only to the coastal current, the lowest values are assumed.
- The speed of sea current at good weather will not exceed 0.5 knots (0.3 m/s), while during the strongest winds it can be up to 1.5 knots (0.8 m s).
- The resistance coefficient is 2.9 and it is equal to the highest measured lateral resistance coefficient for loaded tankers and in the case when the water depth to draft ratio is only 1.1.

The total force of the sea current, under the above mentioned assumptions, is as follows:

Speed of sea current	Conventional LNG	Q-Max LNG
0.5 knots	**74,9 kN (7,5 t)**	**86,3 kN (8,6 t)**
1.5 knots	**532,7 kN (53,3 t)**	**613,5 kN (61,3 t)**

Table31 Total force of sea current for reference vessels

When the LNG carrier is moored at the FSRU terminal, the force at work is only that of the coastal current and it affects both vessels. Therefore, the total force is the sum of the force affecting the LNG carrier and the force affecting at the FSRU. For example, if the conventional LNG carrier (L = 290 m) is moored at the Q-Max FSRU (L = 345 m), the total force of the 0.5 knots sea current is 16.1 t (7.5 t + 8.6 t).

6.1.3 The influence of waves

The way the waves affect floating objects is very complex, so a highly accurate estimation of the effect of waves requires a complex calculation of questionable applicability due to a number of assumed boundary conditions. Therefore, the estimation is done using an empirical formula verified when estimating the required hauling force.

In accordance with the above mentioned, the force of waves that vertically affects the stringer of the vessel can be expressed using the following formula:

$$F_{val} = C_{val(\ )} \quad \tfrac{1}{2} \quad \rho_v \quad g \quad L \quad \left(\frac{Hs}{2}\right)^2$$

where:

Fval	–	the force of the wave [N],
Cval()$_\varphi$	–	empirical coefficient,
ρ_v	–	water density [kg/m³],
g	–	gravitational constant [m/s²],
L	–	length of the vessel on the water line [m],
Hs	–	significant wave height [m].

The following is valid for reference boats:

- Significant wave height is assumed during which a manoeuvre of 1 m is allowed (max. 2 m wave height), and in the case of a significant wave height above 1.5 m, departing manoeuvre in case of extraordinary circumstances is to be expected; the highest expected waves from SW can reach a height of 2.2 m.
- It is assumed that the wave affects the moored vessel at right angle.
- It is assumed that the empirical coefficient, including the security factor value of 2, is 0.7.[47]

Based on the above mentioned, (constant) wave force that affects the stringer of the vessel is:

Wave height	Conventional LNG carrier L=290m	Q-Max LNG L=345m
1 m	**255,2 kN (25,5 t)**	**303,5 kN (30,3 t)**
1,5 m	**574,1 kN (57,4 t)**	**682,9 kN (68,3 t)**
2,2 m	**1.234 kN (123,4 t)**	**1.469,2 kN (146,9 t)**

Table 32 Total force of waves on observed vessels6

It should be noted that the probability of the assumed wave height at the terminal site is very low due to the configuration of the surrounding coasts, especially considering the crossing waves in the area concerned.

When the LNG carrier is moored at the FSRU terminal, wave force affecting the stringer of the vessel should be calculated only for the LNG carrier. In this case, the FSRU terminal is sheltered by the carrier from direct impact of waves. Wave force can, to a lesser extent, directly affect the FSRU if the LNG carrier is significantly smaller than the FSRU. Otherwise, if there is no LNG carrier, the above mentioned values should be taken into account for the wave force affecting the stringer of the FSRU.

6.1.4 Boundary Conditions of Manoeuvring

Following the above mentioned evaluations of external forces and dynamics of reference vessels, as well as standards used on other existing LNG terminals during manoeuvring (during regular weather conditions), the use of the following is assumed:

47 Source: Hensen, H., Tug use in port – a practical guide, The Nautical Institute, London, 1997. According to the mentioned source, the empirical coefficient for the short period wave force is 0.35.

- 4 or more tugs, each with bollard force of at least 500 kN (50 t bollard force) during the docking manoeuvring, and
- 2 or more tugs, each with bollard force of at least 500 kN (50 t bollard force) during the departing manoeuvring.

The total bollard force is estimated taking into account the greatest transverse wind and wave force during permissible weather conditions for docking and the maximum force of the sea current that can be expected in the observed area, as well as additional 25% of force required for manoeuvring.

In the case of vessel having one or more bow thrusters of appropriate power, and if the weather conditions are favourable, the manoeuvring can be done using three tugs for docking and one tug for departing. The power of the tug must be at least 500 kN. Appropriate power of bow thrusters is at least 250 kN of propulsion force.

Following the above mentioned, the boundary conditions for docking manoeuvring are assumed as follows:

- the highest wind speed of 25 knots (≈13 m/s) and
- significant wave height of 1.0 m (max. 2 m wave height).

For the unmooring and departing manoeuvre, depending on its direction, wind speed can be 25% higher than the present limits allowed for the docking manoeuvring. [48]

During manoeuvring at the terminal or in its immediate vicinity, it is not permitted to manoeuvre and navigate other vessels.

Finally, it is suggested that mooring and unmooring manoeuvring during the first year or for the first 10 times the large LNG carrier is accepted, whichever comes first, is performed only during the daylight. After that period, if it can be concluded, based on the collected experiences, that both the mooring and unmooring manoeuvring at night are equally safe, the Harbour Master Office can approve the mooring and unmooring of the LNG carrier during the entire the day following prepared revision of the maritime study

6.2 ANNOUNCEMENT AND ACCEPTANCE OF THE SHIP

Due to organizational, security and safety reasons, the company and the master of the LNG are obligated to inform the terminal about the arrival of the LNG carrier. This announcement obligation with the necessary data and dynamics must be published and are an integral part of the Terminal Booklet. Data of the first announcement must include at least:

- name and identification of the ship,
- information about the last port,
- date and time for when the last cargo loading was completed,
- technical details about the cargo and the volume of the planned unloading, and
- expected time of arrival.

Announcement of arrival. The first announcement must be made upon completion of the cargo loading or upon departure from the previous port, after that 48 hours before the arrival, 24 hours before the arrival and 6 hours before the arrival. Commander of the LNG carrier is obligated to send the Notice of Readiness to the terminal upon arrival at the pilot station, confirming that the vessel is ready for mooring and planned transhipment operation.

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48 Approximately maximum 6 Beaufort at docking and maximum 7 Beaufort at departing.

Concept “acceptance of the vessel” includes all activities undertaken from the moment the LNG carrier enters the territorial sea of the Republic of Croatia until the beginning of the mooring manoeuvring. Vessels report to the VTS service upon entry into the territorial sea of the Republic of Croatia on the VHF channel 10 or 60 (sector B) and upon entering the Management Sector Rijeka (VHF) on the VHF channel 14 or 62. VTS Service, in accordance with the approval of the vessel’s arrival by the Ports Authority, issues a permission for the entry into the Management Sector and supervises the navigation of the ship until it reaches Manoeuvring Sector. Upon arrival at the Manoeuvring Sector Rijeka, vessels report to the Port of Rijeka Authority on the VHF channel 09 which issues approval for mooring or anchoring.[49]

Vessel traffic monitoring. From the point of view of the safety of the vessel, its cargo and conditions governing the waterway (see Chapter 2.5 Maritime Security), LNG carriers must be subject to enhanced surveillance from the moment of entry into the inland sea waters, especially in the Kvarner Bay, until their departure.

Due to the characteristics of the vessel and the prevention of risks of collision, it is recommended to introduce monitoring of the vessel’s domain, i.e. to ensure free space around the vessel by the VTS service or the Port of Rijeka Authority during the navigation from the moment vessel enters Vela Vrata until mooring or anchorage. This measure means that monitoring services would monitor the navigation of the LNG vessel and would warn other vessels in the vicinity of the need to maintain the necessary safety distance. Vessel’s domain that would ensure a satisfactory level of safety even in case of the largest LNG carriers, i.e. provide enough time to avoid collision with a vessel from any other direction, is a space of 1,000 m from the bow and stern of the vessel and 500 m on each side. The specified space is approximately 3 lengths and 10 widths of the Q-Max ship.

By introducing this measure, it would be possible to avoid situations when an LNG carrier is passing by close to other vessels on short distance, , which significantly increases the safety of navigation considering the sensitivity of the cargo they transport.

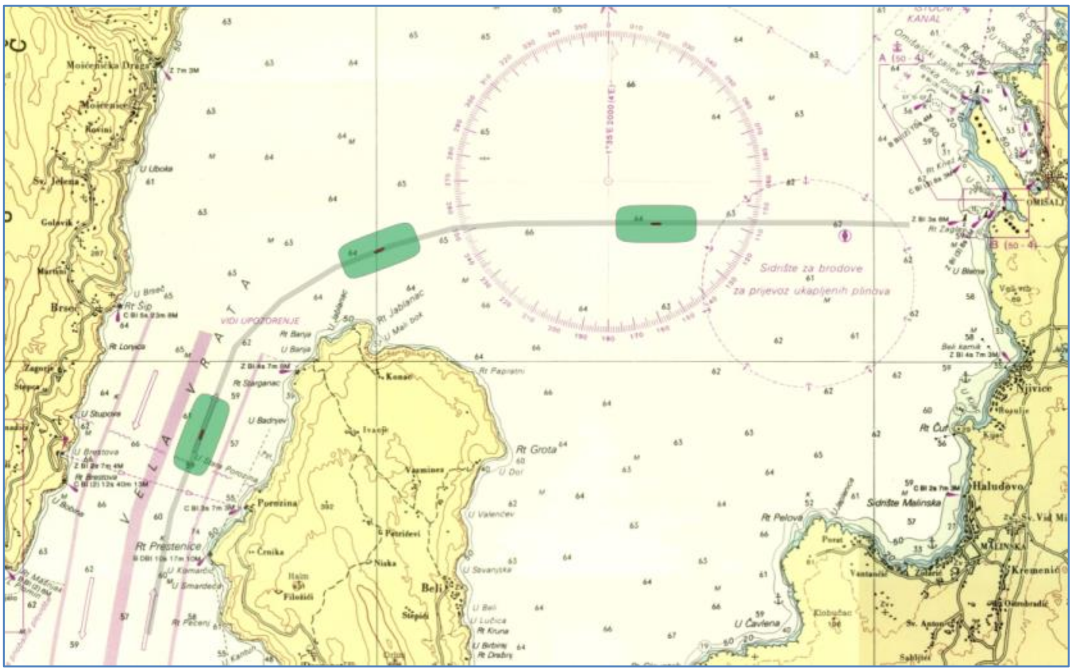

Figure 44 Recommended LNG carrier domain (green) on the usual approaching waterway

49 Pursuant to the Ordinance on maritime safety in the internal waters and territorial sea of the Republic of Croatia and the manner and conditions for carrying out the vessel traffic monitoring and management.

In accordance with the existing arrangements for the navigation through the passage Vela Vrata, the speed for the navigation of merchant ships in the waterways is not limited. However, unlike a tanker that has a normal speed ranging from 12 to 14 knots, LNG carriers can develop a speed of up to 21 knots, thereby significantly reducing the time available for collision avoidance manoeuvres.

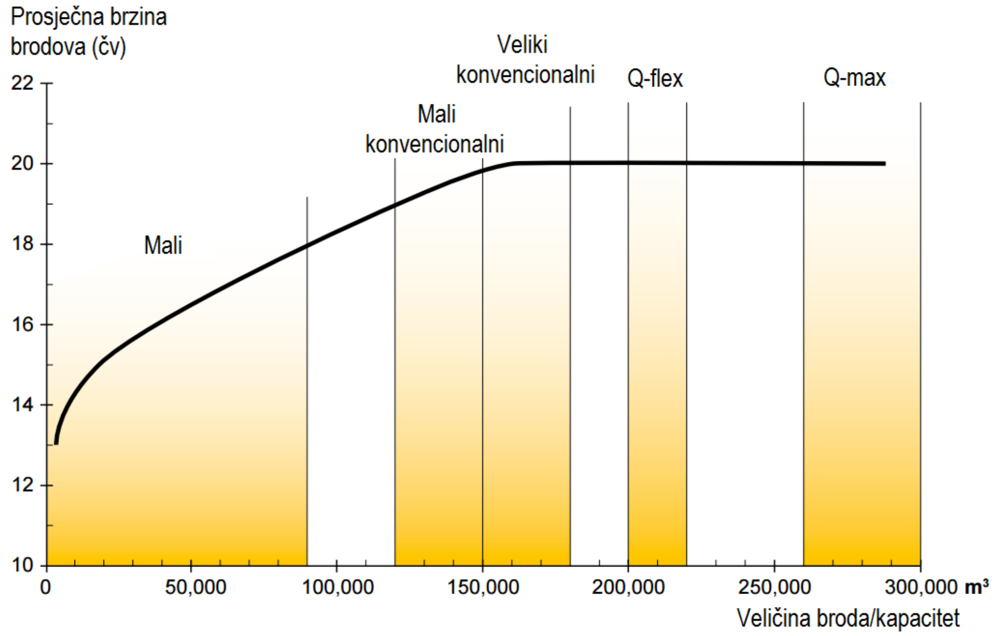

Figure 45 Average speeds of LNG carriers of different sizes8

Considering that the construction of a new LNG FSRU terminal will increase the number of vessels carrying dangerous cargo and at relatively high speeds, it is further recommended to introduce a speed limit of 15 knots for the navigation of all vessels carrying dangerous or polluting substances in a liquid state in the ship's routing system area Vela Vrata. The introduction of this measure would increase the safety in the Rijeka Bay as the tankers and LNG vessels would enter the bay at a reduced speed that they wouldn't increase due to the distance of only 10 M to the dock or anchorage.

Pilotage. The pilotage service is initiated by a call on the VHF channel 12. Pilot comes to the ship with the help of a pilot boat. The ship is obligated to provide lee for the pilot boat when the pilot is coming on board and provide to the pilot a safe boarding to the ship with the help of pilot ladders, ship ladders, or a combination of pilot and accommodation ladders. Navigation with the pilot on board must be conducted according to the usual rules of the profession.

In accordance with the existing arrangements, the reception of the port's pilot for vessels transporting liquefied gas is done at the site for the boarding of the pilot as charted on the charts, i.e. at 45 ° 11.8 'N, 014 ° 29.4' E. The pilotage station is located within the anchorage for ships transporting liquefied gas, approximately 2 M west from the dedicated LNG FSRU terminal. The position of the pilotage station, as it is charted today, is not acceptable for LNG carriers for several reasons, but primarily because it is too close to the berthing point, and in particular because it is hampers the portside and starboard berthing manoeuvring (in one case the ship approaches southward, and in the other northward).

Therefore, guided by the same principles as in the case of speed limitation, it is recommended to introduce mandatory pilotage through the passage Vela Vrata until the vessel reaches the berth for all vessels carrying dangerous or polluting substances in a liquid state longer than 250 m. For the implementation of this measure it is necessary to establish a pilotage station south of the passage Vela Vrata for the boarding or disembarking of the pilot.

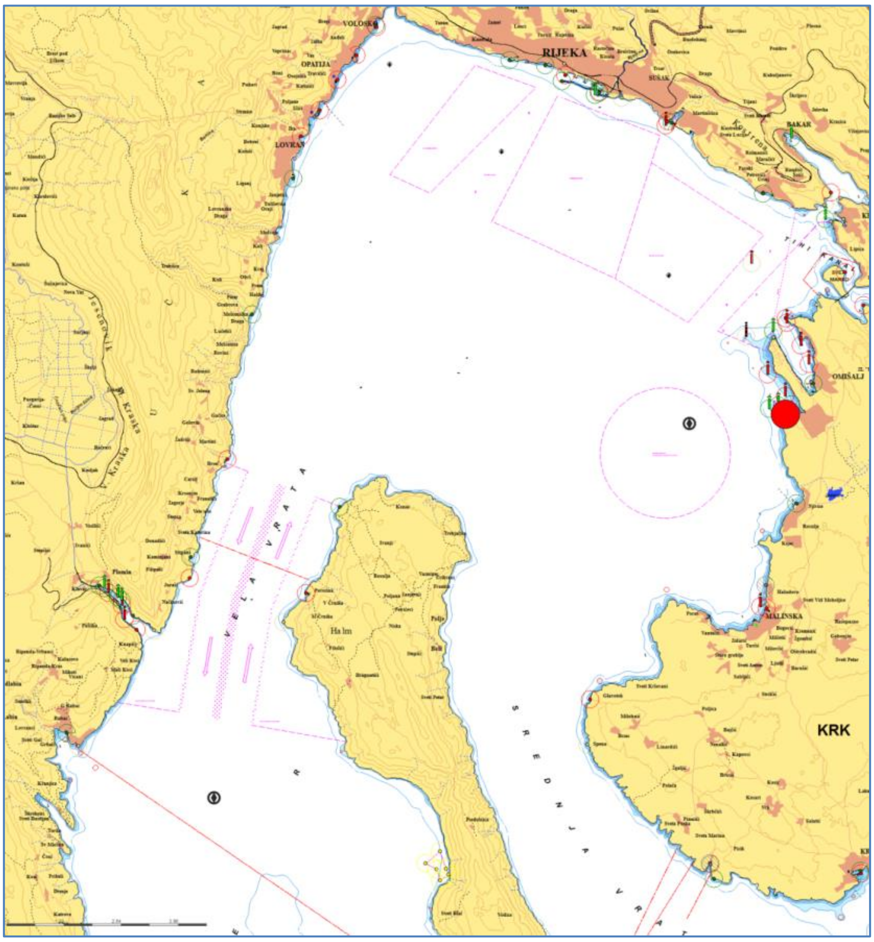

Figure 46 Proposal of the pilotage station location for LNG carriers

Furthermore, the use of two pilots is recommended during the first year after the commencement of the terminal's operation. If experience reveals that one pilot is enough, the obligation to use two pilots can be changed after gaining enough experience.[50]

Considering the complexity of the berthing, especially during the summer period, it is suggested not to allow exemptions from the pilotage obligation, regardless of the number of manoeuvres made by a given commander on a vessel.

In view of the usual practice, mandatory use of Portable Pilot Unit (PPU) is recommended. PPU must meet at least the following:

- it has autonomous determination of the whereabouts of the vessel and the heading direction,
- provides horizontal position accuracy of 0.50 m or less,
- displays the heading direction of the vessel of 0.5º or less (calculated),
- displays change in the heading direction (ROT) of 0.5º or less,
- measures the speed of movement in all directions with an accuracy of 0.02 m/s or less.

Exceptionally, if the visibility is good at berth and wind speed is less than 5.0 m/s, a PPU that retrieves heading data from the ship's system may also be used.

50 It is also recommended to prescribe the mandatory pilotage with two pilots and boarding of pilots at a new pilotage station for all vessels longer than 250 meters carrying dangerous or harmful liquid cargo.

Anchorage. In the case anchoring is required LNG carrier shall be anchored on the existing anchorage intended for vessels transporting liquefied gas. In the case two LNG carriers need to be anchored their mutual distance must be at least 0.8 M or approximately 1.500 m. Anchoring more than two LNG carriers is very unlikely, but even if it happens it is possible to anchor up to 4 LNG carriers on the existing anchorage under the surveillance of the competent VTS service and in a manner that is appropriate to ensure a satisfactory conditions for all anchored vessels. It should be stressed out that the existing anchorage is currently used by LPG vessels that dock at the liquefied petroleum gas terminal Sršćica. The anchoring of LNG and LPG vessels at the same time is permitted if the previously determined distance between LNG carriers is met.

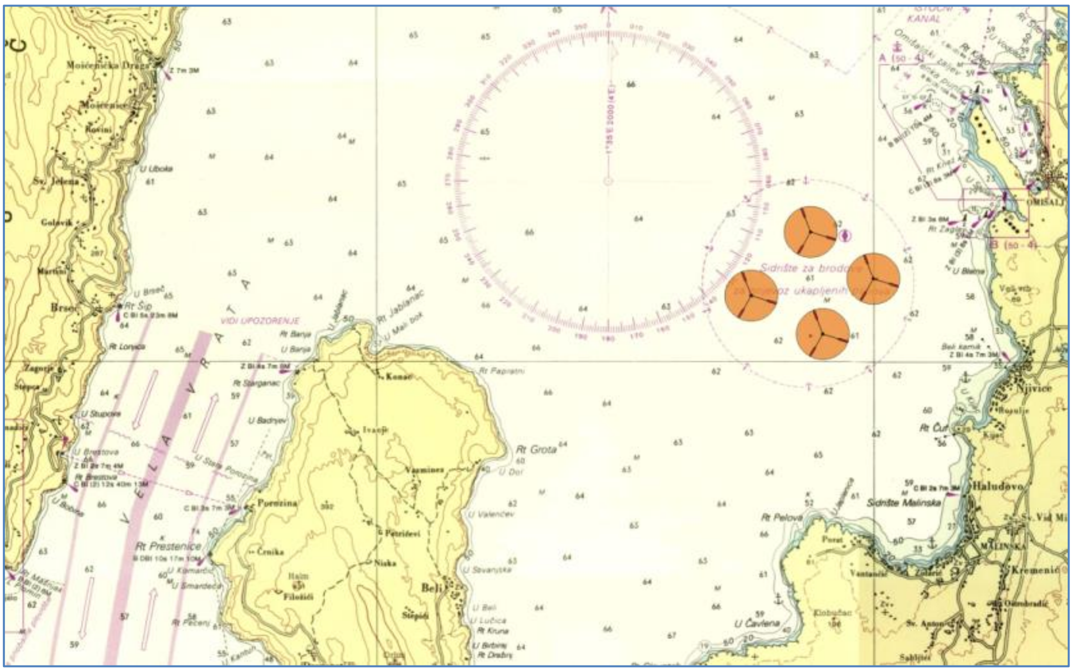

Figure 47 Existing anchorage for vessels transporting gas with charted entrance circles of 1,500m in diameter

Vessels docked in the Sapan Bay at the DINA Petrokemija terminal, were generally smaller vessels up to 150 m long and mostly docked with the portside to the berth. The main reason for such berthing was to direct the bow of the vessel towards the open part of the bay while at berth for the purpose of facilitating the unberthing in the case of extraordinary circumstances, even without tugs. The second reason is that most vessels have right-handed propellers that sway the vessel towards the left side, i.e. toward the terminal when the vessel is going astern as a result of transverse thrust force, which partly simplifies the manoeuvring in the final stage. However, due to the spatial limitations of the Sapan Bay, the entire docking manoeuvring is very complex, i.e. it was performed by vessels approaching from the northwest along the Cape Knez and then by turning the vessel directly in front of the dock.

Manoeuvring of vessels is made more difficult by the shallow water (13.7 m) located about 250 m from the edge of the coast in the northwest direction. Shallow water is marked with two green navigation marks.

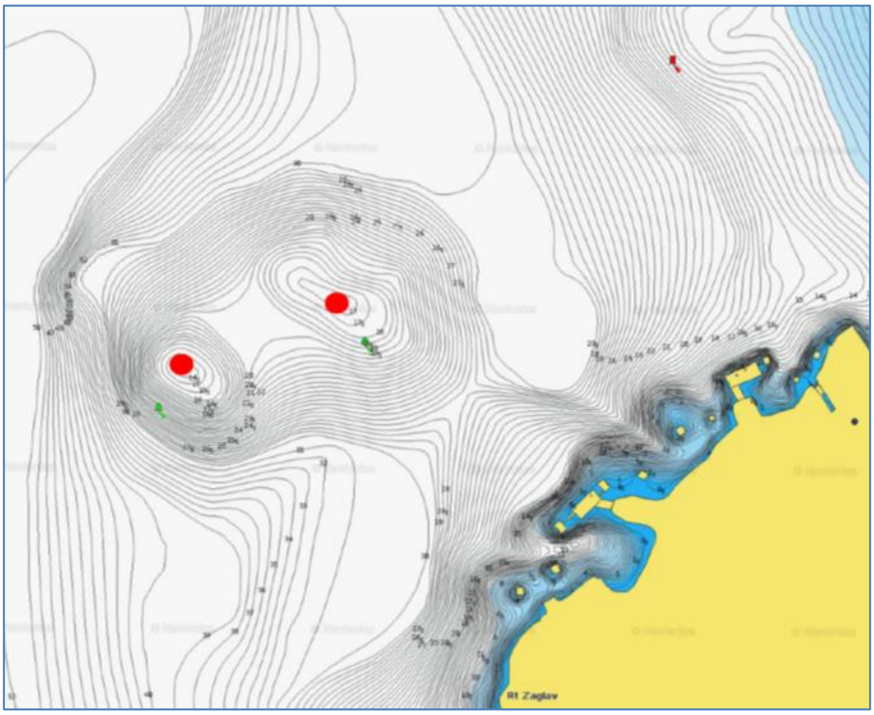

Figure 48 The position of shallow water that needs to be dredged to a depth of 15 m

For safe manoeuvres from any direction and the stay of the largest LNG carriers the dredging of shallow waters (13.7 m) in front of the intended terminal should be done to the depth of at least -15 m and is estimated that it will be necessary to dredge about 11.000 m³.[51]

The FSRU ship will be berthed at the dock portside, with the bow towards the open part of the bay. Given that the FSRU terminal is basically a ship capable of manoeuvring and navigation and that it must maintain that ability at all times, its orientation must be adjusted accordingly. In case of forced unberthing in extraordinary circumstances, FSRU's departing manoeuvre will be significantly facilitated if it's berthed at the dock portside, i.e. with the bow towards the open part of the bay. In some circumstances, depending on the weather conditions, it can be done without the help of a tug, but such departure should be avoided.

Furthermore, the orientation of the terminal affects the orientation of the LNG carrier's berth. Generally speaking, on LNG carriers, and even FSRU vessels, manifold for the transhipment of cargo can be at different distances from the middle of the vessel, but are most often slightly more towards the stern from the middle. As a rule, due to the alignment and joining of the manifolds, vessels of similar or greater length than the FSRU must be moored to the FSRU with the same orientation (bow to bow). LNG carriers that are smaller than the FSRU can be moored to the FSRU with the opposite orientation (bow to stern) in the case their manifolds can be aligned after mooring. Possible berthing interconnections depend on the technical features of the future LNG FSRU terminal and on that of every arriving LNG carrier. The frequency of the arrival of certain vessels in terms of their size and/or features, as well as experience with demanding docking or arriving manoeuvrings can subsequently affect the adjustment or the change of orientation of the FSRU ship from that proposed in this study.

51 Pursuant to the Environmental Impact Study for Import terminal for liquefied natural gas on the island of Krk, Oikon d.o.o, Institute for Applied Ecology, Zagreb.

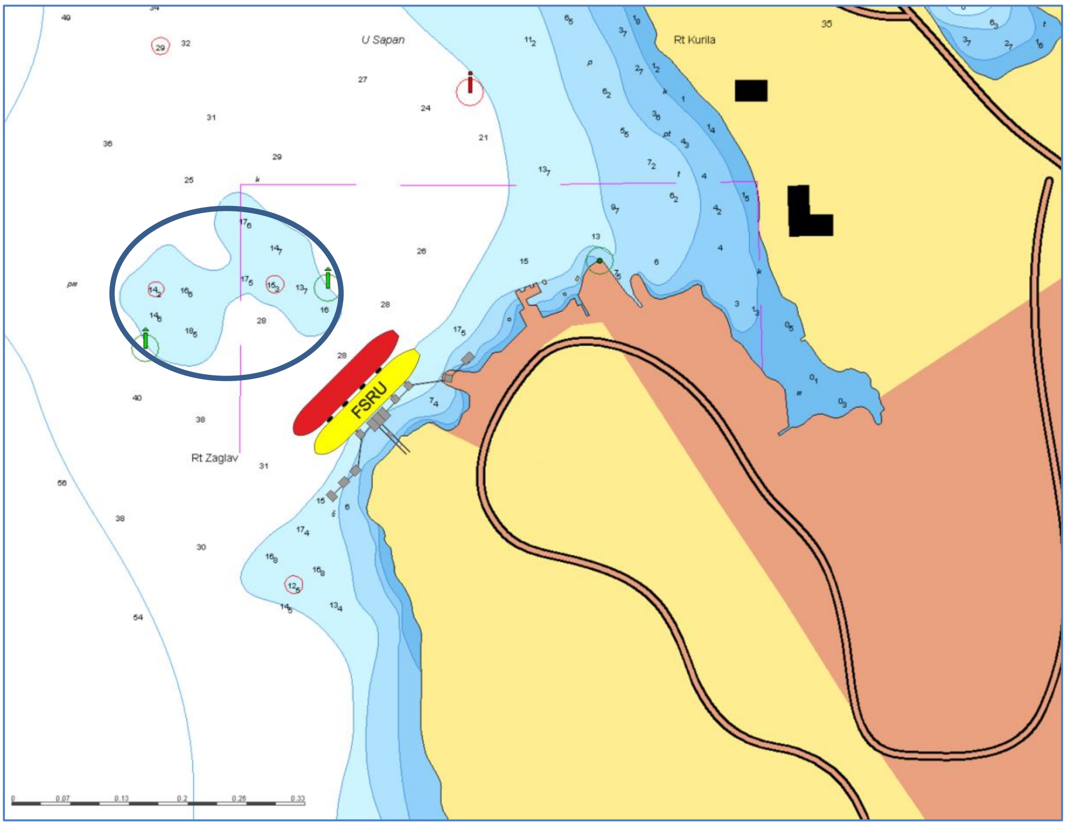

Figure 49 LNG carrier (red) berthed portside on the FSRU terminal (yellow) and the illustration of shallow waters directly in front of the berth

Based on the above mentioned, it is recommended that the FSRU be berthed portside.

Arrival and departure of LNG carriers without tugs is unacceptable. Furthermore, the presence of one tug in stand-by is anticipated at a sufficient distance from the terminal, in case of exceptional circumstances during the stay of the LNG carrier at berth.

The following figures illustrate general (basic) approaching and departing manoeuvrings under the following assumptions:

- shallow waters and the two accompanying green navigational marks are removed, in accordance with the real state after the terminal commenced operation,
- FSRU terminal (L = 300m) is permanently berthed portside, i.e. with the bow towards the open part of the bay,
- LNG vessels (L = 300m) are berthed with the same orientation as the FSRU,
- LNG vessels of smaller length (L <250m) can be berthed with the opposite orientation on the FSRU.

The docking manoeuvrings of LNG carrier are performed using four tugs, which is the smallest number of tugs required for a safe berth without the bow thrusters. Manoeuvres performed with greater or smaller number of tug are not specifically described. The manoeuvring process can be similar to the described one, while the mode and exact place where the tug will be accepted depend on the weather conditions and on the characteristics of the vessel.

Stern tug is generally the first one to be tied, most often by a steel rope through the fairlead. Also, the strongest tug is usually used as the stern tug. Bow tug is the next, and is followed by the side tugs. However, this order may vary if circumstances so require. Pushing tugs can be accepted on the bow and on stern outside the bow and stern curves at approximately 1/5 of the vessel's length from the stern and bow, provided that an appropriate length of the towage is provided if necessary. The choice of manoeuvring mode and how, in what order and where will the tugs be accepted I subject to an agreement between the pilot and the commander, and is based on the technical and technological features of the vessel and the prevailing weather conditions.[52]

Finally, it should be noted that the docking and departing manoeuvring are the same for the arrival of both the FSRU and the LNG carrier.

Portside berthing

In the case of the portside berthing, two manoeuvres are possible – approaching from the inner part of the bay and by directly arriving at the terminal. Approaching from the inner part of the bay is the maneuverer that was used at the existing terminal DINA Petrokemija. In this case, the ship must approach the terminal from the NNW in the direction of the red mark directly in front of Cape Knez. As the vessel approaches tugs are accepted on bow and stern.

Two tugs for towing are accepted on the bow and one on the stern through the fairlead, while one tug for pushing is accepted on the starboard.

From the red mark of the Cape Knez the vessel navigates along the coastline until it reaches other red mark in front of the Cape Kurila. Between the final mark and the terminal, almost parallel with terminal, the vessel must rotate through 90˚ to the right using tugs. In the final stage, the vessel is placed parallel to the terminal to a location approximately one width of the ship away from the terminal. Bow tug is then released and placed along the portside on the bow for pushing.

Upon arriving and stopping parallel to the terminal, the side tugs begin pushing the vessel towards the terminal. The thrust force depends on the direction and speed of the wind, and to a lesser extent on the effect of sea currents and waves. In the event vessel needs to be moved longitudinally, the main ship thruster will be used. The usual speed of vessel's approach to the terminal should be up to 0.15 m/s, and is limited by the use of tugs for pushing at the end part of the bow and stern. The speed of the vessel's approach can also be regulated using side tugs which can shift from pushing the vessel to pulling the vessel and vice versa, using the direction opposite the action of the bow thrusters. Based on the agreement between the pilot and the commander of the vessel, in the final stage of side approach of the vessel, tug that pulls on the bow and/or stern can release its towage and commence pushing.

Once the vessel is sufficiently near the terminal, mooring lines are placed, usually the springs first, and then the breast lines, forward lines and stern lines. Vessels of reference size do not use mooring lines to attract the vessel, instead only tugs that push the vessel along the FSRU are used.

52 The curved part of hull, on the bow and stern, outside the area of the parallel midbody area does not allow the acceptance of tugs if the tug is to be used of pushing the vessel. . When pushing the vessel, tugs must be set against the part of the hull which is constructed for that purpose. That part of the hull is strengthened and marked by the letter "T" or "TUG".

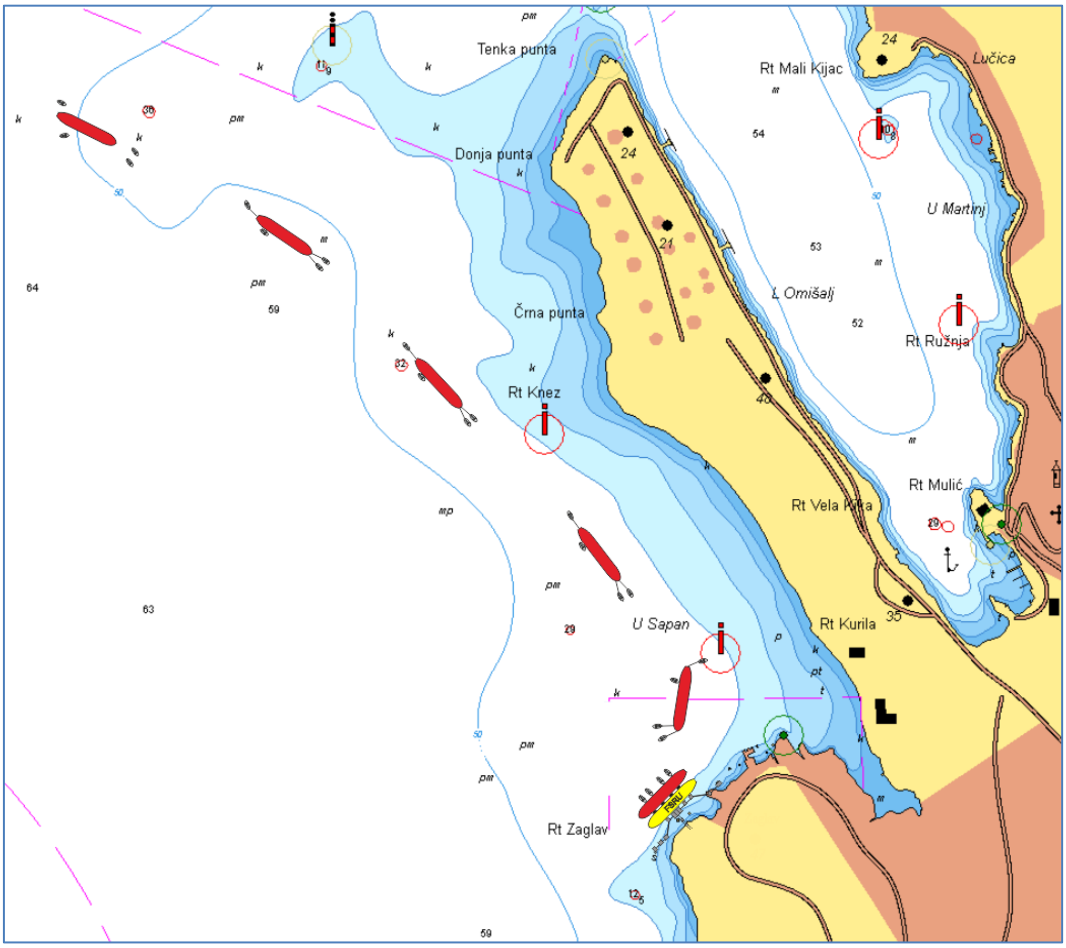

Figure 50 Basic mode of portside berthing manoeuvring

The previous approach won't be used by the largest LNG carriers (Q-Max carrier). For largest LNG carriers, with relatively modest manoeuvring capacity, the manoeuvre of direct arrival is used, if possible.

In the case of direct arrival manoeuvre, the vessel approaches the terminal directly by bow at a reduced speed. In this case, the direction of arrival is not critical. Two tugs are accepted on the bow and stern, one is accepted for pulling through fairlead or other suitable place, and another side tug is accepted for pushing. One to two lengths of the vessel before the terminal, using its own thrust and with the help of a tug the vessel is almost completely stopped, and starts rotating sideward through 90˚.

The power used for rotating is mostly that of the tug on the bow for pulling and the tug on the side of the stern. Other tugs help and also serve to limit the speed of the vessel's rotation. When the boat is placed parallel to the terminal, the vessel is pushed sideways towards the terminal. In this case, portside berthing manoeuvre and starboard berthing manoeuvre are the same. The final sideward approach to the terminal and mooring takes place as in the previous case.

Docking manoeuvre by direct arrival to the FSRU and both portside berthing and starboard berthing can be considered one of the most likely ways of docking for larger LNG carriers using 4 tugs for berthing.

Starboard berthing.

Starboard berthing of the LNG carrier on the FSRU, which is berthed from the portside, can be done if the arriving vessel is smaller than the FSRU and if the alignment of manifolds in the opposite orientation is possible. The basic starboard berthing manoeuvre of the LNG carrier (L = 250m) on the FSRU (L =

300m) is described below, under the assumption that the alignment of manifold with the terminal is possible.

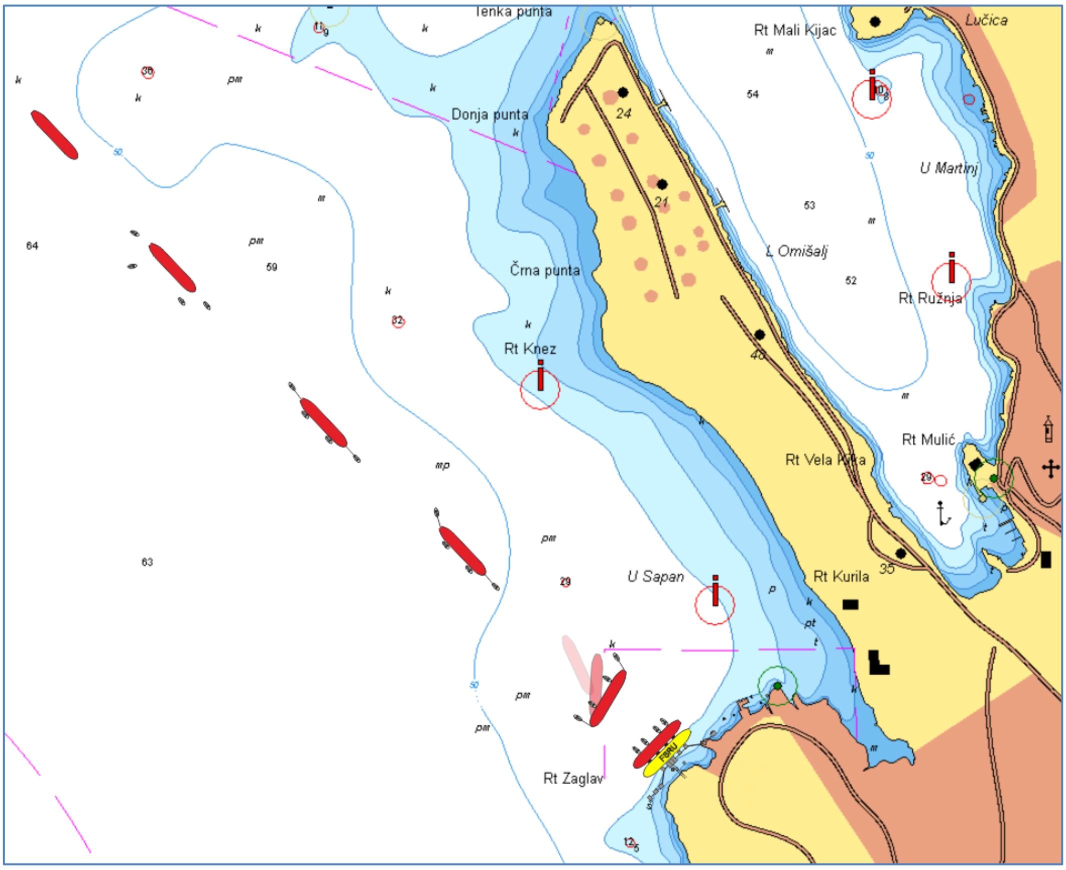

Figure 51 Portside berthing manoeuvre by direct arrival at the terminal (the access route can be different from the illustrated one, depending on the anchorage occupancy and other circumstances) 9

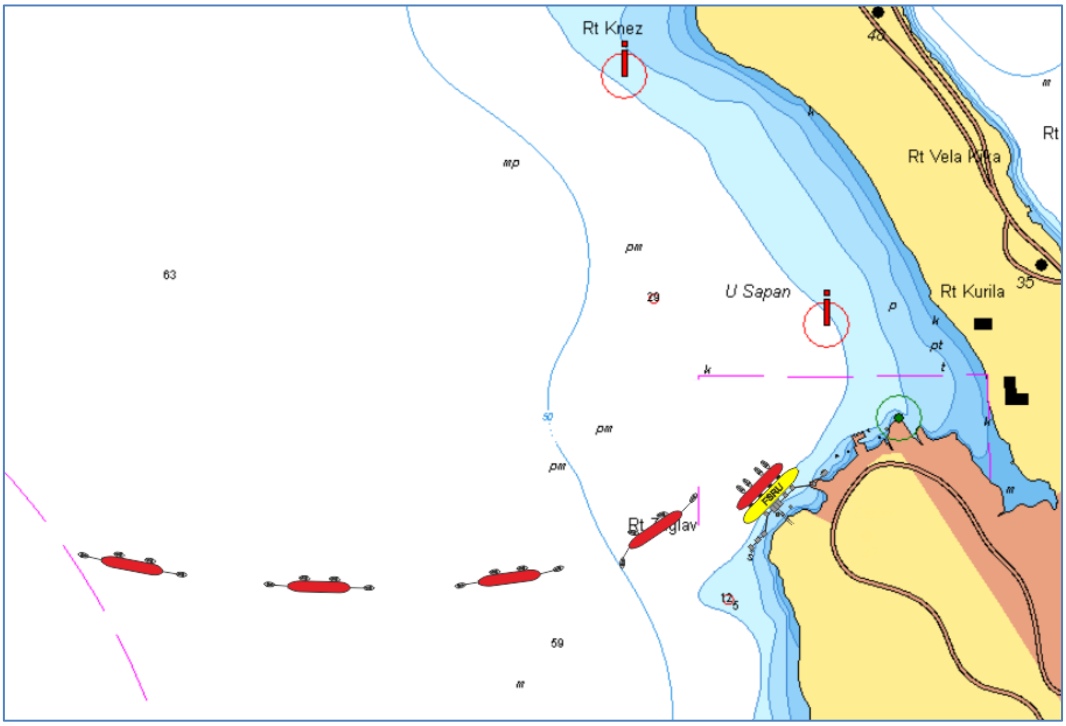

Figure 52 Basic starboard berthing manoeuvre

For the purpose of starboard manoeuvre the vessel can approach by direct arrival, as described above, or from the west. In the latter case, the ship must approach the terminal from WNW to WSW. As the vessel approaches tugs are accepted on bow and stern. On the bow and stern two tugs are accepted, one is accepted for pulling through fairlead or other suitable place, and another is accepted on the starboard for pushing.

When the weather conditions are favourable, the vessel approaches the terminal at an angle of 10° - 20°, and in the final stage it is positioned parallel to the terminal approximately one width of the ship away from the terminal. The vessel is brought to rest using its own thrust and with the help of tugs. When the weather conditions are unfavourable, the approach to the terminal will be changed depending on the direction and speed of the wind and the effect of the sea current.

Upon arriving and stopping parallel to the terminal, the side tugs begin pushing the vessel towards the terminal. The final sideward approach to the terminal and mooring takes place as in the previous case of portside berthing.

6.3 UNMOORING AND LEAVING BERTH

For the unberthing manoeuvre of the vessel all the basic remarks from the section on the berthing of the vessels apply, and the main factor determining the manoeuvring mode is the prevailing direction and speed of the wind.

The mode of carrying out unberthing and departing manoeuvre is illustrated by using two tugs, which represents the smallest number of tugs required for the safe unberthing of the vessel. Manoeuvre performed using more tugs is not specifically described. The manoeuvring process is similar to the described manoeuvres with the help of two tugs, while the mode and exact place where the tug will be accepted depend on the weather conditions and on the characteristics of the vessel. In general, the commander of the vessel and the pilot should reach an agreement on the acceptance of tugs before the manoeuvre begins.

Unberthing and departing manoeuvre under favourable weather conditions is carried out by accepting two tugs for pushing at the end parts of the bow and stern. In case the vessel is equipped with a bow thruster it will be used for additional pushing of the bow.

Five options for departing manoeuvre are illustrated, one in the case of portside berthing, as departing from that orientation is less complex, and four in the case starboard berthing.

As opposed to arriving, the departing manoeuvre for the vessel berthed at the portside is very simple considering that there is no obstacle in front of the bow or in the direction of departure so there is no need to rotate the ship. Once the mooring lines are released, the vessel moves away from the terminal with the help of one tug accepted on the stern, one tug accepted on the bow and/or bow thrusters. At a safe distance from the terminal, of at least one width of the vessel, and using the main ship thruster and the rudder, the vessel moves forward and is set an appropriate departing angle. Under favourable conditions tugs can be released immediately upon leaving the safety zone, i.e. on a distance of 2-3 length of the ship from the terminal.

The first departing manoeuvre option for the vessel berthed starboard is suitable in favourable weather conditions for vessels with right-handed propellers. In this case a heavy use of ship's engine is assumed. Once the mooring lines are released, the vessel moves away from the terminal with the help of one tug accepted on the stern, one tug accepted at the bow and/or bow thrusters. At a safe distance from the terminal, of at least one width of the vessel, using the main ship thruster and the rudder, and with the help of the tug, the vessel reverses to the opposite direction and is set an appropriate departing angle (direction W). When the vessel is going astern, its rotation is helped by the thrust force of the stern to the left side. When rotation into the opposite direction ends and the vehicles is brought to rest the tugs are released (in case of favourable weather conditions they are released earlier during the rotation) and the vessel moves away using its own thrust and towards the place for the disembarking of the pilot accompanied by at least one tug.

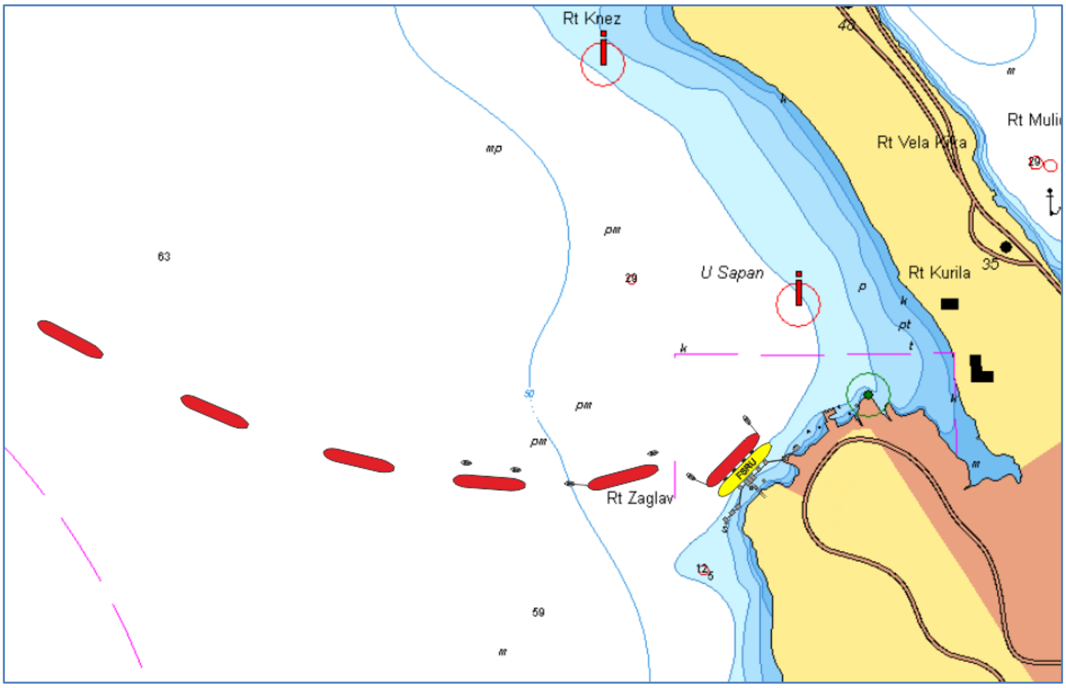

Figure 53 Departing manoeuvre for the portside berthed vessel

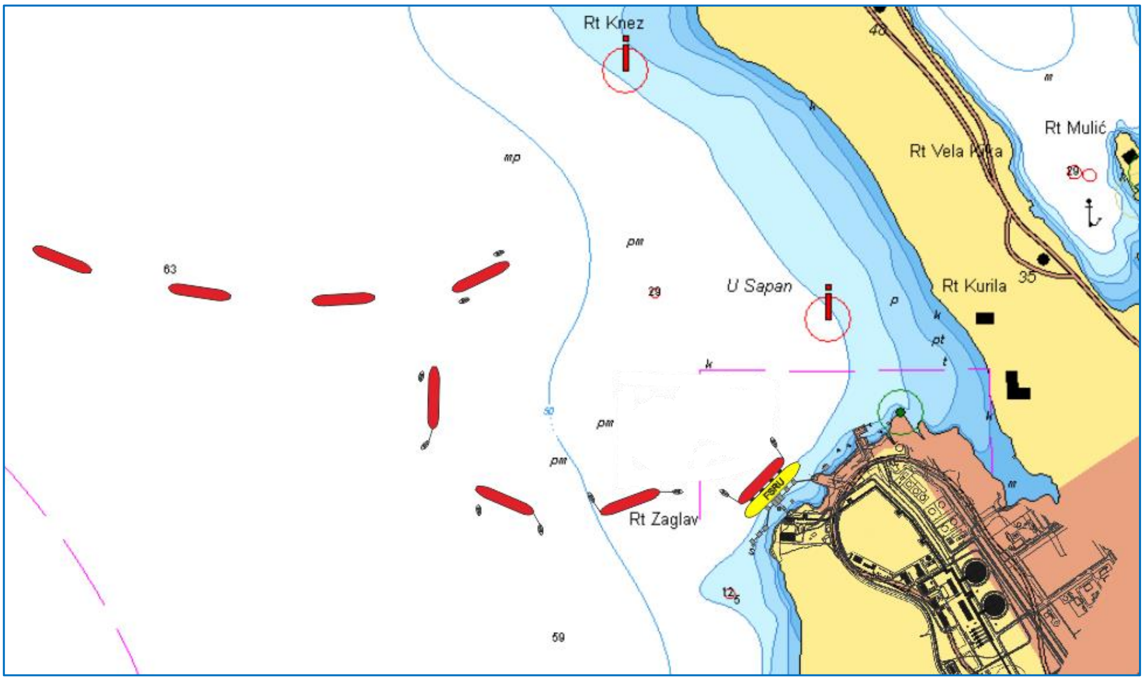

Figure 54 Departing manoeuvre for the starboard berthed vessel - Option 1

In the case of winds from the south, manoeuvre will be easier, but it is worth keeping in mind that there can be a change in the direction and intensity of wind, and is therefore necessary to monitor the yawning of the vessel. Stronger winds from the north and west require the use of more or additional tugs, and the vessel will need to be at a greater distance from the terminal for the safe rotation and departure. In these cases the following options can be more appropriate.

The second departing option for the starboard berthed vessels is similar to the previous one, but the rotation is primarily done with the help of tugs, and, to a lesser extent, the main ship thruster. Once the mooring lines are released, the vessel moves away from the terminal with the help of tugs, and then at a safe distance the vessel turns in the opposite direction almost in place. During that time, the main ship thruster is quiet, while the tugs rotate the vessel on their own until a favourable departing angle is reached.

The third departing option for the starboard berthed vessels is performed by turning the bow towards the departure direction and, as in the previous case, this is done mostly by tugs. Once the mooring lines are released, the vessel moves away from the terminal with the help of tugs on the bow and stern applying equal force. At a safe distance the vessel turns by the bow to the left with a heavier operation of the bow tug and bow thruster. In the second stage of rotation, when the pulling of the stern is no longer needed, the stern tug is released and is then positioned for pushing the stern. With the help of both tugs, the ship turns to a favourable departing angle and tugs are released.

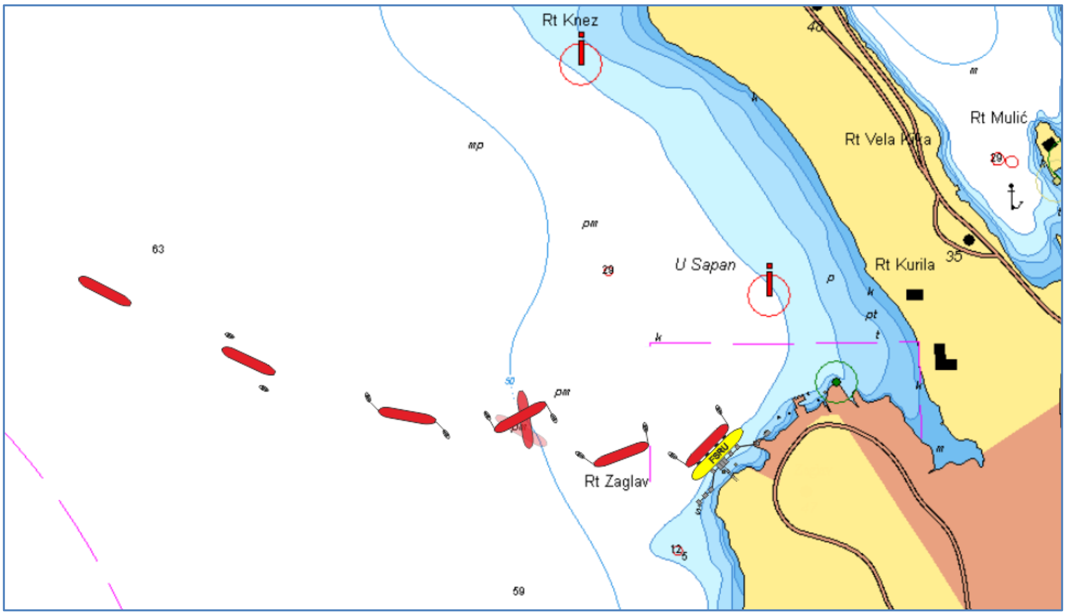

Figure 55 Departing manoeuvre for the starboard berthed vessel - Option 210

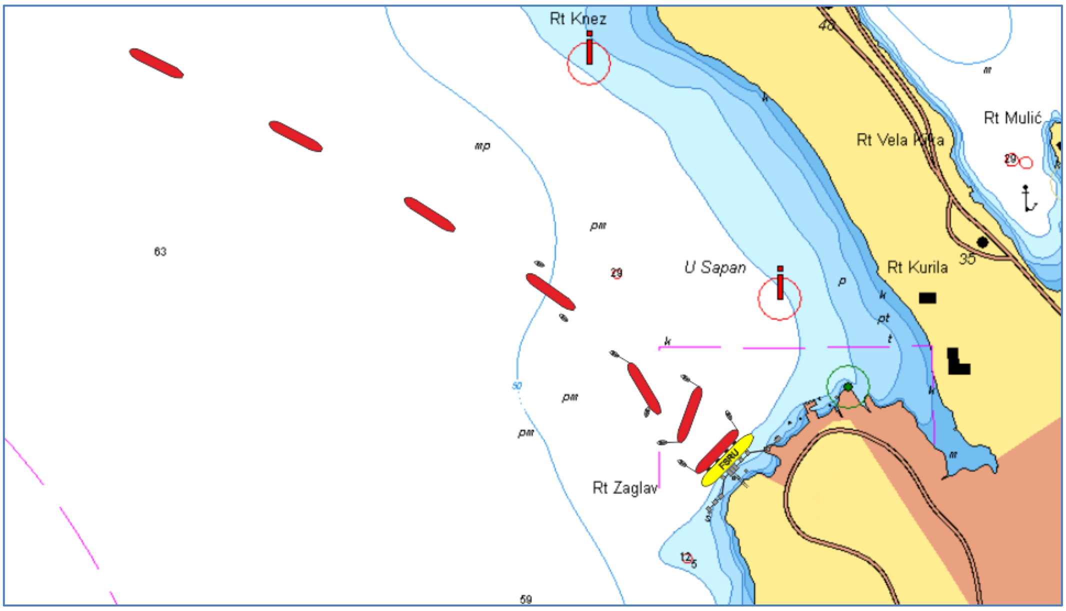

Figure 56 Departing manoeuvre for the starboard berthed vessel - Option 3

The fourth departing option for the starboard berthed vessel includes sideward departing of the vessel from the berth with the use of tugs, after which the vessel reverses using its own thrust in the direction of SE until it reaches a distance of 3-5 lengths of the ship. During the astern movement tugs are placed along the stringer of the vessel and help directing the vessel. In a favourable condition, bow tug can release the towage before the vessel is brought to rest and start pushing the bow from the right. After it is brought to rest, the vessel turns left by navigating forward using its own thrust until it reaches favourable angle for departing and reaching the pilotage station.

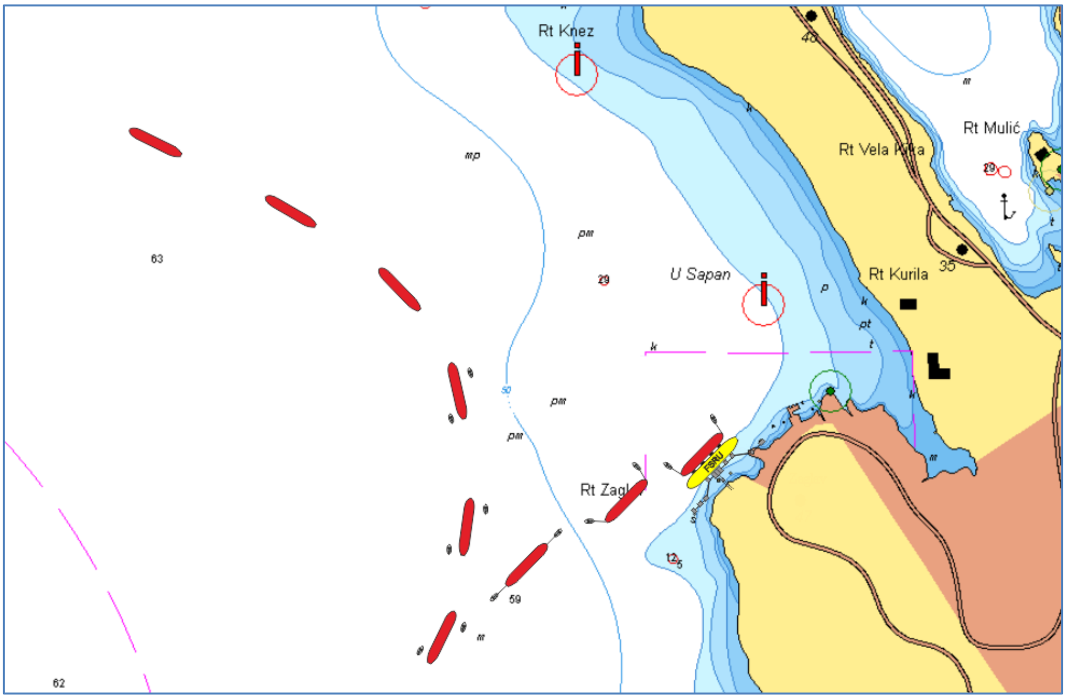

Figure 57 Departing manoeuvre for the starboard berthed vessel - Option 4

Conclusion:

(28) The boundary conditions for docking of LNG carrier at the FSRU terminal are constant wind speeds of 25 knots (≈13 m/s) and a significant wave height of 1.0 m (max. 2m wave height). For the unmooring and departing manoeuvre, depending on its direction, wind speed can be 25% higher than the boundary speeds allowed for the docking manoeuvring.

(29) Standard procedure for the announcement of the arrival of an LNG carrier is provided.

(30) It is recommended to perform enhanced surveillance of the LNG carriers by a competent VTS service during their navigation through the territorial sea of the Republic of Croatia.

(31) It is recommended to introduce the safety domain around the LNG carrier, i.e. to ensure free space around the vessel by the VTS service during the navigation through the navigation in the ship's routing system area Vela Vrata until berth or anchorage. The recommended size of the free space is 1,000 m from the bow and stern of the vessel and 500 m on each side.

(32) It is recommended to introduce a speed limit of 15 knots for the navigation of all vessels carrying dangerous or polluting substances in a liquid state in the passage Vela Vrata.

(33) It is recommended to introduce mandatory pilotage through the passage Vela Vrata until the vessel reaches the berth for all vessels carrying dangerous or polluting substances in a liquid state for longer than 250 m. It is recommended to establish a pilotage station south of the passage Vela Vrata for the boarding or disembarking of the pilot.

(34) It is recommended to use of two pilots during the first year after the commencement of the terminal's operation. If experience reveals that one pilot is enough, the obligation to use two pilots can be changed after gaining enough experience. It is also recommended LNG carriers be exempt from the exemption from the mandatory pilotage.

(35) It is recommended to make use of Portable Pilot Unit (PPU) mandatory, under the condition the characteristics of PPU correspond to that listed in the study.

(36) The change of existing anchorage intended for vessels transporting liquefied gas is not provided.

(37) For safe manoeuvres from any direction and the stay of the largest LNG carriers, it is precondition to perform the dredging of shallow waters (13.7 m), located about 250 m from the coastline of the new LNG FSRU terminal in the northwest direction, to the depth of at least -15 (measured from the hydrographic zero).

(38) During manoeuvring, use 4 or more tugs is compulsory, each with bollard pull of at least 500 kN during the docking manoeuvring, and 2 or more tugboats, each with bollard pull of at least 500 kN during the departing manoeuvring.

(39) As a rule, portside LNG carrier berthing is used, i.e. with the bow of the ship towards the open sea.

(40) Mooring and unmooring manoeuvring during the first year or for the first 10 times the large LNG carrier is accepted, whichever comes first, is performed only during the daylight. After that period, the Harbour Master Office can approve the mooring and unmooring of the LNG carrier during the entire the day following prepared revision of the maritime study

7 PLAN OF MOORING AN LNG CARRIER

Mooring equipment of the dock and FSRU ship has to meet requirements in all envisaged conditions of stay of the FSRU ship and along with it moored LNG carrier. Under mooring equipment it is understood:

- mooring lines of FSRU and LNG carrier,
- mooring equipment of FSRU and LNG carrier (bollards, mooring winches, fairleads),
- shore equipment - quick release hooks and shore ship dock bumpers, and
- quick release hooks on the FSRU ship and fenders between FSRU and LNG carrier.

Forces acting on the FSRU ship and shore respectively (i.e. forces on mooring equipment and fenders): are:

- environmental forces (wind, waves and sea current),
- driving forces of incoming FSRU and/or LNG carrier (occurred by ship movement and/or by acting of tug,
- forces of mooring lines, winches and fenders.

Safety berth of FSRU and LNG carrier is accomplished if it is achieved by mooring equipment and buffers respectively:

- uniform and gradual transmission of kinetic energy from LNG carrier on to the FSRU ship
- balance of all forces acting on FSRU ship or berth during LNG carrier stay.

7.1 ACCESS TO THE SHIP

Approaching of LNG or FSRU ship is a part of navigation by which a ship autonomously or by means of a tug is approaching along ship's side to berthing place after which it goes into standstill.

Due to usual size of (reference) LNG or FSRU ship respectively, further on is anticipated only approach by the use of a tug pushing the ship sideways toward terminal. In case when LNG or FSRU ship is equipped with one or more forward propulsion systems toward mooring place these systems can also be applied. This force is rarely greater than 250 kN and corresponds approximately to trust of a smaller thug.

Ship stopping is achieved by reclining:

- FSRU ship to the dock
- LNG carrier to fenders which are placed at the external side of the FSRU ship.

Characteristics of fenders determines preferably peak energy in course of mooring i.e. stopping LNG or FSRU ship. This energy is determined usually by use of a method recommended by PIANC which is giving satisfactory results. The hereafter calculation is made for two types of ships:[53]

- conventional LNG carrier, displacement 120.000 t, and
- big LNG (Q-Max), displacement 175.000 t.

From the standpoint of ship safety relevant results are those for Q-Max ships, while results for conventional ship are, in the first place, illustrative.

Calculation assumptions are very conservative since anticipated speeds of approach are greater 33% than expected and along with considerable safety factor (1.5). The following results are:

[53] Permanent International Association of Navigation Congresses.

		LNG		Q-Max	
Dead-weight tonnage	DWT	90,000	t	125,000	t
Displacement	MD	120,000	t	175,000	t
Length	LOA	298.0	m	345.0	m
Length between verticals	LBP	285.1	m	333.0	m
Breadth	B	46.00	m	53.80	m
Draft	D	11.80	m	12.30	m
Block coefficient	CB	0.847		0.728	
BERTH					
Type of coast		Indented coast			
Calculation of eccentricity		Full calculation			
Under keel clearance	UKC	3.00	m	3.00	m
Contact point (from bow) %	x	25.00	%.	25.00	%.
Contact point (from bow) m	x	69.28	m	83.00	m
Radius of rotation	K	75.08	m	85.98	m
contact point from centre of gravity	R	73.49	m	87.67	m
Angle of approach	a	5.00	°	5.00	°
Speed vector	F	67.22	°	66.72	°
Added tonnage coefficient	CM	1.268		1.268	
Eccentricity coefficient	CE	0.595		0.552	
Dock configuration coefficient	CC	1.000		1.000	
Coefficient of softness	CS	1.000		1.000	
MOORING ENERGY					
Approaching speed	VB	200	mm/s	200	mm/s
Energy of berth	EN	2,272	kNm	3.365	kNm
Safety factor	FS	1.25		1.25	
Peak energy	EA	2.840	kNm	4.206	kNm

Table 33 Impact energies

Shore fenders. Shore buffers should take over all forces which occur by ship arresting. In this case it is assumed arresting of Q-max ship in such a way as determined in previously presented calculation.

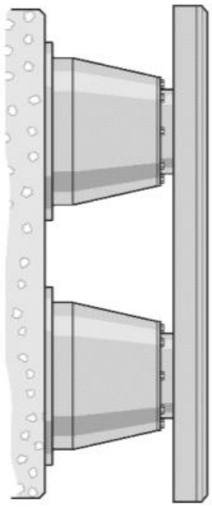

Fig. 58 Common panel-fenders

Consequently, it is assumed to place an energy absorption panel-bumper at the shore dock at least 4.500 kNm (each) and of sufficient surface as to ensure that the pressure onto the ship hull is within allowable limits. It is assumed that the surface of each panel-bumper is at least 25 m². It is usually assumed that even in extraordinary circumstances the pressure on the ship hull should not overcome 200 kN/m².

With regard to assumed dock construction it is envisaged to place at least three panel-bumpers of described characteristics one at each mooring solid structure berth.

Equipment for measuring of approaching speed. In order to ensure acceptable energy of leaning of ship onto bumpers i.e. pier, it is required:

- to limit ship's approaching speed so that load to shore structure (mooring structures) i.e. bumpers is not too big, and
- ensure even leaning onto all bumpers, again, as to transfer energy uniformly onto overall structure.

To that effect are assumed approaching speeds limits of a FSRU ship to 0,15 m/s with recommended speed of 0,08 m/s, which is usual approaching speed of very big ships. In case of smaller ships mooring (length up to 200 m) approaching speed may be even greater, but not greater than 0,20 m/s.[54]

On those grounds the terminal must be equipped with a device for laser measurement of ship distance from the jetty and measurement of approaching speed i.e. angle of declination from dock plane. The system must be capable to measure at least:

- distance to the ship: in range of 0-300 m
- approaching speed: to 1,0 m/s
- angle of ship: to 15º
- accuracy of distance: 25 mm
- accuracy of speed: 2,5 cm/s
- accuracy of angle: 0,5%

[54] Because of anticipated characteristics of shore dock, FSRU ship and fenders the access speed of ships shorter than 200 m depends only on ship's hull strength.

Data display must be seen in day and night, in all circumstances of illumination, and show distance from the stern and bow respectively, approaching speed on stern and bow as well as the angle of ship relative to dock plane.

Fig 59 Coastal system for data display

All values shall be displayed at least with one decimal place of measured value. Lasers shall be placed at far borders of the shore dock and shall send a signal into control room at FSRU ship. It is preferable that they can be seen from LNG carrier as well, at least during direct docking. It is recommended to place data displaying screen on the roof of terminal control building on shore or near utmost solid structure berths.

The system shall have possibility of ship approaching data storage and data memorizing for at least 30 days. Resolution of distance measurement and derived data to be kept shall be maximum one second.

Other dock safety equipment. In addition, the dock shall be furnished with anemometer with remote data reading with measurement of wind direction and speed at the height approximately 10 m above sea level. Speed wind data shall be available to FSRU and LNG carrier shipmasters.

Ship fenders. Ship fenders are bumpers that absorb energy of approach of LNG carrier to be moored to FSRU ship. For this purpose it is assumed furnishing FSRU ship with four pneumatic bumpers at parallel midbody and in addition with two smaller at utmost points of anticipated contact (so called ‘‘Baby Fenders").

It is consequently supposed to use four, so called “Yokohama“ fenders at FSRU terminal of the following characteristics:

– size 9,0 x 4,5 m
– pressure 50 kPa
– absorption energy 4.600 kNm or more
– pressure onto hull 150 kN/m² or less

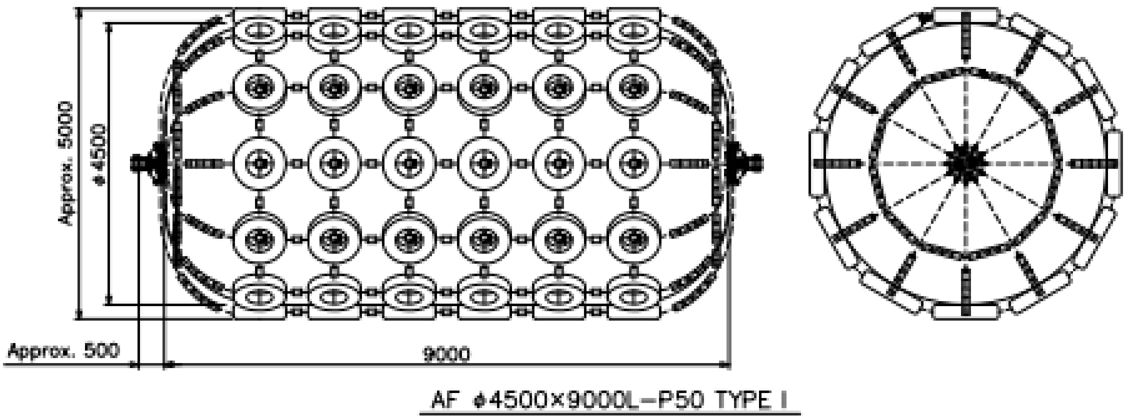

Fig 60. Common „Yokohama“ fender11

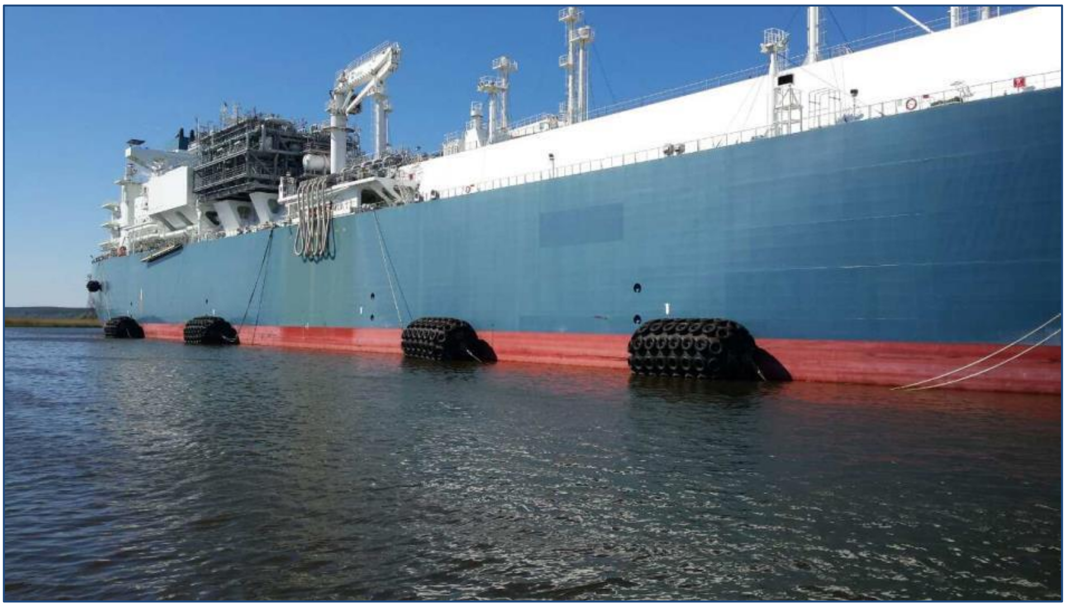

Fig. 61 FSRU ship with "Yokohama“ fenders at side of mooring LNG carrier

Ship fenders have to be located in such way that they are not exposed to damages caused by low temperatures of liquefied gas during transhipment i.e. after transhipment is finished. It is also supposed the protection with rubber elements in order to ensure greater lifetime.

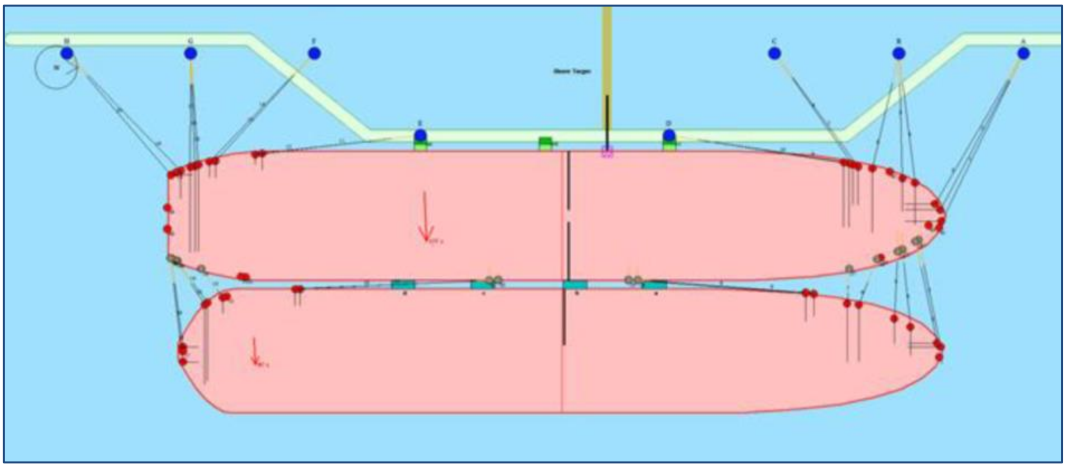

Fig. 62 Schematic view of berthing LNG carrier to FSRU ship

Two smaller rubber fenders are placed at the part where FSRU ship's parallel midbody ends, at height of approximately 2-3 meters below FSRU ship's main deck. Their main purpose is to prevent impact of LNG carrier on arrival manoeuvre and side docking to FSRU ship if it is not parallel with FSRU ship.

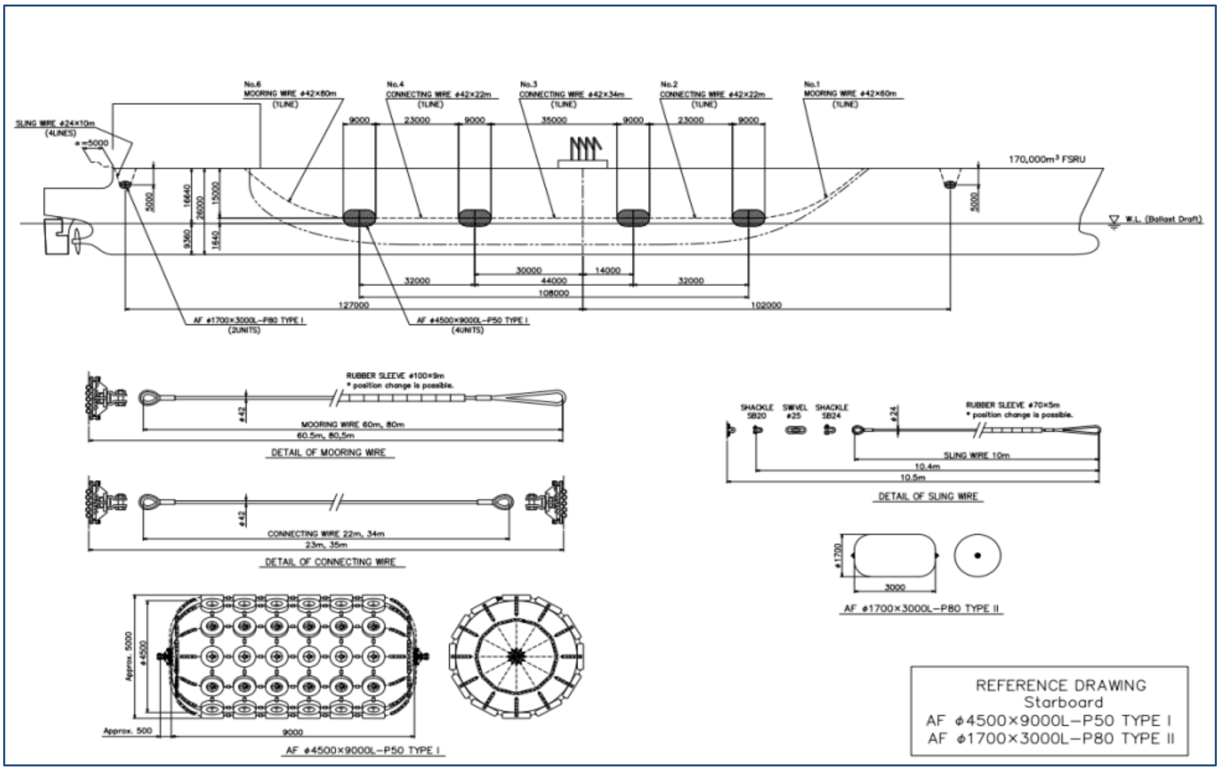

Fig. 63 Example of ship fenders positioning plan

Adjustment of ship fenders and their inspection is performed prior each mooring of LNG carriers. Position as a rule has to be in accordance with Compatibility Study i.e. calculation of forces in individual mooring lines. Based on data minimum number of mooring lines is determined in order to enable safe mooring to FSRU ship (Optimoor Mooring Study)[55]

55 The analysis of ship's behaviour independently or together with LNG ship under various weather conditions of stay at terminal is performed by using Optimoor program. The analysis has been performed by Tractebel company. All proposals in this study take over solutions from previous study.

In case reception of LNG feeder ships fenders are placed closer one to other as to enable more correct leaning of LNG carrier to FSRU ship.

7.2 MOORING SYSTEM

Mooring system, especially mooring lines, must ensure during entire stay of FSRU ship under all allowable situations of wind, waves, sea currents or other circumstances, mooring of FSRU ship to dock in such way, that no essential function of FSRU ship or dock's equipment shall not be endangered.

As far as equipment is concerned it is supposed its use in accordance with requirements set forth in Mooring Equipment Guidelines 3. edition OCIMF, and in accordance with recommendations from International Safety Guide for Oil Tankers and Terminals, (ISGOTT), 5. Edition.

Mooring system can be divided:

- FSRU ship - coastal dock (solid structure berths),
- FSRU ship – LNG carrier.

FSRU ship is moored to solid structure berths by mooring wires of high tensile strength, diameter 42 to 46 mm depending on FSRU ship size. Steel ropes are connected by means of Mandal shackle or Boss link with synthetic ropes - tails 11 m long.

Fig. 64 FSRU ship mooring to solid structure berths

Since FSRU ship has a function of receptive terminal, FSRU ship is also furnished with additional equipment which serves for safety reception and mooring of LNG carrier. Hereafter in this chapter is described equipment assumed to be on the FSRU ship which will be used at Krk terminal.

Besides standard mandatory equipment (such as winches, bollards, and fairleads), the most important part of mandatory equipment are quick release hooks of similar performance to those used with coastal dock.

The purpose of quick release hooks on a FSRU ship (at ship's seaside) is to release quickly LNG carrier in case of emergency.

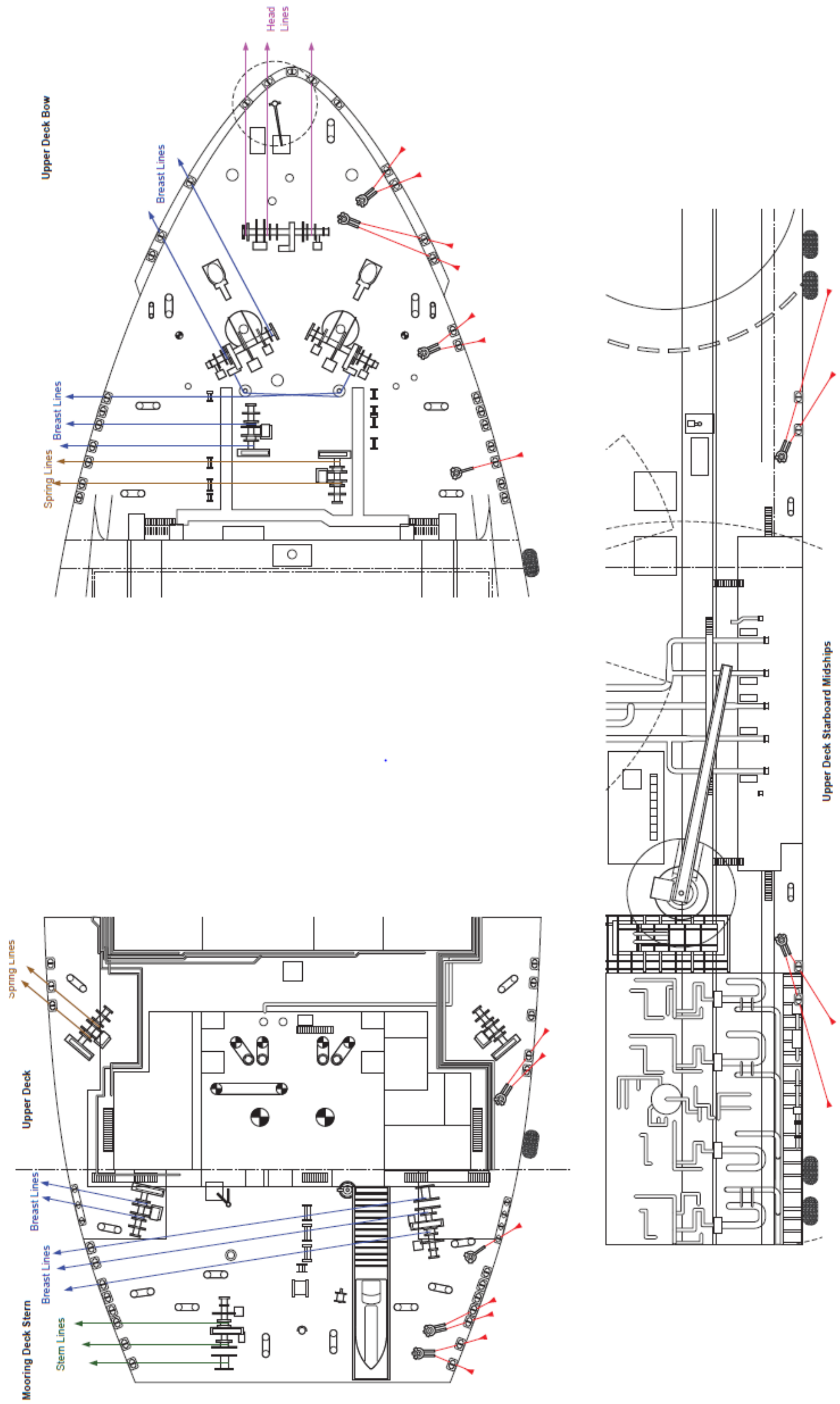

Fig 65 Schematic view of equipment for mooring at FSRU ship

FSRU ships are usually equipped with quick release hooks of single and double execution. For mooring of springs single quick release hooks are used while for all others mooring lines and/or steel ropes double hooks are used.

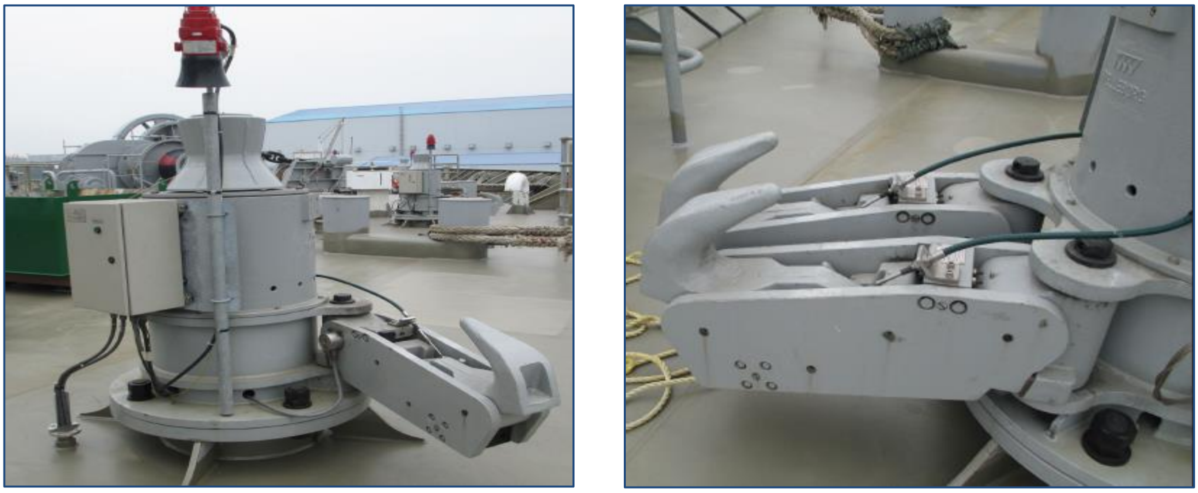

Fig 66 quick release hooks at FSRU ship (single and double)

Each quick release hook has to be equipped with dynamometer and connected to the FSRU ship's control room as to ensure monitoring of load in ropes that is to prevent overload exceeding allowable values. Rope release in case of emergency has to be possible from control room. Graphic presentation of load values in hooks (for each hook) has to be accessible in terminal's control room, cargo's control room at FSRU ship and at each mooring assembly (locally) for each steel rope. Hooks have to release rope that is laid down in the range from 0º to 25º from basic plane. Release of ropes which second link point is below plane of quick release hook basis has to be ensured by mandatory use of fairlead or in some other equally effective way. Mooring assembly has to be furnished with steel rope lifting winch and placement on each hook.

It is assumed constant load in each rope during ship's stay in amount up to 150 kN (15 t). In case of need this load can be increased, but by no means more than 300 kN (30 t). Mooring equipment must have light and audible alarm in case of overload of 400 kN.

Execution of mooring assembly, including communication lines, has to meet safety requirements and has to be in condition to withstand all weather circumstances that might be expected, that is, temperature within the range at least from -20º to +60º C. The substructure and each hook have to withstand load at least 1.500 kN (150 tons) and be tested with safety coefficient minimum 1,5.

Since LNG carrier during transhipment is also exposed to external effects such as wind, waves, sea currents, tide and ebb tide it is necessary to monitor and register forces in each individual mooring line. For this purpose FSRU ship has to be furnished with receiver showing forces, usually expressed in metric tons (t). Besides numeric, usually exists also graphic presentation with scale from minimum to maximum allowable hook load (at which the automatic release system is activated).

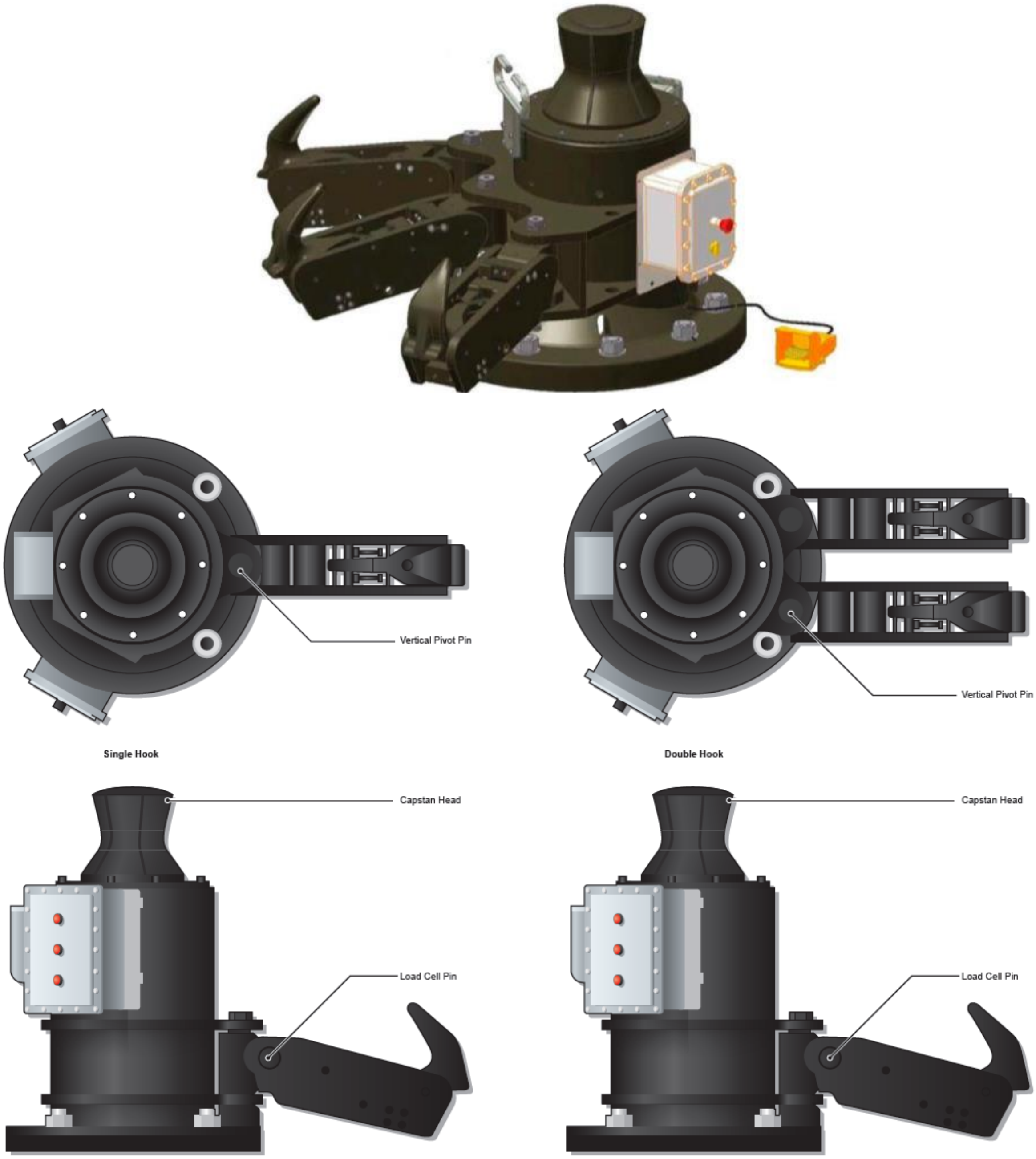

Fig. 67 Executions of quick release hooks

In addition, in case of emergency, when direct danger threatens to LNG carrier or FSRU ship, ship officer on duty in CCR has to have possibility to release manually each individual hook.

Satisfactory mooring to shore dock is achieved by placing enough number of mooring lines with corresponding characteristics, and the following are principles which are supposed to be:

- mooring lines have to be placed symmetrically as much as possible with respect to the middle of ship because it is ensured in such way better distribution of load in individual lines;
- bow and stern mooring lines should be placed as close as possible to bow and stern of ship at angle of approximately 45° with respect to coastal edge (if possible);

- breast lines should be placed as much as possible vertically to ship longitudinal and as much as possible toward ship's bow and stern (horizontal angle relative to ship longitudinal should not be less than 75°);
- springs shall be, as much as possible, placed parallel to ship longitudinal (horizontal angle relative to ship longitudinal need not be greater than 10°), and they have to be placed from mooring points which are located approximately on one fourth of ship's length form bow and stern;
- vertical acting angle of mooring lines shall be as small as possible; it is recommended that it is less than 25°, and in no case shall exceed 30°;
- mooring lines of the same kind and strength at all mooring places shall be used, and if not possible, then at least lines which are placed for the same purpose and at the same place, for example all springs, all breast lines, all bow and stern lines should be of the same or very similar characteristics;
- kind and strength of synthetic tails which are used at steel ropes must be equal at all mooring lines (length of such synthetic tail is approximately 11 m, and tensile strength at least 25% greater from tensile strength of steel rope at which it is placed;
- mooring lines that are placed for the same purpose and at the same place have to be approximately equal in length between place of mooring on ship and on shore.
- the length of mooring lines should be between 35 and 50 m.

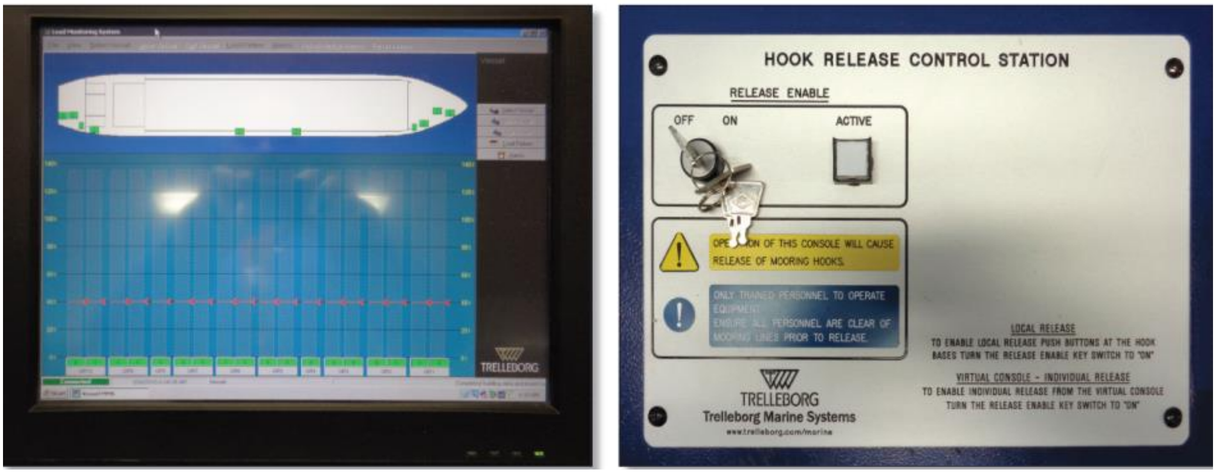

Fig. 68 Monitoring system of mooring LNG carrier to FSRU ship

Subsequently, for mooring of FSRU ship, capacity 170.000 m3, it is anticipated placement at least the following number of mooring lines:

- 9 forward lines,
- 2 forward springs,
- 2 stern springs,
- 9 stern lines,

For mooring FSRU QMax ship it is anticipated placement of the following mooring lines:

- 11 forward lines,
- 2 forward springs,
- 2 stern springs,
- 11 stern lines.

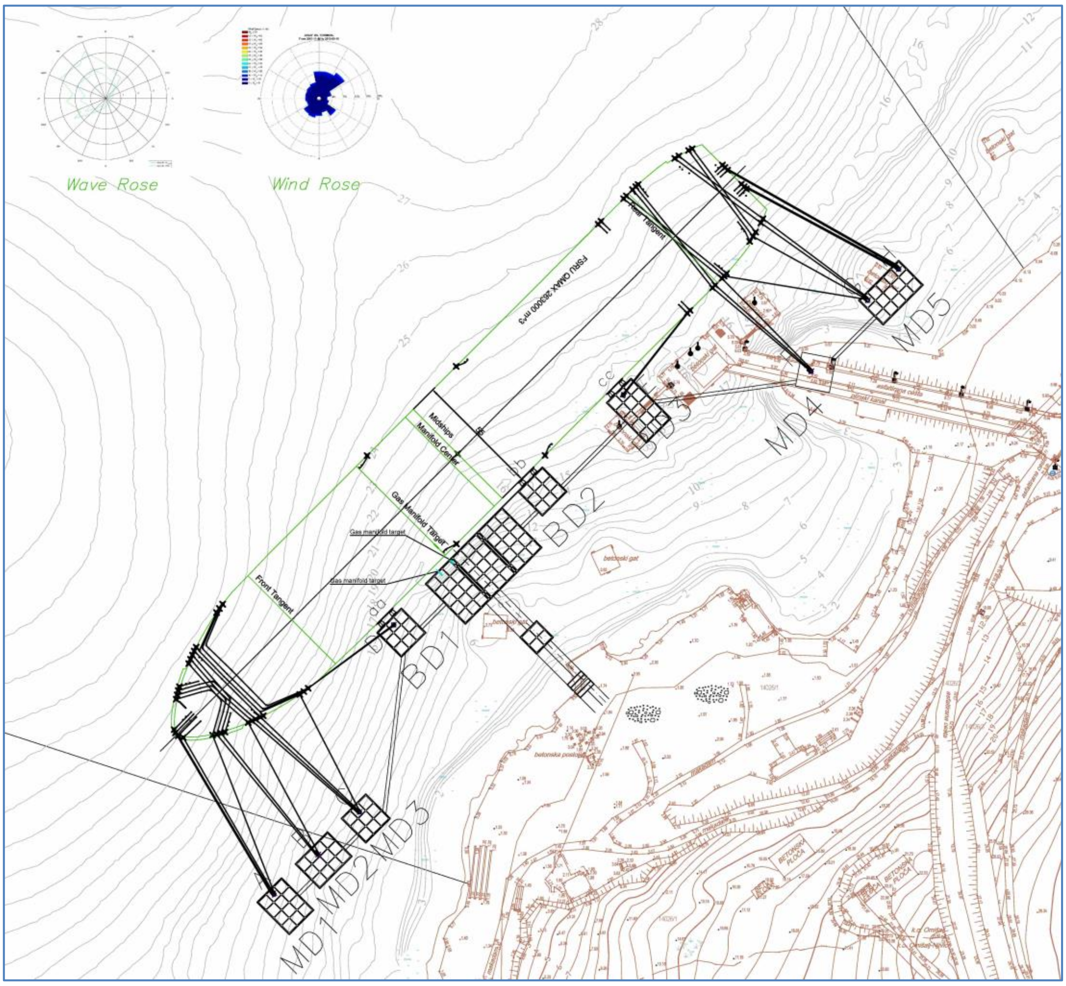

Fig. 69 QMax FSRU ship mooring

Lines which are placed to the same solid structure berth must have the same technical characteristics with regard to elasticity (the same diameter and approximately the same tensile strength, that is, degree of wear). Combination of various types, e.g. steel ropes with synthetic ropes is not allowed

In case of use of steel ropes each line must have at least 11 m flexible tail as to ensure enough elasticity of the complete assembly. Tensile strength of tail has to correspond to nominal tensile strength of steel rope.

Each individual mooring line to be used for mooring LNG tanker by mooring system has to be in accordance with safety allowable tensile strength of line on FSRU ship (according OCIMF Mooring Equipment Guidelines). The record about their regular maintenance with associated certificates shall be available during each mooring.

Mooring lines from LNG tanker are placed on quick release hook on FSRU ship according to beforehand worked out and agreed sequence by exchange of information between LNG and FSRU ships.

Subsequently presented above, for mooring LNG carrier to FSRU ship shall be used at least the following number of mooring lines (tensile strength not less from 1.200 kN):

for mooring of LNG carrier, capacity 170.000 m3 to FSRU ship of the same size or FSRU QMax size:

- 6 forward lines,
- 2 forward springs,
- 2 stern springs,

– 6 stern lines,

for mooring of LNG QMax ship to FSRU QMax ship:

– 7 forward lines,
– 2 forward springs,
– 2 stern springs,
– 7 stern lines,

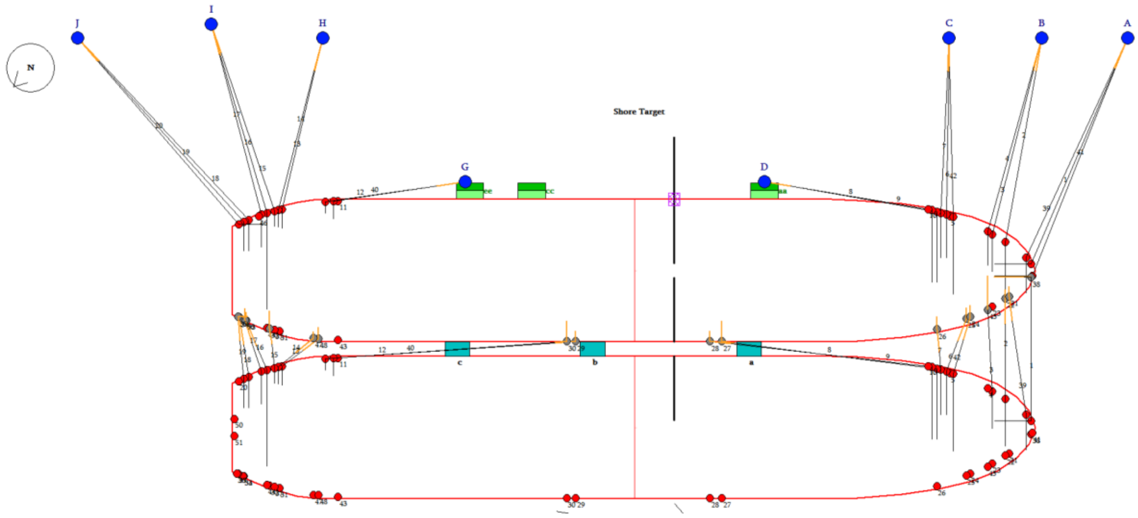

Fig. 70 mooring of LNG ship to FSRU ship (both 170.000 m³)[56]

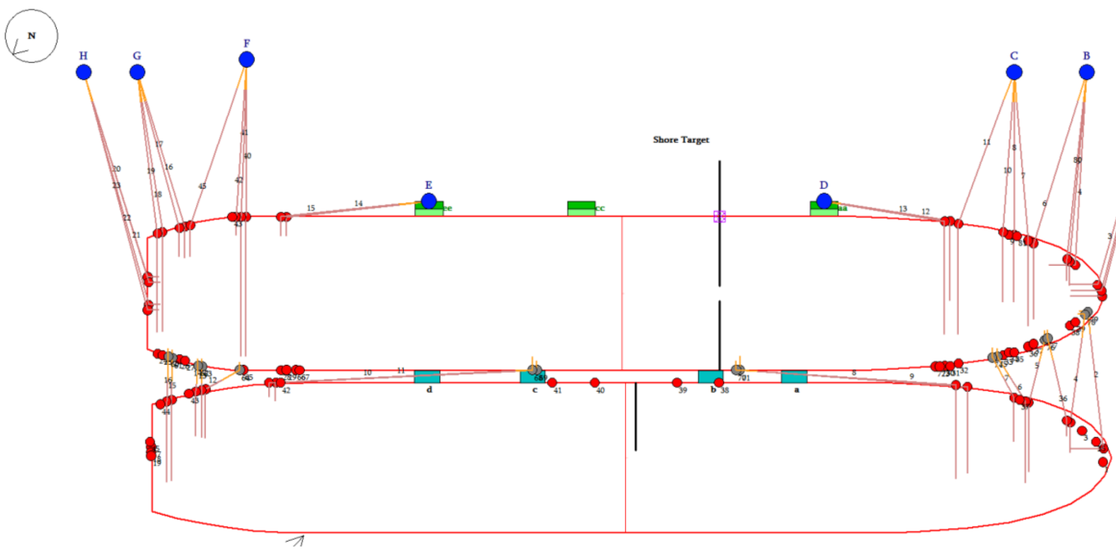

Fig. 71 Mooring of LNG QMax ship to FSRU QMax ship

56 Taken over from FEED documentation, Tractebel,

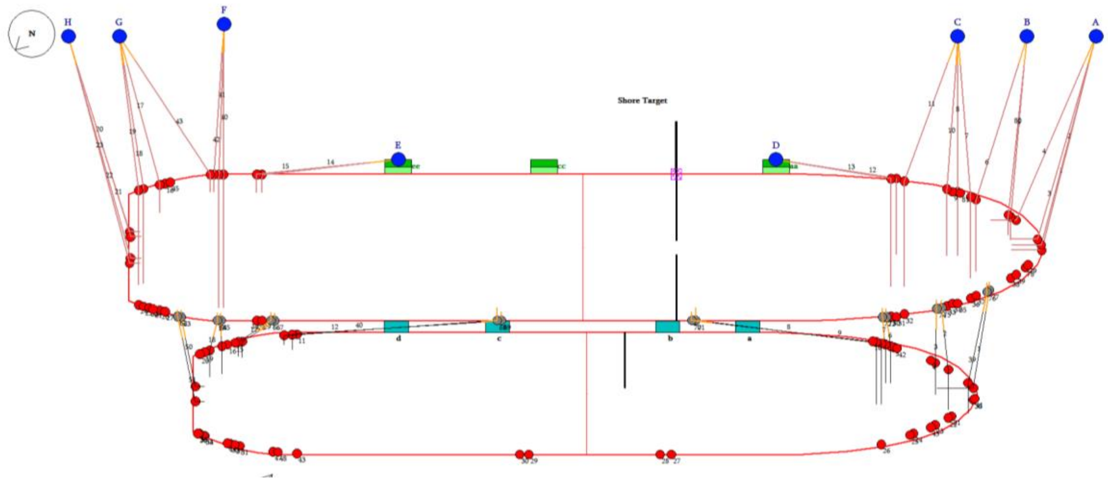

Fig. 72 Mooring of LNG carrier 1700.000 m3 to FSRU QMax ship

In mooring of FSRU ship first are placed springs (by use of berthing boat) and after this other lines. Ship adjustment in longitudinal direction relative to loading arms is performed, as a rule, by use of tug. Moving the ship by line dragging, that is, by use of ship's engine under regular circumstances is not acceptable.

The use of automatic ship's winches for mooring is not acceptable.

In case of mooring of smaller LNG carriers (LNG carrier in feedering) to FSRU ship it is supposed a reduction of total number of lines, where this number cannot be less than 6 lines out of which 2 must be springs.

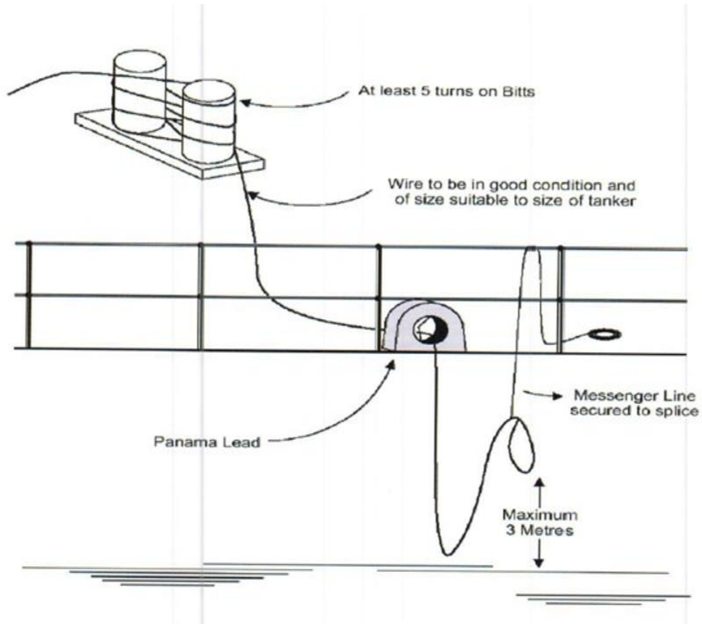

Fig. 73 Positioning of steel ropes for emergency towing

During stay of LNG carrier at corresponding places at bow and stern have to be placed fire wire-lines for mooring of tug in case of emergency having at least tensile strength of 1000 kN.

Conclusion:

(41) Three ship panel fenders to each solid structure berth, each having energy absorption at least 4500 kNm and sufficient surface as to ensure that pressure to ship's hull is within allowable limits should be installed. Surface of each panel fender is at least 25 m².

(42) Even in extraordinary circumferences pressure on ship's hull should not exceed 200 kN/m².

(43) Approaching speed limit toward terminal should not exceed 0,15 m/s. In case of smaller ships mooring (length up to 200 m) approaching speed may be even greater, but not greater than 0,20 m/s.

(44) It is recommended that jetty will be equipped with laser device for measurement ship's distance from the jetty and ship approaching speed as well as approaching angle. Display is recommended to be placed at the terminal so that could be seen at any time from the approaching LNG carrier or FSRU.

(45) It is recommended that dock is equipped with an anemometer with data distant reading in terminal's control room of wind speed and direction measurements at height of 10 m above sea level.

(46) It is recommended that dock is equipped with: 1) mooring structures (mooring solid structure berth) as described in the study, furnished with fourfold quick release hooks for installation of forward and side lines, 2) two mooring assemblies with double quick release hooks for springs.

(47) Quick release hooks must be furnished with dynamometer and connected with terminal's and ship's control rooms. Pedestal and each hook must withstand loads at least 1.500 kN and be tested with safety coefficient at least 1,5. Mooring assembly has to be furnished with steel rope lifting winch and placement on each hook.

(48) The biggest FSRU ship QMax size should berth to berth by at least eleven forward lines, eleven stern lines and two forward and two stern springs. Parallel lines have to be of the same characteristics. For smaller ships it is allowed less number of lines as set forth in the study.

(49) Mooring of a LNG carrier to FSRU ship should be done by at least 6 forward lines, 6 stern lines, two stern springs and two forward springs. Parallel lines have to be of the same characteristics. For smaller ships it is allowed less number of lines as set forth in the study, while for mooring of LNG QMax ship the number of forward and stern lines should be increased by one.

(50) For berthing, the use of steel lines (with tail) of high tensile strength should be used.

(51) It is supposed the biggest constant load in each line during ship's stay at terminal 150 kN i.e. maximum 300 kN (30 t).

(52) During ship's stay, at bow and stern must be placed mooring lines for emergency mooring of tug having tensile strength at least 1.000 kN.

8 MEASURES OF MARITIME SAFETY OF LNG CARRIERS DURING THEIR STAY AT THE BERTH

Under maritime safety measures during stay of ship at terminal are understood all those environmental features or concerned technological procedures due to which people, ship or terminal and its facilities can come at risk. Further on are elaborated most important requirements regarding most important measures of maritime safety.

Depths. Depth stand for one of limiting element of safety navigation and vessel's stay on a waterway i.e. during stay along the coast. Basic relationship describing navigation safety level is relationship of current depth and draft, i.e. free space below the keel (UKC – Under Keel Clearance).

To required water depth for safe navigation and manoeuvring many factors have influence out of which the most significant is draft (for current water density), tide and ebb tide, ship movement on waves, trim, additional squat, atmospheric pressure, type of sea bottom, errors in depth measurement as well as errors in dredging and silting between two dredgings if it is likely.

Required sea depth for safe navigation and vessel manoeuvring of specific draft can be determined using the following expression:

$$D = T + Z1 + Z2 + Z3 + Z4$$

where:

- D depth in area of manoeuvring, that is, at place of mooring (hydrographic survey),
- T draft (maximum) taking into consideration water density
- Z1 draft change (due to waves, additional squat, change of trim, list),
- Z2 net free space bellow keel (depending on type of sea bottom)
- Z3 sea-level change (due to change of atmospheric pressure and other adverse weather and oceanographic) conditions
- Z4 changes in sea bottom level (due to silting, errors in dredging or depth measurement).

On waterway up to manoeuvring area, immediately next to terminal, sea depths amount more than 40 m and do not limit safe navigation even for the biggest ships. However, for safe manoeuvring and stay of the biggest LNG carriers at terminal it is necessary to ensure the least safe depth D at mooring area. It is specially related to shallows (13,7 m) which take place about 250 m from coastal line of terminal in north-west direction.

Value of the biggest expected ship's draft (T) amounts 12,2 m which represents the biggest allowable draft of Q-Max ship.

The factor Z1 value is directly connected with characteristics of the ship. Vertical movement of ship due to wave impact can be estimated by relation 0,5 × h where h stands for wave height. In case of the highest allowable waves during ship's stay at terminal (significant wave height of 1,5 m) vertical movement of the ship can amount up to 0,75 m). For big ships the wave impact with period of movement shorter than 10 seconds can be neglected. Also, it should be emphasized that probability of such vertical movement of big LNG carrier is exceptionally unlikely.

Additional squat and trim change appears due to accelerated water current below keel when the ship is moving in shallow water, which causes changes in hydrodynamic water pressure around the hull and consequently additional squat. This effect can be estimated by various empiric equations. Additional squat is increased approximately proportionally with square of the ship's speed. It is usually needed speed greater than 6 knots for occurrence of squat, so that its impact at smaller speeds is negligible.

Because LNG carriers in immediate vicinity of terminal shall manoeuvre at considerably lesser speeds, this effect can be neglected.

Ship's list can occur due to impact of wind onto above water surfaces, due to acting of tug, turn of ship due to manoeuvring, wrong handling with balance and other, which results in increase of ship's draft. The list of 1° is considered as real expectancy with LNG carriers during manoeuvring (low speeds of approaching) and in allowable meteorological conditions. Exceptionally, during unfavourable meteorological conditions the list can be 2°. Increase of draft due to ship's list of 1° i.e. 2° around longitudinal axis for reference LNG carriers amounts as follows:[57]

Ship list	Conventional LNG (B=43m)	Q-Max LNG (B=55m)
1°	**0,34 m**	**0,43 m**
2°	**0,67 m**	**0,86 m**

Hereafter, for determination of safety depth, it shall be assumed that the ship's list is not greater than 2°.

Based on said above total value of factor Z1 amounts to 1,61 for Q-Max ship.

Net depth below keel (Z2) depends on type of sea bottom For muddy sea bottoms this value amounts to 0,3-0,5 m, for sandy 0,5 m, while for rocky amounts at least 1,0 m. At the area of manoeuvring and mooring LNG FSRU terminal the sea bottom is partly rocky and partly sandy. However, the quoted values are used at ship's navigation and for its stay at berth limitations are too rigorous. Due to said above net depth below keel for LNG terminal can be taken 0,5 m.

The change of sea level (Z3) due to change of atmospheric pressure and other adverse meteorological and oceanic conditions at terminal site is possible and certain. In case of lasting high pressure and blow of northern wind (bora) decrease of sea level is estimated up to 0,3 m.

Changes in sea bottom levels (Z4) include silting between the two dredging, errors in dredging and error in depth measurement. Silting between two dredgings depends on bottom type as well as intensity of local currents, and the value is obtained by constant monitoring and measuring of depth. For the observed area it can be concluded by experience, that does not exist significant silting. No matter how, real value of silting can be determined only after expiration of longer time from terminal construction, when it will be possible determine with confidence to which extend currents along the coast deliver and leave material close to the coastal terminal structure. Regarding error by dredging or depth measurement and taking into consideration unknown speed of silting, the least recommended value which shall be taken in consideration is 0,3 m.

LNG carrier	T (m)	Z1 (m)	Z2 (m)	Z3 (m)	Z4 (m)	**D (m)**
Q-Max	**12,20**	**1,61**	**0,50**	**0,30**	**0,30**	**14,91**

On the basis of above mentioned values, the necessary minimum depth at manoeuvring and terminal berth zone for reception of FSRU and LNG carrier with the greatest expected draft (at seawater density 1,025 t/m3) amounts 15 meters.

57 In calculation has been taken the most conservative coefficient of swaying keel (0,9), according to PIANC Report N°121 Harbour Approach Channel Design Guidelines.

Works. During ship's stay at terminal all works on ship’s engine are forbidden due to which ship might be unable to sail out, in case of emergency, by use of its own engine. If needed to perform such works after completion of cargo transhipment and securing of loading equipment system the request for execution of these works can be applied to Harbour Master's Office Rijeka. Other works on ship maintenance, which neither create danger of fire or other incidents, nor disable engine start or other equipment parts essential for safe emergency float out are allowed providing previous announcement and approval of terminal's person in charge.

Main engine. After mooring the main engine of LNG carrier shall be switched off and terminal's person in charge should be informed about this. Thus it is protected from its uncontrolled switching on (so called Main Engine Disengaged or Steam off main engine). Above said procedure precedes any other communication ship-terminal including placing accommodation ladder, earthing cables or unloading arms. Similar procedure is mandatory before sailing when the same rule is valid, that engine is not being preparing before detachment of all equipment that had been connected to ship.

Safety zone. Safety zone is the zone around LNG FSRU terminal in diameter at least 500 m from the end points of FSRU ship or LNG carrier inside which is forbidden navigation of all vessels, anchoring and fishing. Access to and entrance in safety zone is allowed only to LNG carriers which are approaching to mooring place, tugs which participate in ship manoeuvring, tugs in stand-by, terminal berthing boats and other vessels being support to LNG carrier or terminal which get permission from terminal responsible person.

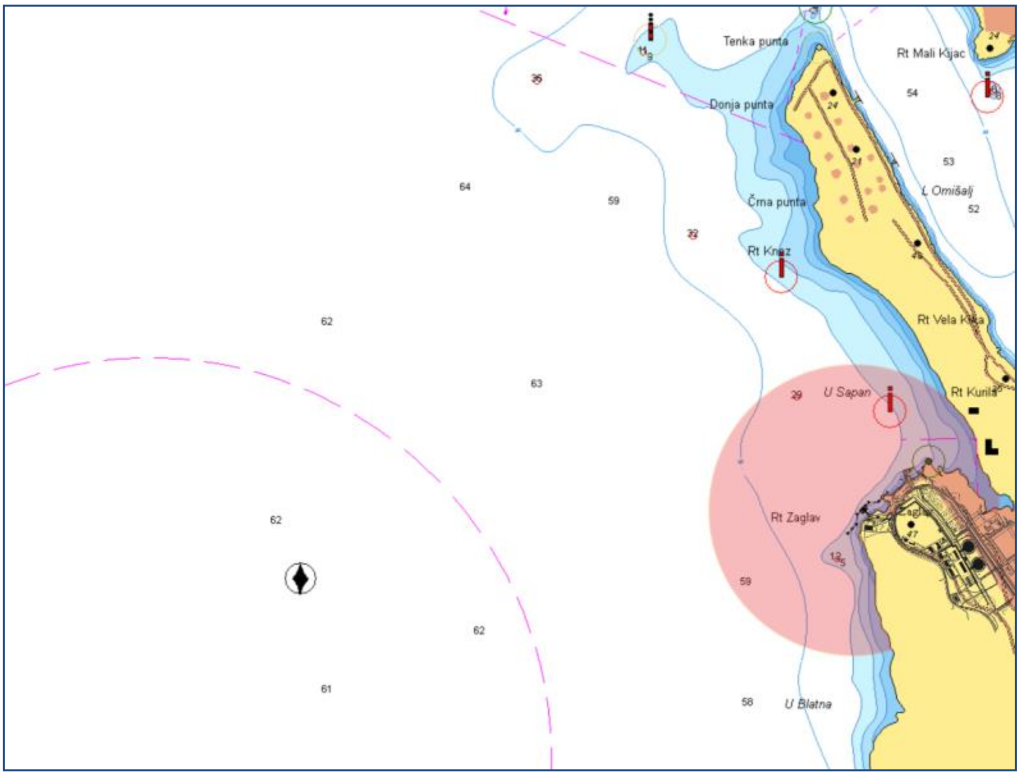

Fig. 74 Safety zone in diameter of 1.000 m around LNG terminal

Tugs During entire stay of LNG carrier at terminal minimum one thug must be continuously in stand-by. Mooring of tug has to be at such distance from FSRU ship that upon call from shipmaster or terminal person in charge in case of need can be available to ship in full gear within maximum 10 minutes. The basic purpose of this tug is rendering help in case of any emergency, and most of all in case of fire or occurrence of adverse meteorological conditions at which it is possible sudden abandoning of berthing place. The additional tug's duty can be, if agreed and confirmed, monitoring of safety zone around terminal in order to provide safety protection. Tug shipmaster's duty is listening continuously of defined communication VHF channel which is used for communication with terminal or ship Tug in stand-by must mandatory have installed fire extinguishing system which meets the following conditions:

Mandatory conditions are:

- at least two monitors,
- at least 1.200 m^3 water per hour and monitor,
- at least 2.400 m^3 pressure capacity of fire pumps,
- at least 24 hours of continuous operation,
- at least 120 m horizontal jet range,
- at least 45 m vertical jet range
- water self-protection system.

Security protection. LNG FSRU terminal is a facility of high security risk. Subsequent to the Law of Ship and Port Facility Security and ISPS Code, the concessioner is obliged to prepare implement Port facility security assessment and on the base on that Port facility security plan. It is assumed full application of security protection measures set forth in the approved security plan.

Compatibility study. Elaboration of Compatibility study is a procedure by which are confirmed particularities and constrains of terminal and ship, that is, by which it is checked can a specific LNG carrier (or more ships of the same characteristics) in physical, technical, working and safety aspect moor and perform cargo transhipment to FSRU. Compatibility study is carried out for each individual ship planned to arrive.

Basic determinants taken into consideration in elaboration of the study are:

- physical dimensions and restrictions of a ship and FSRU
- possible impact of external forces and number and availability of tugs,
- configuration, characteristics and limitations of mooring system at FSRU and ship,
- number, dimensions and constrains of flexible pipes, cargo pumps, compressors and other equipment essential for transhipment.
- kind and possibility of connection of the Emergency Shutdown system (ESD),
- basic characteristics of cargo (composition, temperature, quantity and others),
- type, dimensions and location of loading platform,
- fire extinguishing equipment and alarms for extraordinary circumstances on FSRU ship,
- possibility of establishing direct communication link and harmonization of communication in case of extraordinary circumstances,
- comparison of procedures in case of extraordinary circumstances.

Following exchange of all necessary data and after completion of compatibility study terminal responsible persons issue to company a certificate by which is allowed arrival and mooring of LNG carrier. The permit for each individual ship is valid up to three years.

In addition, individual ship-owners, in accordance with their mandatory procedures, require prior to each arrival of LNG carrier to the terminal, submittal all relevant data related to safety navigation and foreseen procedures during ship's stay at terminal (e.g. data about features of tugs to be used and similar).

Communication. All communication between ship and terminal shall be in English. Basic communication in connection to work with cargo is accomplished by communication link (Ship to Shore Communication Link - SSL) using optical and electric technology. Both types are used for establishing telephone and data link and sending signals for termination of cargo transhipment in case of emergency (ESD). It is mandatory to establish in compatibility study compatibility of ship and coastal systems SSL and types and limitations of connectors. Telephone sets, connected by means of cables, take place in control stations for work with cargo i.e. on LNG carrier in CCR - Cargo Control Room, in corresponding room at FSRU and in terminal control room. Separately for ESD system is installed additional safety link by pneumatic system. Communication cables are laid down and checked immediately after mooring and placement of ship's accommodation ladder and are disengaged immediately prior to removal of accommodation ladder before ship is untied.

Basic radio-link between ship and land is on UHF frequencies which terminal puts at disposal. Alternatively, communication can be carried out by means of VHF link on agreed channel.

If during cargo transhipment occurs break of cable telephone link, all communication is immediately rerouted to UHF devices. In such case, cargo transhipment is stopped until breakdown in link is eliminated or until is reached agreement between persons in charge at terminal and ship so that transhipment can be safely continued using only radio link.

In so far during work with cargo appears break of telephone cable and radio link, cargo transhipment is immediately stopped. If breakdown is discovered from ship's side, LNG carrier is obliged to give agreed audio signal immediately by ship horn, and if breakdown is discovered at FSRU, then it is obliged to give agreed signal to LNG carrier and terminal by speaker phone about termination of work with cargo.

After cargo operations have been suspended, work with cargo can be continued only after establishing and checking effectiveness of communication link.

Conclusion:

(53) The minimum required depth at area of manoeuvring and terminal berth for acceptance of LNG carriers with most expected draft is 15,0 m.

(54) During ship's stay at terminal all works on drive assembly are forbidden due to which ship might be unable to float out, in case of emergency, by use of its own drive. Other works on ship maintenance, which neither create danger of fire or other incidents, nor disable engine start or other equipment parts essential for safe emergency float out are allowed providing previous announcement and approval of terminal's person in charge.

(55) Safety zone around LNG terminal in diameter at least 500 m from the end points of FSRU ship or LNG carrier, inside which navigation of all vessels anchoring and fishing is forbidden with exception of LNG carrier’s vessels having terminal's permit, should be set up.

(56) During overall stay of LNG carrier at terminal one tug with installed fire extinguishing system has to be in stand by and upon call to be at disposal to FSRU and LNG carrier in maximum 10 minutes.

(57) Terminal must have approved Port facility security assessment and Port facility security plan.

(58) For the acceptance of any LNG carrier(s) it has to be elaborated a compatibility study by which it is confirmed compatibility of ship's equipment and procedures with respective equipment and terminal procedures in respect with safety mooring and cargo handling.

(59) Basic communication link (telephone, data and ESD) between ship and terminal is accomplished by communication link which can be realized by optical cable and/or electric cable. Separately for ESD system is installed additional safety link by pneumatic system.

(60) Basic radio-link between ship and land is UHF radio device which terminal puts at disposal... Alternatively, communication can be carried out by means of VHF link on agreed channel.

9 SAFETY MEASURES AND ENVIRONMENT PROTECTION WITH PROCEEDINGS IN CASE OF DANGER OR MARITIME ACCIDENTS

Extraordinary circumstances are considered all circumstances due to which, during acceptance and stay of ship along the shore, can be in danger FSRU, moored LNG carrier, ships in vicinity, terminal and facilities on land or immediate environment. Distinctiveness of event means that event has not been anticipated i.e. consciously or deliberately carried out and/or approved by the ship's crew and/or responsible persons at terminal associated with mooring or loading/unloading works at ship.

Extraordinary circumstances are not considered work accidents in which safety of ship, other ships, and facilities at land or maritime environment are not endangered. In case of such work accidents, usual procedures set forth by work protection system on LNG terminal i.e. prescribed by ISM system of FSRU and LNG carrier, shall be applied.

Pursuant to Protection and Security of Sea Vessels and Sea Ports Act, a port open for international traffic is obliged to elaborate an estimate of security protection taking in account particularities of individual parts of port operational zones as well as zones outside of port. Based on assessment a port Facility Security Plan should be made. Subsequently, extraordinary circumstances in connection with war activities, sabotage and other criminal actions shall not be considered further on since they are mandatory content of the Plan.

It is generally assumed that on FSRU and LNG carrier have been conducted general work safety measures set forth by rules of their companies based on international standards and general measures for work safety set forth by work protection rules and rules of respective regulations and plans of LNG terminal.[58]

Persons authorized for issuing orders for termination of cargo transhipment or leaving the port or informing to Harbour Master's Office Rijeka or MRCC Rijeka in case of an accident are equally:

- responsible person of LNG FSRU terminal,,
- master of FSRU ship,
- master of LNG carrier.

Communication channels, used in case of accidents are VHF channel 10 or 16 by radio and mobile phones for direct connection between responsible persons. Informing other public services which may be included in rendering help has to be set forth in respective terminal regulations.

Subsequently in this study, under extraordinary circumstances are considered:

- adverse weather condition - wind force with speed more than 13,8 m/s or more i.e. significant wave heights of 1,5 m high or higher (3 m wave height);
- liquefied gas discharge (from FSRU, LNG carrier or terminal):
- fire and/or explosion (on FSRU, LNG carrier or land part terminal);
- collision of other ship or vessel with FSRU or LNG carrier;
- pollution with oil, oily waters or other prohibited substances into sea;
- list LNG carrier due to cargo overturn or any other cause.

Basically, in case of extraordinary circumstances, as much as resulting situation allows, FSRU i.e. LNG carrier stay moored at dock i.e. one alongside other. Accordingly, it makes possible direct and quick access and easier elimination of accident cause and consequences.

[58] The ship-owner's rules are unified in ship system for safety control and maritime ambient protection (ISM) based on International Convention of Safety of Life at Sea (SOLAS '74).

Leaving berth, either LNG carrier or FSRU or vice versa is considered an ultimate necessary measure and is undertaken only if there is not any other possibility of acting and in case of immediate danger. If the berth is still to be left in unfavourable circumstances, it should be done with prior notice to Harbour Master's Office Rijeka and in presence of pilot and tug in agreement with shipmaster and pilot. After leaving berth both FSRU and LNG carrier are directed, as a rule, to nearest anchorage or other appropriate place in Bay of Rijeka region.

Finally, if masters of LNG carrier or FSRU estimate that further waiting for pilot or enough number of tugs is not possible and should they estimate that less danger threatens to ship during emergency leaving than in case of stay alongside they are expected to undertake manoeuvre of leaving berth in emergency in the most secure way under given circumstances.

After shore part of terminal is built and FSRU ship is placed all measures of maritime security and measures and procedures in case of emergency shall be incorporated in a separate instruction to LNG carrier masters and other interested persons. Content of rules (instructions) has to include, as minimum, all items that are specified in SIGTTO Ship/Shore Interface Communications.

9.1 ADVERSE WEATHER CONDITIONS

With respect to meteorological and ocean characteristics of the observed region special care should be paid to cases of rapid local gales from W-SW direction, especially during summer period. Reference values are considered 30 seconds averages.

During ship's stay at terminal ship's master and FSRU's master as well as terminal responsible person have to receive and monitor weather reports from State Hydro-Meteorological Institute (DHMZ) minimum twice a day as well as data from local meteorological station. Inherent to local terrain, thunderstorm from W-SW and bora from NE come suddenly with considerably less time for preparedness, unlike from south winds. Therefore if bora or gale thunderstorms are in weather forecast it is reasonable to follow weather forecasts more frequently, at least every 6 hours and monitor natural glimpses for wind gusts. It is desirable to establish contractual obligation with DHMZ for reception of warnings about piezoelectricity from clouds within diameter of 10 M from terminal.

By wind strengthening over 6 Beaufort (> 10,8 m/s) or wave occurrence higher than 1 meter (significant wave height 1,5 m or higher), the responsible person or master FSRU should announce state of alert for possible extraordinary circumstance, and inform about this LNG carrier's master and Harbour Master's Office Rijeka. In this case cargo operation interruption is considered, and in case of possible wind strengthening tugs shall be informed about state of alert and possible leaving the berth of LNG carrier. [59]

LNG FSRU terminal and FSRU ship crew is obliged continuously monitor state of the ship and loads on mooring hooks and lines. Weather reports and instruments shall be continuously followed. State of alert must be in power until wind weakens below 6 Beaufort (< 10,8 m/s), and forecast does not show worsening weather conditions.

If wind strengthening above 7 Beaufort (> 13,8 m/s) is anticipated, further measures should be taken as to prevent accident including preparation for flexible pipes between LNG carrier and LNG FSRU terminal are disengaged and disembarking all persons from LNG carrier. When wind force reach 7 Beaufort (> 13,8 m/s) extraordinary circumstances are stated, the pilot is called, while stand-by tugs should tie tow-ropes on LNG carrier, one at stern and one at bow, as close as possible to utmost points of the ship. If the ship is pushed then tugs are positioned at part of ship designated for pushing by tug. In case of wind strengthening over 20,0 m/s the LNG carrier begins preparation for leaving the berth, and depending on

59 Work limitations due to wind impact on crane used to transfer transshipment pipes is not considered as extraordinary circumstances.

circumstances and after increasing the wind speed to more than 25 m/s,, leaves berth and goes to anchoring area. In case of further wind strengthening and after LNG carrier left and production is stopped FSRU ship will be supported by at least two tugs, depending on circumstances, trying to keep it at the berth. In the case that safe berth of FSRU is endangered and safe berthing is not any more possible, additional tugs will be required, the FSRU will leave the berth with support of minimum 3 tugs.

Generally, depending on anticipated or measured wind speed (it is understood 30-second averages measured at terminal at height of approximately 10 m) it is necessary to undertake the following:

- > 10 m/s it is confirmed state of alert,
- > 13 m/s pilots and tugs are informed about rendering possible help,
- > 20 m/s pilot on board, tugs rendering LNG carrier,
- > 25 m/s LNG carrier leaves berth,

Terminal responsible persons, FSRU master and/or master of LNG carrier can decide about termination of cargo transhipment, disconnection of loading/unloading arms, that is, pipes and leaving berth and in case of other circumstances in any moment, if they estimate that safety of any unit is endangered.

Because the gale front from SW comes extremely suddenly, in case of its coming it is necessary to position tugs in towing position and undertake other measures as soon as possible, that is, before front with strong wind comes to terminal region.

State of extraordinary circumstances remains in power until wind weakens below 7 Beaufort or significant wave height falls below 1,5 meter.

In case of occurrence of electric discharges within diameter less than 10M it is necessary continuously monitor clouds movement and frequency of lightning and in case of approaching to terminal, and on the basis of decision of terminal responsible person FSRU shipmaster or LNG carrier master break cargo transhipment.

9.2 LIQUEFIED GAS LEAKS

Liquefied gas is transhipped from LNG carrier to FSRU in closed piping system and during regular work there is no discharge. In case of extraordinary circumstances discharge of LNG can occur from:

- ship tanks and piping,
- transhipment piping,
- transhipment arms connection.

Causes of uncontrolled LNG discharge on the ship can be:

- structural damage (rupture) of pipe or connection of manifold due to irregular maintenance, testing or work procedure;
- collision, strike or stranding of ship to the extent that comes to rupture of cargo tank wall or
- unauthorized and deliberate action (sabotage or terrorist act).

The most frequent causes of drainage is defect of pipe or manifold connection what leads, as a rule, to smaller extend discharges.. In case of other causes discharges might be of very big scale. LNG leaks do not mean primarily a danger to environment pollution, but because of:

- fire and explosion occurrence,
- damage to ship infrastructure and
- injury of people.

Liquefied gas (LNG) in uncontrolled discharge to environment suddenly is converting in cold cloud of vapour (aerosol) which is heavier than air. Drops of liquefied gas mainly completely evaporate, however part of them can come in contact while being liquid, with base below or in vicinity of place of leak creating smaller evaporating pools. Aerosol cloud heated to ambient temperature and mixed with air becomes lighter than air and gradually lifts up. Aerosol cloud, in initial phase, while is heavier than air, behaves similar as liquid, i.e., its spreading depends, to the greatest extend, on wind strength, and then on base configuration (ship's hull, sea or land with various obstacles. Gas is always moving down the wind and at stronger wind quicker mixes with air and dilutes.

Ignition may occur if at the same time occurs: uncontrolled discharge of LNG, concentration of methane in an air mixture of 5 to 15% and contact of this concentration with the source of ignition. Fire can take various characteristics such as burning of gas jet under pressure from pipeline, burning vapours above pool of liquefied gas on open base, flash burning of sprayed cloud of vapours etc.

An explosion occurs if prior ignition occurs, for which precondition is the uncontrolled discharge of LNG, the concentration of methane in the air mixture of 5 to 15% and the contact of this concentration with the source of ignition. Gas explosion in open air, what terminal area is, is not probable. Generally, explosion of inflammable gases can be divided on detonation and deflagration. Detonation is extremely destructive burning phenomenon by which occurs a shock wave moving at supersonic speed (often more than 1.500 m/s). Detonations can originate by combustion of very reactive gases such as acetylene or hydrogen, but not natural gas. In deflagration shock wave is moving slower than speed of sound (usually less than 250 m/s) and has no big destructive power. To deflagration of natural gas can come in closed spaces or in open air where exists of obstacles preventing its propagation and dilution with air.

Besides fire, liquefied gas (drops jet or accumulated LNG) can considerably damage ship steel structure (deck, other pipeline, equipment etc.) in immediate vicinity of leak. Ship steel below -40˚C becomes brittle, and especially in contact with liquefied gas (-160˚C), wherein can appear local cracks. Because of this it is preferred to use water curtain for hull protection from low temperatures in manifold area before, during and after termination of transhipment.

Natural gas presents danger to people, especially in case of inhalation and contact with aerosol or sub-cooled steel. Breathing of natural gas can cause adverse effects above concentration (Mol) of 6,7%, and suffocation and death above 71,3% Gas concentrations, dangerous for inhalation can spread up to several tens of meters depending on pressure and place of leakage. Direct contact of body parts with sub-cooled steel (e.g. touching handrail of ship's accommodation ladder, piping and similar during ship evacuation) can significantly damage skin and other tissue and cause chilblains and serious injuries.

In purpose of prevention of escaped gas cloud spreading, prevention of fire and damage to ship structure due to low temperatures of escaped cargo, as a rule are used stationary fire extinguishing systems with water on FSRU ship, LNG carrier and shore part of the terminal (water firefighting monitors).

In detection of leakage of liquefied gas on ship or terminal immediate procedures have to include the following:

- annunciation of agreed alarm,
- shut down of operations with cargo or if it is necessary start emergency procedure to stop cargo transhipment (ESD - Emergency Shut Down)
- informing responsible persons on terminal/ship,
- gathering ship's crew/personnel at rendezvous,
- insurance/elimination of all possible sources of combustion and totally announce prohibition of smoking at any place on ship, terminal, tugs or any other naval or shore object within security zone,

and in addition, if necessary, with greater discharges:

- evacuation of present persons at berth,
- start deck system for fire extinguishing by spray water (Deluge system, Deck water spray),
- start of fixed fire extinguishing system at shore part of the terminal

– call stand-by tug to start fire extinguishing system

Tugs upon coming and rendering help have to be positioned upwind from place of leak, as far as possible, in order to prevent possible ignition of gas.

Cargo transhipment can be resumed only after detection of gas leakage cause and elimination of possibility recurrence of leakage.

Safety measures for prevention of gas leakage prior beginning and in course of cargo transhipment from LNG carrier to FSRU must include as minimum:

– inspection of flexible transfer pipes between LNG carrier and FSRU, high pressure arms between FSRU and shore gas pipeline and connection of manifold with nitrogen to FSRU under corresponding pressure and external application of water and soap solution on the connection before beginning of cargo transhipment (Leak test),
– check of correctness of gas detector on LNG carrier, FSRU terminal and shore,
– check of ESD system and communication system between FSRU and LNG carrier and shore part of terminal;
– continuous monitoring of deck and loading/unloading arms of ship's crew,
– regular checking and inspection of all closed and unused manifolds on LNG carrier.

Degassing of cargo tanks into atmosphere is not allowed.

9.3 FIRE OR EXPLOSION

Fire on the vessel is uncontrolled burning of whole vessel or its parts. Explosion is understood as instant burning part of cargo i.e. inflammable gases and vapours of liquid cargo or fuel of the vessel. Explosion often foregoes fire or vice versa. Fire or explosion very often occur as consequence of some other accident or as consequence of disrespect work procedures of crew or visitors, that is, missing to perform prescribed safety measures, and infrequently as consequence of technical malfunction, device or equipment breakdown.

Fire or explosion might occur on FSRU, LNG carrier or on shore facility of LNG terminal. In both cases direct procedures are:

– discovering fire, alerting and immediate extinguishing by fire extinguishing devices (if possible) ,
– starting emergency procedure for shut down cargo transhipment.
– Report to responsible persons, risk estimation, fire volume and determination of fire extinguishing measures.
– extinguishing fire, independently or in cooperation with public firefighting squads,
– termination, inspection and monitoring fired area.

In case of fire on FSRU or LNG carrier master is responsible for timely execution of all essential procedures in accordance to Ship's Firefighting plan and terminal Regulation, and mandatory includes:

– announcement of firefighting alert and corresponding signal by ship horn
– termination of emergency cargo transhipment,
– informing other responsible persons,
– gathering ship's crew at rendezvous,
– preparation for disengagement of transhipment arms or pipes,
– firefighting procedure is in accordance with ship's Fire-extinguishing Plan
– call to stand-by tug, i.e. tugs in order to extinguish fire from sea side, if necessary.

Upon receipt of information about extraordinary circumstance on LNG carrier, the procedure of responsible person on FSRU terminal includes:

- start up actions in accordance to Terminal Fire-fighting Plan,
- establishing communication with stand-by tugs
- establishing communication with responsible person FSRU i.e. LNG carrier.

Master of FSRU, master LNG carrier or terminal responsible person are obliged to inform County Centre of State Directorate for Protection and Rescue (DUSZ) by call 112 and Harbour Master's Office Rijeka by VHS radio station (channel 10 or 16). Duty of DUSZ is, with regard to received information and estimate of danger, to inform further and send to fired area public firefighting squad (JVP), police and ambulance service. .I needed, additional tugs in order to extinguish fire from sea will be sent. In addition, if unberthing of ship or some other vessel is needed, pilots will be sent. .

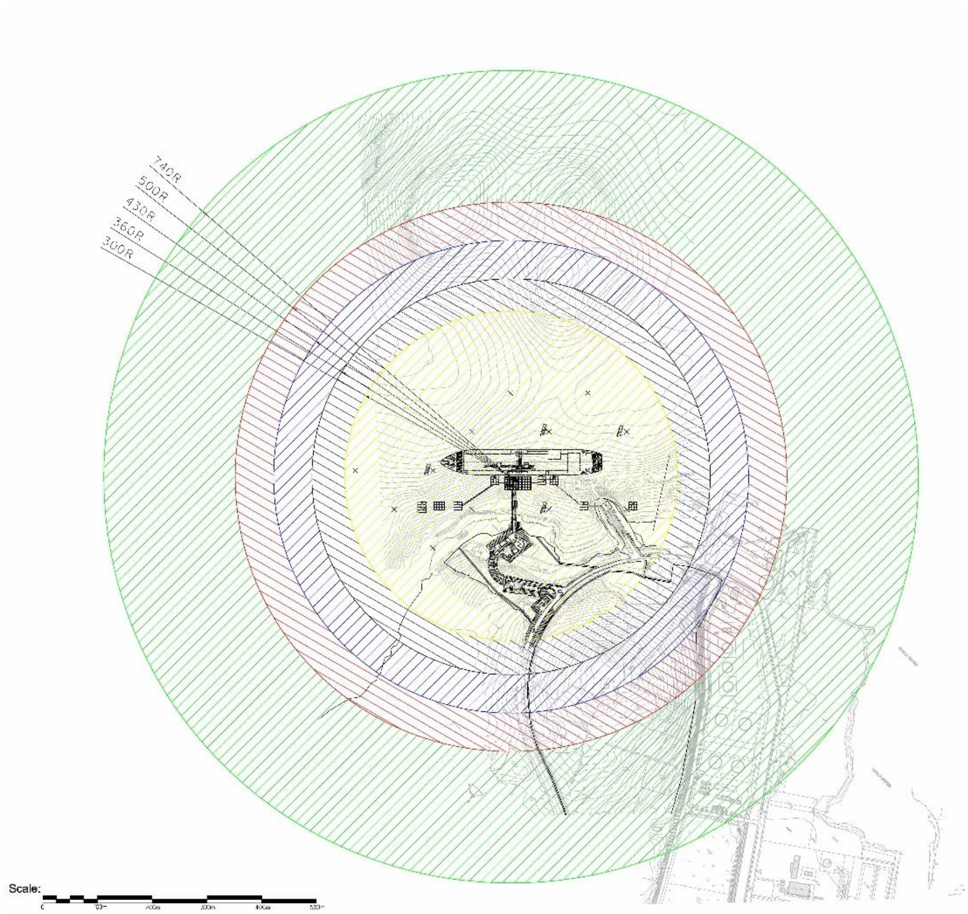

Figure 74 Impact area in case of fire (heat flow 1,5, 5, 8, 15 and 32 kW/m²)

In case of big scale fire the commander of JVP on fired area, as a rule, takes command over all firefighting procedures. Should fire be of such scale that endangers marine or shore facilities at terminal zone and threatens spreading, it is necessary to consider unmooring or moving the ship. Decision about unmooring is brought by the same procedure i.e. following the same principles as in case of weather disasters.

FSRU and LNG carrier leave all persons who are not necessary for fire extinguishing. On the occasion of gathering of ship and terminal personnel at rendezvous it is carried out counting. If somebody is missing, this should be reported to responsible persons and appoint a team for search and help of missed persons.

After fire is extinguished it is mandatory to leave somebody to guard and monitoring fired place in case fire occurs again. Responsible persons on terminal, commanding officer on FSRU and master of LNG carrier with JVP commander have to make report about occurred extraordinary circumstance.

Firefighting measures have to be executed and checked in accordance with security measures check list between LNG carrier and FSRU (Ship to Ship Safety Check List) and FSRU and shore (Ship/Shore Safety Check List) and have to include:

- Plan of fire extinguishing equipment and Plan of safety equipment has to be put on main deck near ship accommodation ladder.
- main deck fire extinguishing systems have to be under pressure during ship's stay at terminal and firefighting pipes with nozzles have to be ready to use;
- mobile dry powder extinguishers have to be located near manifold, and fixed dry powder firefighting system has to be ready for use and control panel for activation has to be unlocked;
- fixed system for firefighting by dry chemical powder at deck has to be in constant stand-by;
- all external openings (entries in superstructure and windows) must be closed, and ventilation/air-condition; set to partly recirculation in a way that all openings towards cargo tanks have to be closed.
- ship radio equipment can be used only for reception of information; all transmitting antennas must be switched off and grounded during connection of loading/unloading arms;
- use of ship radars during cargo transhipments is prohibited;
- all fixed and mobile electric and electronic devices which are used on ship's deck have to be of safe execution and approved by terminal responsible person;
- smoking on ship and terminal is prohibited, except in approved rooms which are specially designated;
- possession and carrying of cigarette lighters (except of safety matches) on ship and terminal strongly is prohibited;
- works by which can appear a spark, open flame or heat (Hot work) are prohibited during ship's stay at terminal.

In case of fire and explosions in the LNG FSRU terminal zone, terminal personnel is acting according to Terminal firefighting plan. Sequence of informing is very similar to previous case, but in inverse direction. After announcement of fire-fighting alert on terminal, under leadership of manager credibility, place and volume of fire is checked. Using earlier mentioned means of alarming and communication follows informing of terminal responsible persons and other vessels present at berths. By this procedure it is informed ship's commanding officer who puts the crew and ship's main engine in stand-by. After gathering and checking number of terminal workers it is established whether somebody is missing and accordingly starts search and rescue of missed person. Terminal responsible persons determine volume of fire and estimate need for informing DUSZ and Harbour Master's Office. Arrival and acceptance of land fire-fighting, medical and police help, as well as help of tug by seaway is the same as in previous case.

After successful extinguishing terminal responsible persons are obliged to report to shipmaster about termination of extraordinary circumstance.

9.4 COLLISION WITH ANOTHER SHIP OR VESSEL

Collision and bump according to their characteristics may be classified in the same sea accidents. The reason for this are circumstances at which they occur, and characterize them physical touch with foreign object by which always occur material damages. Collision or bump LNG carrier may have fire, explosion, spillage or leakage of liquefied gas as the consequence.

Basically, by collision is considered impact a vessel with another vessel in navigation or at berth, while a bump of vessel is considered impact with an object that is not a vessel. Collision in most cases happens at full speed both or one vessel due to which damages to hulls are relatively large and it can come to creation of big openings and water breakthrough.

If a collision happens during FSRU, LNG carrier's stay at terminal or within terminal's safety zone, the initial procedures include informing to terminal responsible persons, termination of cargo transhipment, disengagement of loading/unloading arms and/or transhipment pipes, call to tugs and also informing Harbour Master's Office Rijeka about event that happened, all are the same as with occurrence of fire. As in every extraordinary circumstance follows establishing if there are missed or hurt people. On the ship, it is necessary as soon as possible, to establish volume of damage, find out if there has come to break of hull and flooding, leak of liquefied gas, oil or harmful liquids and general condition of the berth. It shall be necessary in due time to establish communication and state of the other ship, particularly number and status of hurt persons and render help if required.

Based on collected information about state of own ship, particularly on the basis of diver's reports, ship's master and terminal responsible person estimate risk and inform to Harbour Master's Office Rijeka about state.

Depending on scope of damage it depends whether will be called help and external rescuers. If it comes to water breakthrough, immediately must begin emptying of flooded part by ship's pumps, and terminal should be ready to render help with its available mobile pumps. Terminal responsible persons are obliged to call additional tugs, and by DUSZ call JVP of city of Rijeka. Tugs have available reversible fire extinguishing pumps by which they can empty flooded vessels. Firefighting squads have also mobile pumps and they can help in emptying from shore. The crew is obliged, to the extent that is technically executable, try to reduce water breakthrough. If water emptying capacity is greater than sea breakthrough and ship retains buoyancy, it shall be necessary to start with damage repair.

In order to reduce probability of collision with other ships and vessels, that is, nearing of potential unattended sources of fire in vicinity FSRU, LNG carrier i.e. terminal it is suggested establishing prohibition zone for navigation of all ships, boats and yachts i.e. divers at distance of minimum 300 m from end point of FSRU ship or LNG carrier.

9.5 POLLUTION OF A LARGE AMOUNT OF OIL, OILY WATER OR OTHER PROHIBITED SUBSTANCES INTO THE SEA

Preventive measures for sea pollution depend on cargo, fuel and other pollutants characteristics as well as applied technology of transport and transhipment. Because natural gas does not represent special danger to environment, possible ambient pollution from FSRU and LNG carriers are primarily effusion of fuel or oily waters from engine room. Conventional GTT (Gaz Transport & Technigaz) LNG carriers might have 6.000 tons of fuel, and, a Q-Max LNG carriers up to 10.000 tons of low sulphur heavy fuel oil.

Mostly open sea space in front of LNG FSRU terminal Krk can favour bigger scale pollution in case of considerable scale discharge of fuel.

Pollutions from LNG carriers that could be expected can be divided:

- as result of regular work (work pollutions)
- as result of shipping incidents.

Basic cause of pollution from the first group is smaller incidents during ship's stay at terminal, mostly because of poor maintenance of ship's cleanliness. Basic characteristics of such pollutions are that they are relatively small volume, and occurred damages can be kept under control by applicable measures. Basic protection measure from pollution in such case is closing all openings at ship's deck (Scupper Plugs) and maintenance of cleanliness. Putting the floating protective booms around the LNG carrier during transhipment is not assumed. It is recommended provision of floating protective booms (or other equal means of pollution confinement) or assurance of their delivery in due time and in length enough to encircle both FSRU ship and LNG carrier as well as relevant part of terminal. Encircling is recommended to be mandatory only in case of loading or unloading of diesel fuels or during unloading of oiled waters to another ship.

Pollutions resulting from other incidents, primarily stranding, fires and explosions belong to most frequent big ecological accidents. In case of such pollutions, upon discharge of big quantity of fuel or oily waters the only possible measure to prevent ecological damages is multiple encircling of ship by appropriate floating barrages. Generally preventive measures against sea pollution should be agreed in advance between ship and FSRU and terminal and FSRU by means of check list (Ship/ship and Ship/Shore Safety Check List).

During the first year from beginning of work it is assumed prohibition of fuel loading into ships moored at terminal. If needed, the loading of fuel can be performed at near anchoring area for ships transport liquefied gases. After expiration of the first year of work it is proposed considering permission of fuel loading during stay of LNG carrier at terminal, but not during cargo transhipment. In such case the ship delivering fuel and from which fuel is transferred, FSRU and LNG carrier have to be encircled by protective barrages.

In case that during LNG carrier’s stay at terminal have come to uncontrolled discharge of harmful liquids at ship's deck or into sea FSRU master and/or LNG carrier master are obliged to act according to Shipboard oil pollution prevention plan. Direct ship and terminal procedures have to cover the following actions:

- informing terminal responsible persons;
- break cargo transhipment;
- undertake preventive measure for further drainage of liquids into sea;
- secure all possible sources of ignition;
- organize in shortest possible time deck cleaning and removal of oily and greasy materials from ship to appropriate place on shore;
- report Harbour Master's Office Rijeka about causes, quantities of substance being drained into sea, its characteristics and protective measures undertaken as well as source of pollution;
- if it matters of bigger quantities i.e. if it has come to pollution spreading outside protected zone of one barrage, inform an organization qualified for removal of pollution and about quantity of substance being drained into sea, its characteristics and measures undertaken and agree supply of additional quantities protective barrages;
- start with preparations for limitation of pollution and its cleaning including collecting people and equipment, informing authorized persons, collecting liquids that have run out into sea etc.,

If it matters about estimated quantity up to 2.000 m³ County Operating Centre (ŽOC) is alerted. ŽOC is authorized for all pollutions caused by oil or oil mixture up to 2000 m³ and in such cases it is applied County Intervention Plan for Sudden Sea Pollutions. Supervision on acting according to Intervention plan at polluted place carry out authorized inspector of Harbour Master's Office Rijeka ŽOC commanding officer is harbour master, having headquarters in Harbour Master's Office Rijeka In case of outpouring of quantity bigger than 2.000 m³ oil or other pollutants it is applied State Intervention Plan for sudden sea pollution. For this plan authorized is Headquarters for enforcement of Intervention Plan which has headquarters in Central Body of State Administration authorized for sea. The role of coordinative activities for the information required for Headquarter is performed by central national Maritime Rescue Coordination Centre in Rijeka (MRCC).

In purpose to reduce danger from sea pollution at ŽOC level, it is necessary to undertake the following measures:

- putting in stand-by tugs or vessels with sufficient towing capacity and ability to render support in elimination of pollution;
- putting in stand-by cleaning ships, suitable equipment and personnel for acting in case of pollution;
- putting in stand-by Civil Defence;
- putting in stand-by firefighting department, emergency medical help; and mountain rescue.
- undertaking other measures commensurate to detected danger from pollution.

Undertaking measures for reduction and elimination of sea pollution orders commanding officer or ŽOC commander depending on pollution scale, and according to competence.

9.6 OTHER ACCIDENTS

Under other accidents it is understood all other extraordinary circumstances which might be dangerous for people, moored ship, ships in vicinity or terminal. Other accidents can include:

- A man over board - Accident is understood as unaware fall crew member and terminal personnel into sea who can get drowned, can be injured due to fall (head or body shock) or while being in sea (under waves impact and sea current) to be sub cooled.
- Shift of LNG carrier and/or FSRU at berth - Ship and FSRU have to be moored in accordance with agreed mooring plan, and forces at mooring winches have to be monitored so that longitudinal shift of vessel is within technical characteristics of high-pressure loading/unloading arms (for FSRU i.e. the biggest allowable shift of flexible transhipment pipes for the LNG carrier. In case of too big shift it comes to activation of ESD system, which should be avoided as much as possible. Subsequently it is forbidden starting LNG carrier's engine while ship is moored along FSRU.
- Roll-over effect – In some exceptional cases, as a rule, during LNG loading into tanks where already previously loaded gas is, it can come to stratification (splitting of cargo in two layers due to difference in density). Due to heat transfer and equalization of density it comes to sudden mixing and evaporation of gas which can cause unwanted pressure increase in tank, its damage and finally gas emission. The consequence is sudden increase of pressure in tank with possible gas emission into atmosphere.
- Ship list– Ship list during stay at berth can happen due to irregular work with ship ballast system or implementing of wrong balancing plan. Direct cause of list is the construction of central balance tanks, usual with older LNG carrier performance, where side tanks are connected in the middle of ship by incomplete partition of approximate height up to 3 m which makes possible uncontrolled transverse flow of ballast water and consequently uncontrolled list. Usually in case of list bigger than 1.5˚ or sudden increase of list switch on safety systems ship-terminal that is, ESD procedure is initiated.

Figure.75 LNG EDO ship list due to irregular ship balancing

Such as for extraordinary circumstances from previous chapters are quoted expected procedure, so it is also for other accidents necessary to have clear action procedure. How much these procedures shall be described in official ship or terminal manuals depends on ship-owner's safety policy i.e. terminal concessioner.

Generally, procedures in case of any other accident occurred at terminal zone and which can (to whatever extent) endanger safety of ship have to include the following:

- annunciation of agreed alarm,
- starting up the procedure of transhipment emergency shutdown(ESD),
- inform responsible persons on LNG FSRU ship (and if necessary also other persons, primarily authorised harbour master's office) about occurred circumstances,
- starting up safety procedure on interface ship-shore as required (disconnection of loading/unloading arms, preventive start-up of fire extinguishing systems, departing berth etc.).
- acting according to set forth procedures from Terminal Safety Plan.

In the same way in case of any other accident which occurs on ship, and which can to any other scale endanger safety of ship or terminal, the commanding officer i.e. crew have to consider:

- starting up the procedure of transhipment emergency shutdown(ESD),
- inform responsible persons on terminal i.e. FSRU and LNG carrier about occurred circumstances,
- start up safety measure on the interface FSRU-shore and LNG carrier-FSRU according to need (disconnection of loading/unloading arms towards FSRU and/or disconnecting flexible transhipment pipes towards LNG carrier, preventive start up fire extinguishing systems, departing berth etc.).
- acting according to prescribed procedures from Ship Safety Plan.

Conclusion:

(61) Under extraordinary circumstances at the LNG FSRU terminal it should be considered: 1) wind strength 7 Beaufort (> 13.8 m/s) or more i.e. waves of significant height of 1,5 m or more; 2) emission of liquefied gas (from ship or from terminal); 3) fire and/or explosion (on LNG carrier or FSRU or terminal facility on shore); 4) collision of other ship or vessel; 5) drainage of bigger quantity of oil, oily waters or other prohibited matters into sea; 6) other dangerous

circumstances for which terminal's or ship's responsible person estimate that can present danger to ship or terminal.

(62) In case of weather disasters it is announced stand-by state in case of wind of 6 Beaufort (>10,8 m/s) or waves of significant height higher than 1 meter (max. wave height 2 m).

(63) Terminal responsible persons, FSRU master and/or master of LNG carrier can bring decision about termination of cargo transhipment, disconnection of loading/unloading arms, that is, pipes and leaving berth and in case of other circumstances in any moment, if they estimate that safety of any unit is endangered.

(64) In case of extraordinary circumstances besides actions by which adverse consequences are prevented, cargo loading/unloading arms and /or transhipment pipes are disconnected, all terminal persons get off from FSRU and LNG carrier, pilot is called, and standby tug places towing rope.

(65) Principally, in case of extraordinary circumstances, as much as occurred circumstances allow, LNG carrier remains moored along FSRU. Accordingly, it makes possible direct and quick access and easier elimination of accident cause and consequences.

(66) Limiting value for berth departure for LNG carrier, as a rule, is wind speed of 25 m/s.

(67) Leaving the berth of a LNG carrier or FSRU ship is considered a measure in extreme necessity and is undertaken only if there is no other possible action and in case of direct danger. If the berth is still to be left, this must be done, as a rule, with prior notice to Harbour Master's office Rijeka and in presence of pilot and tug and according to agreement with shipmaster and pilot.

(68) In case of individual extraordinary circumstances procedures foreseen in this study and all other procedures are conducted, as set forth by terminal, FSRU and individual LNG carrier rules, i.e. as appropriate to circumstances.

(69) In case that real conditions are different from those anticipated in this study the SFRU commanding officer, master of LNG carrier and terminal responsible persons can amend some of foreseen (set forth) procedures and safety measures or conditions. All in advance confirmed procedure and safety measures have to be referred to in respective compatibility study.

(70) It is proposed to follow-up all proposed safety navigation measures in course of the first year of terminal work and by expiration of this period re-examine proposed safety measures.

10 CONCLUSION

The most important conclusions in this study are:

(1) The waterway stretching from the open part of the Adriatic to the LNG FSRU terminal allows for a safe navigation of LNG carriers of a specified size and does not require implementation of any special measures of safe navigation due to the anticipated increase in traffic.

(2) Orientation points and waterway markings of the waterway stretching from the open part of the Adriatic to the LNG FSRU terminal allow for a safe navigation of LNG carriers. There is no need to introduce new markings of the waterway.

(3) The existing navigational and communication support ensures a safe access to the LNG FSRU terminal for the LNG carriers. The measures for navigation management (VTS) are adequate for the existing traffic.

(4) The total existing traffic of ships in the Rijeka Bay, i.e. towards the ports in Rijeka Bay, is of small or average intensity and does not call for additional safety measures for navigation.

(5) The area of the access waterway that does ask for special attention is the area of Vela Vrata.

(6) The probability of running aground of any type and size of vessel at the access waterway comes down to approximately 0,50 instances a year. The highest probability is in the area of Vela Vrata. Running aground due to a loss of power is more probable than running aground due to an error in making navigational decisions. According to statistical data, the grounding of tanker was not recorded at the approaching waterway.

(7) The probability of collision at the access waterway is, at the point of being insignificant. Passenger ships are at risk the most.

(8) Weather conditions do not significantly hinder the navigation of larger ships in the access waterway.

(9) The heights of waves and gusts of wind during the strongest storms may delay the mooring of LNG carriers, i.e. delay the handling of cargo. The highest waves should be expected during winds coming from the northwest and west directions and they should not affect a safe stay of the ships at the terminal, however they can hinder the ship manoeuvring.

(10) The LNG FSRU terminal is partially protected from winds coming from the north, northeast, south and southeast.

(11) The likelihood of more significant wave heights of over 1,5 m in the area of the terminal is very small, especially as a result of westerly winds.

(12) A delay upon mooring of LNG carrier or a cancelation in cargo handling can be expected during strong winds from the NE quadrant. Those types of unfavourable weather conditions are significantly more likely during the winter period.

(13) Local storms may have an effect on deciding to halt cargo handling throughout the year.

(14) On LNG FSRU terminal LNG carriers having capacity greater of 3.500 m3, i.e. LNG Feeder ships can be expected.

(15) The estimation shows that the most frequent vessels to be accommodated are those with the capacity from 140.000 to 180.000 m^3. Probability of acceptance of the biggest LNG carriers (265.000 m^3) is relatively small.

(16) At LNG FSRU terminal shall be expected acceptance of LNG carriers equipped with all existing technologies of ship tanks for liquefied gas.

(17) At LNG FSRU terminal shall be expected LNG carriers equipped with all recently known driving systems. In this regard, manoeuvrability of the LNG carriers to be accommodated will be considerably various.

(18) Manoeuvrability characteristics depend on the following characteristics of LNG carriers: large freeboard lateral surface exposed to the wind, low draught of a ship, i.e. low lateral resistance, low visibility from the command bridge, and extremely slow engine start-up for some propulsion system configurations.

(19) To ensure safe operations on board of LNG carriers all safety regulations should be observed.

(20) LNG FSRU terminal Krk in Omišalj is planned to be located on the north-west part of Krk island on Cape Zaglav at the site approximately 1,5 south-east from Omišalj village and about 2 km to the north from Njivice village.

(21) Basic components of FSRU LNG terminal are FSRU, shore berth (includes a platform, solid structure berths for docking and mooring) for acceptance FSRU ship capacity 160.000 m3 to 265.000 m3 and FSRU ship enabling mooring of LNG carrier capacity 125.000 m3 to 265.000 m3.

(22) The biggest planned annual capacity of terminal amounts to 8.3 billion cubic meters gas i.e. an average in the first years of terminal work amounts to 2.6 billion m3 gas with possible of increasing the capacity depending on the development of land gas transportation network..

(23) Anticipated annual traffic of LNG carriers delivering gas in first years of work is estimated from 15 to 30 ships for cargo unloading. LNG carriers' traffic for the biggest capacity of FSRU ship is estimated from 50 to 70 LNG carriers annually for gas unloading.

(24) It is envisaged the LNG loading to feeder ships of a capacity from 3.500 m^3 to 35.000 m^3. It is impossible to estimate the number of LNG feeder ships since it depends on further development of the onshore gas transmission grid.

(25) Anticipated unloading time LNG carriers in delivering is estimated to 24 hours depending on instant cargo quantity on FSRU ship and on capacity of gasification and consumption of the natural gas by end users. The estimated total time of LNG carriers stay at berth is up to 50 hours.

(26) Terminal transhipment equipment on shore includes high pressure arms (12") for delivery of gas from FSRU ship to shore and its dispatching to gas network. LNG shall be transferred from LNG carrier to the FSRU vessel via cryogenic flexible hoses.

(27) The design provides for the depth of 15 meters alongside the waterway at the terminal.

(28) The boundary conditions for docking of LNG carrier at the FSRU terminal are constant wind speeds of 25 knots (≈13 m/s) and a significant wave height of 1.0 m (max. 2m wave height). For the unmooring and departing manoeuvre, depending on its direction, wind speed can be 25% higher than the boundary speeds allowed for the docking manoeuvring.

(29) Standard procedure for the announcement of the arrival of an LNG carrier is provided.

(30) It is recommended to perform enhanced surveillance of the LNG carriers by a competent VTS service during their navigation through the territorial sea of the Republic of Croatia.

(31) It is recommended to introduce the safety domain around the LNG carrier, i.e. to ensure free space around the vessel by the VTS service during the navigation through the navigation in the ship's routing system area Vela Vrata until berth or anchorage. The recommended size (as standard practice) of the free space is 1,000 m from the bow and stern of the vessel and 500 m on each side.

(32) It is recommended to introduce a speed limit of 15 knots for the navigation of all vessels carrying dangerous or polluting substances in a liquid state in the passage Vela Vrata.

(33) It is recommended to introduce mandatory pilotage through the passage Vela Vrata until the vessel reaches the berth for all vessels carrying dangerous or polluting substances in a liquid state for longer than 250 m. It is recommended to establish a pilotage station south of the passage Vela Vrata for the boarding or disembarking of the pilot.

(34) It is recommended to use of two pilots during the first year after the commencement of the terminal's operation. If experience reveals that one pilot is enough, the obligation to use two pilots can be changed after gaining enough experience. It is also recommended LNG carriers be exempt from the exemption from the mandatory pilotage.

(35) It is recommended to make use of Portable Pilot Unit (PPU) mandatory, under the condition the characteristics of PPU correspond to that listed in the study.

(36) The change of existing anchorage intended for vessels transporting liquefied gas is not provided.

(37) For safe manoeuvres from any direction and the stay of the largest LNG carriers, it is assumed to perform the dredging of shallow waters (13.7 m), located about 250 m from the coastline of the new LNG FSRU terminal in the northwest direction, to the depth of at least -15 (measured from the hydrographic zero).

(38) During manoeuvring, use 4 or more tugs is compulsory, each with bollard pull of at least 500 kN during the docking manoeuvring, and 2 or more tugboats, each with traction force of at least 500 kN during the departing manoeuvring.

(39) As a rule, portside LNG carrier berthing is used, i.e. with the bow of the vessel towards the open sea.

(40) Mooring and unmooring during the first year or for the first 10 times the large LNG carrier is accepted, whichever comes first, is performed only during the daylight. After that period, the Port of Rijeka Authority can approve the mooring and unmooring of the LNG carrier during the entire the day following prepared revision of the maritime study

(41) Three ship panel fenders to each solid structure berth, each having energy absorption at least 4.500 kNm and sufficient surface as to ensure that pressure to ship's hull is within allowable limits should be installed. Surface of each panel fender is at least 25 m².

(42) Even in extraordinary circumferences pressure on ship's hull should not exceed 200 kN/m².

(43) Approaching speed limit toward terminal should not exceed 0,15 m/s. In case of smaller ships mooring (length up to 200 m) approaching speed may be even greater, but not greater than 0,20 m/s.

(44) It is recommended that jetty will be equipped with laser device for measurement ship's distance from the jetty and ship approaching speed as well as approaching angle. Display is recommended to be placed at the terminal so that could be seen at any time from the approaching LNG carrier or FSRU.

(45) It is recommended that dock is equipped with an anemometer with data distant reading in terminal's control room of wind speed and direction measurements at height of 10 m above sea level.

(46) It is recommended that dock is equipped with: 1) mooring structures (mooring solid structure berth) as described in the study, furnished with fourfold quick release hooks for installation of forward and side lines, 2) two mooring assemblies with double quick release hooks for springs.

(47) Quick release hooks must be furnished with dynamometer and connected with terminal's and ship's control rooms. Pedestal and each hook must withstand loads at least 1.500 kN and be tested with safety coefficient at least 1,5. Mooring assembly has to be furnished with steel rope lifting winch and placement on each hook.

(48) The biggest FSRU ship QMax size should berth to dock by at least eleven forward lines, eleven stern lines and two forward and two stern springs. Parallel lines have to be of the same characteristics. For smaller ships it is allowed less number of lines as set forth in the study.

(49) Mooring of a LNG carrier to FSRU ship should be done by at least 6 forward lines, 6 stern lines, two stern springs and two forward springs. Parallel lines have to be of the same characteristics. For smaller ships it is allowed less number of lines as set forth in the study, while for mooring of LNG QMax ship the number of forward and stern lines should be increased by one.

(50) For berthing, the steel lines (with tail) of high tensile strength should be used

(51) It is supposed the biggest constant load in each line during ship's stay at terminal 150 kN i.e. maximum 300 kN (30 t).

(52) During ship's stay, at bow and stern must be placed mooring lines for emergency mooring of tug having tensile strength at least 1.000 kN.

(53) The minimum required depth at area of manoeuvring and terminal berth for acceptance of LNG carriers with most expected draft is 15,0 m.

(54) During ship's stay at terminal all works on drive assembly are forbidden due to which ship might be unable to float out, in case of emergency, by use of its own drive. Other works on ship maintenance, which neither create danger of fire or other incidents, nor disable engine start or other equipment parts essential for safe emergency float out are allowed providing previous announcement and approval of terminal's person in charge.

(55) Safety zone around LNG terminal in diameter at least 500 m from the end points of FSRU ship or LNG carrier, inside which navigation of all vessels anchoring and fishing is forbidden with exception of LNG carriers and other vessels having terminal's permit, should be set up.

(56) During overall stay of LNG carrier at terminal one tug with installed fire extinguishing system has to be in stand by and upon call to be at disposal to FSRU and LNG carrier in maximum 10 minutes.

(57) Terminal must have approved Estimate of Safety Protection of port operating zone and Plan of Safety Protection.

(58) For the first acceptance of LNG carrier(s) it has to be elaborated a compatibility study by which it is confirmed compatibility of ship's equipment and procedures with respective equipment and terminal procedures in respect with safety mooring and cargo handling.

(59) Basic communication link (telephone, data and ESD) between ship and terminal is accomplished by communication link which can be realized by optical cable and/or electric cable. Separately for ESD system is installed additional safety link by pneumatic system.

(60) Basic radio-link between ship and land is UHF radio device which terminal puts at disposal. Alternatively, communication can be carried out by means of VHF link on agreed channel.

(61) Under extraordinary circumstances it should be considered: 1) wind strength 7 Beaufort or more i.e. waves height 1,5 m or more; 2) emission of liquefied gas (from ship or from terminal); 3) fire and/or explosion (on LNG carrier, FSRU or terminal facility on shore); 4) collision of other ship or vessel; 5) drainage of bigger quantity of oil, oily waters or other prohibited matters into sea; 6)

other dangerous circumstances for which terminal's or ship's responsible person estimate that can present danger to ship or terminal.

(62) In case of weather disasters it is announced stand-by state in case of wind of 6 Beaufort (>10,8-m/s) or waves of significant height higher than 1 meter (max. wave height of 2 m).

(63) Terminal responsible persons, FSRU master and/or master of LNG carrier can bring decision about termination of cargo transhipment, disconnection of loading/unloading arms, that is, pipes and leaving berth and in case of other circumstances in any moment, if they estimate that safety of any unit is endangered.

(64) In case of extraordinary circumstances besides actions by which adverse consequences are prevented, cargo loading/unloading arms and /or transhipment pipes are disconnected, all terminal persons get off from FSRU and LNG carrier, pilot is called, and standby tug places towing rope.

(65) Principally, in case of extraordinary circumstances, as much as occurred circumstances allow, LNG carrier remains moored along FSRU. Accordingly, it makes possible direct and quick access and easier elimination of accident cause and consequences.

(66) Limiting value for berth departure from LNG carrier, as a rule, is 25 m/s.

(67) Leaving the berth of a LNG carrier or FSRU is considered a measure in extreme necessity and is undertaken only if there is no other possible action and in case of direct danger. If the berth is still to be left, this must be done, as a rule, with prior notice to Harbour Master's office Rijeka and in presence of pilot and tug and according to agreement with shipmaster and pilot.

(68) In case of individual extraordinary circumstances procedures foreseen in this study and all other procedures are conducted, as set forth by terminal, FSRU and individual LNG carrier rules, i.e. as appropriate to circumstances.

(69) In case that real conditions are different from those anticipated in this study the SFRU commanding officer, master of LNG carrier and terminal responsible persons can amend some of foreseen (set forth) procedures and safety measures or conditions. All in advance confirmed procedure and safety measures have to be referred to in respective compatibility study.

(70) It is proposed to follow-up all proposed safety navigation measures in course of the first year of terminal work and by expiration of this period re-examine proposed safety measures.

REPUBLIKA HRVATSKA
Ministarstvo mora, prometa i infrastrukture
Uprava sigurnosti plovidbe
Lučka kapetanija Rijeka

P / 3984919

KLASA: UP/I-350-05/18-01/31
URBROJ: 530-04-4-2-2-18-2
Rijeka, 08. ožujka 2018. godine

LUČKA KAPETANIJA RIJEKA nadležna temeljem članka 1. Zakona o lučkim kapetanijama (NN br. 124/97), temeljem članka 96. Zakona o općem upravnom postupku (NN br. 47/09), **povodom zahtjeva LNG Hrvatska, a u predmetu prihvaćanja i potvrđivanja MARITMNE STUDIJE – LNG FSRU Krk, donosi**

R J E Š E N J E

Prihvaća se i potvrđuje MARITMNA STUDIJA – **LNG FSRU Krk**, izrađena u Rijeci 2017. godine od strane Pomorskog fakulteta u Rijeci uz pridržavanje uvjeta i obveza donesenih u studiji i zaključku.

O b r a z l o ž e n j e

LNG Hrvatska, obratila se dana 07. ožujka 2018. ovom tijelu sa zahtjevom da se prihvati i potvrdi MARITMNA STUDIJA – **LNG FSRU Krk**, za potrebe naručitelja izrađena u Rijeci 2017. godine od strane Pomorskog fakulteta u Rijeci, Studentska 2, 51000 Rijeka.

Uvidom u navedeni elaborat utvrđeno je da ista formalno udovoljava uvjetima propisanim Pomorskim Zakonikom, članak 54 a, stavak 3 i stavak 4 (NN br. 181/04, 76/07, 146/08, 61/11, 56/13, 26/15,), te članku 5. Uredbe kojima moraju udovoljavati luke (NN110/04), odnosno da sadržajno udovoljava osnovnim mjerama maritimne sigurnosti u predmetnoj luci posebne namjene.

Slijedom iznijetog riješeno je kao u izreci.

Upravna pristojba u iznosu od 35,00 kuna naplaćena je po Tarifi Zakona o upravnim pristojbama (NN br. 115/16 s izmjenama) u korist Državnog proračuna RH.

UPUTA O PRAVNOM LIJEKU
Protiv ovog rješenja može se uložiti žalba Ministarstvu mora, prometa i infrastrukture, putem ovog tijela, u dva primjerka, u roku od 15 dana od dana primitka ovoga rješenja. Na žalbu se plaća upravna pristojba u iznosu od 35,00 kuna.

REPUBLIKA HRVATSKA – MINISTARSTVO MORA, PROMETA I INFRASTRUKTURE – UPRAVA SIGURNOSTI PLOVIDBE – LUČKA KAPETANIJA RIJEKA 2

LUČKI KAPETAN
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