UNIVERSITY OF RIJEKA
FACULTY OF MARITIME STUDIES

AMENDMENT TO THE MARITIME STUDY FOR THE LNG FSRU KRK - "BERTHING OF SMALL-SCALE LNG SHIPS AT THE LNG FSRU KRK"

Rijeka, April 2021

Name: **AMENDMENT TO THE MARITIME STUDY FOR THE LNG FSRU KRK - "BERTHING OF SMALL-SCALE LNG SHIPS AT THE LNG FSRU KRK"**

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Content:

1 INTRODUCTION

This study was prepared pursuant to the agreement entered into between LNG Croatia d.o.o. as the client and the Faculty of Maritime Studies in Rijeka as the contractor.

The subject-matter of the agreement is the Amendment to the Maritime Study for LNG FSRU[1] terminal Krk (hereinafter: the Maritime Study) prepared by the Faculty of Maritime Studies in Rijeka pursuant to the agreement entered into with EKONERG d.o.o. within the scope of the Public Tender for preparing “Services of preparation of the design and permitting documentation for the construction of the Krk LNG terminal and consulting services related to obtaining of all necessary permits and approvals: FEED preparation and main design preparation for Krk LNG FSRU and obtaining of the construction permit and LNG FSRU power supply system documentation” from 2017. The concerned Maritime Study was delivered to the client and subsequently accepted by the authorised Rijeka Harbour Master Office.

The purpose of amending the study was to establish maritime safety measures for the berthing of LNG ships of sizes different from those for which maritime safety measures were established in the Maritime Study. The Amendment to the Maritime Study presumes the berthing to the FSRU ship “LNG Croatia” of LNG ships with a capacity of up to 30,000 m^3, i.e. of so-called *Small Scale LNG Ships*. Special consideration is given to reference LNG ships with a capacity of 3,500 m^3, 7,500 m^3, 20,000 m^3, that is ships with a capacity of up to 30,000 m^3 which are currently the largest of the small-scale LNG ships.

Ships and their technical and technological characteristics were obtained from the Client and as such are considered the reference for establishing maritime safety measures.

The preparation of the Amendment to the Maritime Study presumes the condition of the LNG FSRU terminal on Krk as on the date of the signing of the contract. This particularly applies to the berthing equipment on the LNG FSRU ship and the navigation characteristics in the port area and on approaches to the LNG FSRU ship.

The Amendment to the Maritime Study takes over all the presumptions, limitations, instructions, recommendations and conclusions established in the original study. The Study does not presume any amendment, cancellation or addition of conditions or limitations established under the Maritime Study except those relating to the berthing of reference LNG ships (ships for transportation of liquefied natural gas - LNG ships) established for the preparation of the Amendment to the Study.

1 LNG means liquefied natural gas.

2 THE TECHNICAL AND TECHNOLOGICAL CHARACTERISTICS OF LNG FEEDER SHIPS (SMALL-SCALE LNG SHIPS)

LNG ships with a capacity of up to 30,000 m^3 are classified as the smallest LNG ships. As a rule, the smallest LNG ships include small-scale ships: from the smallest ones with a capacity of 1,000 m^3 (usually constructed as barges) to those with a capacity of 30,000 m^3. The ships are intended for transportation of smaller volumes of LNG on shorter distances, that is, within one region, and are therefore called LNG feeder ships. In general, regardless of the navigation area, LNG ships of the said capacity, such as the reference ships in this study, are called *Small-scale LNG ships*.

Except for transporting LNG on shorter distances within a region (e.g. the Adriatic Sea), ships are also used as supply ships for other ships which use LNG as fuel (*LNG bunkering ships*). The capacity of these ships is usually approximately 5,000 m^3. These ships are called LNG BV (LNG bunker vessels) and are also ships from the “*LNG small-scale*” range.

The LNG FSRU terminal in Omišalj is designed to accept all sizes of small-scale ships with a capacity of up to 30,000 m^3, primarily ships with a capacity of 3,500 m^3, 7,500 m^3 and 20,000 m^3.

In general, development of smaller LNG ships began only recently, so there were only 44 ships at the beginning of 2017 at the global level. However, there has been an abrupt increase in the number of orders, so, in 2020, the international fleet increased to approximately 80 ships.

In early 2019, only six dedicated LNG bunkering ships were operative in the whole world. This number has almost doubled since the beginning of 2020, so that now 15 dedicated LNG bunkering ships are operative world-wide. According to the latest reports, 25 more dedicated LNG bunkering ships have been ordered or are being built and will be operative in the upcoming years. This is related to the abrupt increase in the international fleet of LNG-powered ships, first and foremost container ships and cruise ships as well as ro-ro passenger ships. Therefore, intensified development and construction of new LNG bunkering ships is expected in the future. It must be noted that LNG bunkering ships’ size is increasing, and that, at the moment, the largest LNG bunkering ship in the world is “Gas Ability” with a capacity of 18,600 m^3. Such a capacity is consistent with the fuel capacity of ultra large container vessels (ULCV) exceeding 400 m, built by CMA CGM (e.g. *CMA CGM Jacques Saade*), the company which intends to build 26 more of such ships in the next few years.

LNG feeder ships are usually designed with a capacity of up to 30,000 m^3. These are used for coastal short distance transport from one LNG terminal to the other, but they can also be used for supplying other ships with LNG. Moreover, in the next years, an increase is expected in the number of larger LNG feeder ships, with a capacity of 30,000 m^3.

Table 1 Common sizes of LNG feeder ships (*small-scale LNG ships*)

Capacity (m³)	Deadweight (t)	L (m)	B (m)	T (m)	Approximate surface above water / side and front (m²)	Approximate surface under water / side and front (m²)[2]
3,500	2,300	94	15.8	4.6	970 / 270	430 / 70
7,500	3,800	123	18.6	5.6	1,550 / 390	700 / 100
20,000	12,000	160	24.0	8.0	2,700 / 650	1,250 / 190
30,000	16,400 – 18,500	180-185	28.0 -36.0	7.4 - 7.8	3,400 / 850	1,300 / 280

The cargo system on LNG feeder ships consists of the primary barrier (cargo tank), secondary barrier (if any), the pertaining thermal insulation, interspace and the stronghold for these elements.

Ships usually also have fenders (one or two sets of two fenders each) on both sides of the ship with their own system for lifting and lowering to enable berthing to other ships during the provision of the fuel supply service.

Please find below a description of the technical and technological characteristics of reference LNG ships that can be expected at the LNG FSRU terminal in Omišalj.

2.1 LNG SHIP WITH A CAPACITY OF 3,500 M³

The reference ship with a capacity of 3,500 m³ is designed as a dedicated ship for supply and handling of LNG during transport and for supplying LNG as fuel to other ships, meeting all applicable rules and regulations of the International Maritime Organisation and the relevant requirements of the flag state administration.

These ships are usually equipped with a dual fuel engine which powers the controllable pitch propeller, effective bulbous bow, the flap type rudder and fine ship contours for the optimum speed to power ratio and minimized fuel or gas consumption.

The ship has only one main deck structure, in the centre of which LNG tanks are located. The cargo area is split by a single transverse partition into 2 units for storage of cargo tanks. Side ballast tanks, located alongside the cargo area, act as a partition between the cargo area and the ship's plating.

Figure 1 LNG bunkering ships with a capacity of 3,500 m³

The engine room area and the crew accommodation superstructure, including the navigation bridge are located on the stern. The stern part of the hull includes steering gear, aft peak tank and potable water tanks.

2 These surfaces are assessed using simplified ship profiles assuming that actual sizes are app. 5-10 % smaller than the indicated ones.

The engine room is, as a rule, the area where the main propelling machinery is located. In addition, the machine room is designed to include a sufficient number of decks and platforms for an efficient arrangement of auxiliary machinery and equipment, storage areas and fuel tanks.

The navigation bridge is located on the topmost superstructure deck, enabling all-round visibility, unobstructed view of the horizon and satisfactory visibility over the bow. The part above the engine room with the machinery devices exhaust pipes is separated from the superstructure.

The ship's fore part consists of the fore peak tank, the section hosting the bow thruster, chain locker and storage area for deck equipment and tools.

According to prior experience, LNG feeder ships have very good manoeuvring abilities. The reference ship is equipped with a power-operated bow thruster with 300 kW nominal power which is the usual power of side bow thrusters on similar ships. The bow thruster is remotely controllable from the navigation bridge and bridge wings.

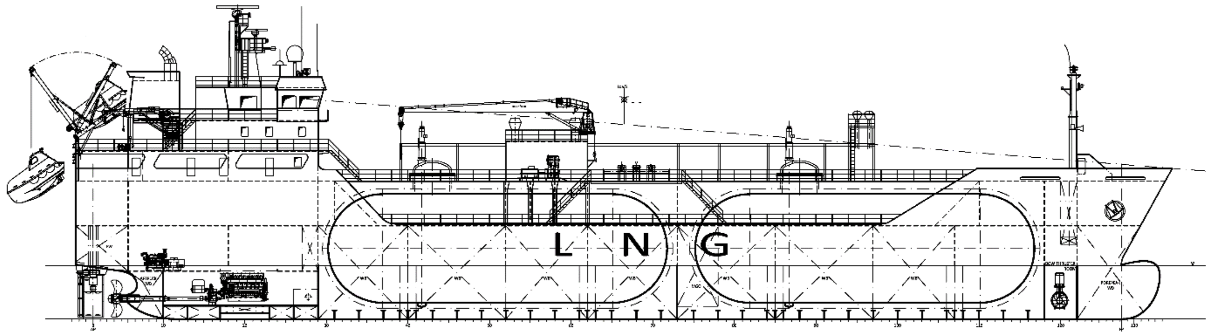

Figure 2 The profile of the LNG reference ship with a capacity of 3,500 m^3

(Source: Technical outline specification for a 3,500 m3 LNG feeder vessel - Inženjering za naftu i plin d.o.o. Zagreb)

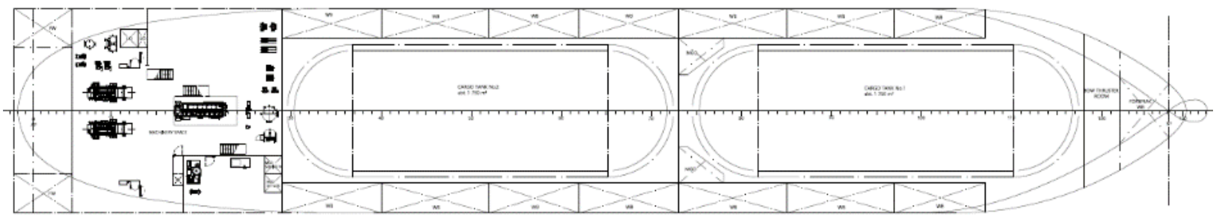

Figure 3 Cross-section of the tank and machine room of the reference ship

(Source: Technical outline specification for a 3,500 m^3 LNG feeder vessel - Inženjering za naftu i plin d.o.o. Zagreb)

The ship is equipped with 2 tanks, each with a capacity of 1,750 m^3 and a diesel-fuel tank with a capacity of 120 m^3.

Table 2 Technical and technological characteristics of the reference LNG ship with a capacity of 3,500 m^3

LNG ship with a capacity of 3,500 m^3	
Length (m)	94.1
Width (m)	15.8
Draught (m)	4.6
Deadweight (t)	2,300
Capacity (m^3)	3,500
Speed (kts)	11.6
Engine power (kW)	880
Bow thruster (kW)	300

The propulsion used by LNG feeder ships must enable excellent manoeuvring abilities. In the reference ship, the main component of the propulsion machinery consists of a single diesel engine (four-stroke) powered by one controllable pitch propeller (CPP). The main engine is a dual-fuel engine, i.e. an engine which can be powered by both gas and liquid fuel. Electric power comes from 2 generators (Mitsubishi GS6R2-PTK or similar) with equivalent fuel and gas specifications as the main engine.

The diesel fuel tanks capacity for all fuel users is sufficient for autonomous operation of app. 4,000 nautical miles in the conditions of the design speed and main engine loading of 90 % MCR (maximum continuous rating).

Based on the specific fuel consumption for the main engine of app. 204 g/kWh under ISO 3046 reference conditions and a lower calorific value of 42,700 kJ / kg, the daily fuel consumption is approximately 6.6 t. Based on the specific calorific value for the main engine, that is, when the engine is powered by gas, of about 8,130 kJ/kWh under ISO 3046 reference conditions and lower calorific value of 49,500 kJ/kg, the daily gas consumption amounts to app. 5.3 t (90 % MCR).

Also, the ship uses very small amounts (app. 0,3 t/day) of pilot fuel (MDO, marine diesel fuel) in all modes of operation (gas and diesel mode). In gas mode, the compound of compressed gas and air is ignited by injecting pilot fuel.

On the ship at hand, cargo is transported in two independent C-type IMO tanks (of cylindrical shape), sized Φ 9.3 m x B 29.0 m, with the minimum design temperature of -163°C. The LNG ship system observes the pressure build-up procedure without gas reliquefication, but including gas exploitation by combustion within the power system. The gas combustion unit (GCU) is installed on the ship for additional safety, allowing for the loading of LNG cargo tanks up to 98 % liquid-phase cargo filling level.

Each tank is equipped with one cargo pump with an unloading capacity of 175 m^3/h. In addition, each tank has a fuel gas pump with a capacity of 5 m^3/h. Its primary goal is the supply of LNG into the fuel vaporizer and/or it can be used further for line cooling during sailing.

Cargo handling pipelines are made of stainless steel and consist of pipes, flanges, studs, screws, nuts, seals, etc., according to DIN standards pursuant to the requirements of the classification society, that is, the IGC code.

Manifolds consist of three connections: two 12'' connections for the liquid phase and one 8'' connection for the gas phase. The unloading capacity is 350 m^3/h max., and the loading capacity is 550 m^3/h (including the return gas phase). Such a capacity enables full ship loading in an approximate time of less than 12 hours.

The ship's fuel system is designed for a full capacity at 100 % MCR of the main engine of the dual-fuel type and one auxiliary engine also of the dual-fuel type with forced vaporization and/or compression of the gas LNG phase. The system consists of two BOGs (Boil Off Gas) compressors, of the oil-free piston, with 100 % capacity at 100 % MCR of the DF engine at a pressure of 1.05 bar in the cargo tank, located in the compression room. The same compressor can be used for the gas phase return during cargo loading. It must be mentioned that, in case the gas LNG phase (BOG) in the cargo tanks is not sufficient to meet the ship's fuel requirement, additional fuel can be produced by forced vaporization. For this purpose, each tank has one fuel pump which sends LNG to the LNG Vaporiser. Fuel is brought from the BOG compressor or vaporiser to the main engine through the fuel system.

The reference ship is equipped with a manifold crane for cargo handling on each side of the ship, located in the centre of the ship, i.e. cargo section. The manifold crane is an electro-hydraulic swivel crane. The crane's nominal safe operating loading is 4.0 t. The crane's reach is app. 16.0 m, and at least to the area of 2.0 m over the ship's width along the entire length of the manifold. Moreover, the ship is equipped with a provision crane located at the stern, near the superstructure. This crane's nominal safe operating loading is 2.0 t, that is, enough for proper handling of provisions. This crane's reach over the ship's width is at least 3.0 m.

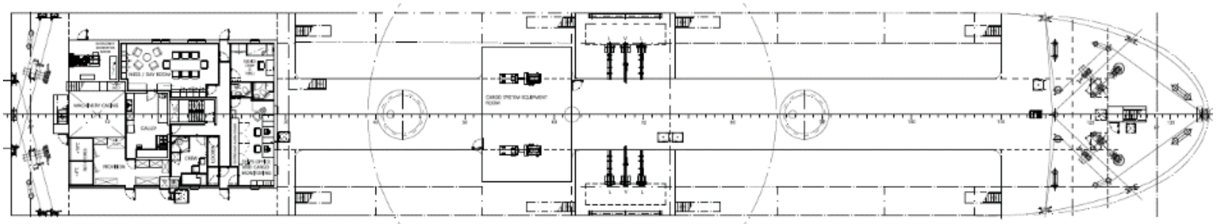

Figure 4 Cross-section of the reference ship's main deck

(Source: Technical outline specification for a 3,500 m3 LNG feeder vessel/bunker vessel - Inženjering za naftu i plin d.o.o. Zagreb)

The fenders between the LNG FSRU ship and the reference ship must be app. 15 metres away from the manifold centre.

All berthing and anchoring winches on the ship have their own electro-hydraulic motor drive. The berthing winches are powered by a low-pressure hydraulic system. The ship is equipped with a total of four berthing winches. Two of these are located at the bow in combination with the anchoring winches, and two at the stern, enabling simultaneous control of bow and stern ropes. Each anchoring/berthing winch is designed to operate separately as a berthing winch and separately as a winch for controlling the anchoring chain. Anchoring winches are powered by two hydraulic units.

The ship is equipped with safety equipment for the maximum foreseen number of persons aboard. As regards the rescue equipment, the ship is equipped with rescue boats located near the superstructure. At the ship's stern, there is an enclosed lifeboat (free fall lifeboat) with a diesel engine and a water spray fire protection system. Near the superstructure, there is also a rescue boat with its own davit for lifting and lowering the boat.

The ship is equipped with fire-fighting equipment in accordance with the valid rules and regulations. The fixed CO_2 fire-extinguishing system is used for the area of the engine room, engine room's control station, the room hosting the power control panels, compressor room and the area hosting the emergency generator. Local CO_2 fire extinguishing systems cover the dye storage room and the kitchen.

The seawater fire-extinguishing system covers the area of the main deck including the manifold, the machine room area including the steering gear, and the superstructure. The system is served by fire pumps and general service pumps in the engine room and the emergency fire pump. The stationary dry-powder system covers the area of the main deck and the manifold. The spray water system covers the front part of the superstructure, main deck, manifold and compressor room. The ship's fire protection system is highly efficient.

2.2 LNG SHIP WITH A CAPACITY OF 7,500 M3

LNG ships with a capacity of 7,500 m3 are the latest generation of LNG feeder ships, that is, LNG bunkering ships. The LNG ship "Avenir Accolade" was taken as the reference ship.

Figure 5 LNG ship "Avenir Accolade" with a capacity of 7,500 m3 (Source: https://avenirlng.com/vessels/)

Due to their operative capacities, ships of these sizes have good manoeuvring abilities and seaworthiness. They are usually equipped with a controllable pitch propeller with a flap-type rudder and a bow side thruster that facilitates manoeuvring through narrow approaching areas and during the berthing. Furthermore, such manoeuvring characteristics allow use of a smaller number of tugboats during docking or during the berthing and unberthing, thus minimizing operative costs.

For ships of this size, two tugboats are usually used during berthing. The ships are usually of low freeboard, that is, the tugboat receiving area is limited, so the only area on which a safe reception of tugboats is possible is at the ends: ship's bow and stern.

Table 3 Technical and technological properties of the reference LNG ship with a capacity of 7,500 m3 ("*Avenir Accolade*")

LNG ship with a capacity of 7,500 m3	
Length (m)	123.44
Width (m)	18.60
Draught (m)	5.65
Deadweight (t)	4,500
Capacity (m3)	7,500
Speed (knot)	13.5
Engine power (kW)	2,250
Bow thruster (kW)	250

LNG ships with a capacity of 7,500 m3 are most widely used in the supply of other ships powered by LNG as engine fuel. Following the increase in the number of floating terminals for storage, regasification and reloading (LNG FSRU ships) world-wide, these ships often dock to FSRU ships for the purpose of reloading and transporting of LNG within the area where the FSRU ship is located. The reloading of LNG from the FSRU onto a smaller ship is called a reload operation.

Figure 6 Two-level loading platform design

Due to significant differences in the characteristics of the manipulation pipelines for loading and unloading of LNG onto smaller LNG ships, the ships are designed so that the manifolds are at different heights so as to enable the berth at different loading/unloading terminals. For this purpose, the flexible hoses must also be of adequate length. Ships are usually built with two platforms: upper and lower manipulation platform, containing all the connections and valves for manipulation. The crane located in the centre of the ship enables manipulation of flexible hoses and it is enough long to reach both sides of the ship.

Figure 7 Berthing of the LNG bunker ship onto a commercial ship

Figure 8 Supplying fuel to a cruise ship from a LNG bunker ship with a capacity of 7,500 m^3

An additional particularity of these ships is their equipment with own fenders located on the deck of the LNG ship, intended for automatic lowering and lifting. This, in the end, facilitates the ship's preparedness for berthing onto another ship in case of LNG reloading to another commercial ship that uses LNG as engine fuel.

The size of fender is of optimized to allow safe berthing of LNG bunker ship alongside of the receiving ship in terms of maintaining a safe distance either in protected areas (e.g. jetty in the port basin) or on outer anchorages where the condition of the sea, i.e. wave height significantly affects the safe stay of the LNG bunker ship. The fenders must be placed at a safe distance from the bow or stern, as measured from the centre of the manifold (vapour manifold), that is, from the centre of the manifold platform.

Figure 9 Fenders and cranes on the LNG bunker ship

As the FSRU terminal in Omišalj is planned to accommodate the said ships, it is presumed that the existing "Yokohama" fenders will be used to enable their safe berthing. Using fenders for berthing is possible under the condition that the Compatibility Study defined which also determines the forces applied to berthing lines.

Figure 10 Berthing of the LNG bunker ship onto a LNG FSRU ship

Since other LNG ships with a capacity of more than 140,000 m^3 dock to the FSRU terminal, fenders of the LNG FSRU ship, in case FSRU ship's "Yokohama" fenders are used, must be distributed so as to enable complete leaning of the smaller LNG feeder ship with its flat hull side. Due to larger dimensions of the existing fenders (9,00 m x 4,50 m), the positioning of so-called "baby fenders" on the very ends (bow-stern) of the FSRU ship usually will be not used in case of berthing small scale LNG ships. Special attention should be paid to the fenders' position so that they never end up under the loading platform for cargo manipulation for safety reasons and for their own protection in case of leakage of liquid LNG during reloading as well as the impact of seawater splatter from the water curtain above the area during reloading.

The type of tanks installed, as a rule, onto small-scale LNG ships are independent IMO tanks of the type “C”. “C” type tanks enable greater flexibility in terms of commercial operations because there are no restrictions regarding their partial filling, i.e. they enable the filling of tanks up to any level.

The greatest advantage of such tank design is in their operating pressures because they allow pressure of up to 5 bar which, in the end, allows disposal and managing of cargo vapours during the loading/unloading operations and during navigation when cargo vapours are used for propulsion during combustion in the main engine.

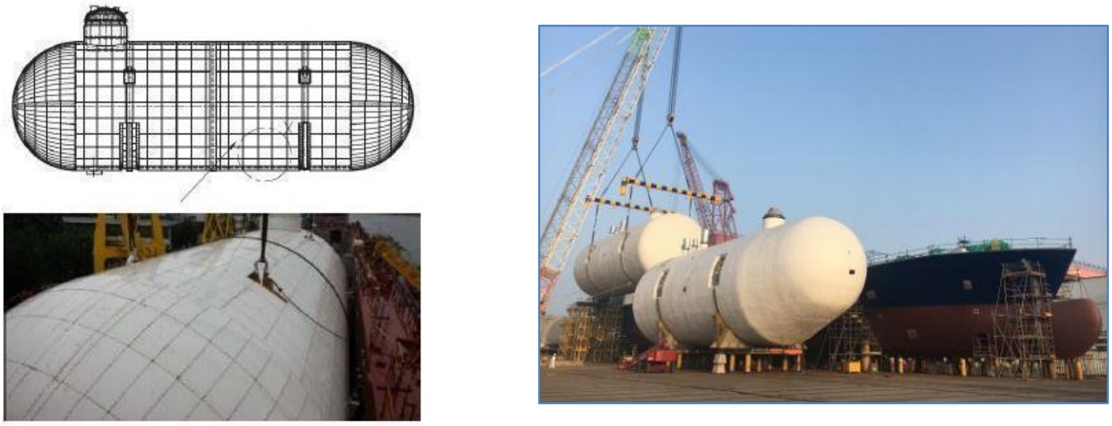

Figure 11 IMO ¨C¨ tank of the cargo tank on LNG ships with a capacity of 7,500 m^3

Ships usually have a maximum loading rate of 700 m^3/hour and 4 cargo pumps, each with a capacity of 250 m^3/hour.

The latest concept of LNG bunker ships with a capacity of 7,500 m^3 are ballast free ships.

Such a ship concept does not require any equipment to be installed for ballast water manipulation nor the construction and maintenance of ballast tanks which in the end has the most advantages in view of the marine environment and minimized duration of reloading operations. Since ships of this type are primarily intended for transporting in port areas and for transport in very short periods between destination locations, a greater share of ballast-free LNG ships with a capacity of 7,500 m^3 can be expected in the future.

Figure 12 Illustration of ˝Ballast free˝ LNG ships with a capacity of 7,500 m^3

2.3 LNG SHIPS WITH A CAPACITY OF BETWEEN 20,000 M³ AND 30,000 M³

Small-scale LNG ships with a capacity of 20,000 m³ or more, as well as the above reference ships, are intended for secondary distribution of LNG, that is, for transporting smaller amounts of LNG from the local receiving LNG terminal toward smaller users which can include the provision of the LNG bunker supply service to other ships.

Table 4 Technical and technological characteristics of feeder ships with a capacity between 20,000 m³ and 30,000 m³

	Capacity 20,000 m³ (reference ship)	Capacity 30,000 m³
Length (m)	160	180 - 185
Width (m)	24.0	28.0 - 36.0
Draught (m)	8.0	7.4 - 7.8
Deadweight (t)	12,500	15,000 – 18,500
Capacity (m³)	20,000	30,000
Displacement (t)	22,670	35,000 – 40,000
Speed (knot)	15.5	15.0 – 16.0
Engine power (kW)	7,200	8,000 – 10,000
Bow thruster (kW)	1,000 – 1,500	1000 - 1500

Figure 13 Reference ship with a capacity of 20,000 m³

As a rule, just as the other LNG small-scale ships, these ships are designed with good seaworthiness. They are usually equipped with a controllable pitch propeller (CPP) and with a standard ballast or semi-ballast rudder design. The standard manoeuvring equipment includes bow thrusters and, in some cases (depending on the operative requirements of the operation area), also stern thrusters with a power of 1,000 - 1,500 kW that allow for easier and safer manoeuvring through narrow approaching channels and in port basins as well as berthing by other ships, FSRU terminals and LNG terminals. According to experience, LNG feeder ships have good manoeuvring abilities at lower speeds.

The propulsion of the reference feeder ship of 20,000 m^3 enables excellent manoeuvring characteristics. The main engine is the dual-fuel XDF engine produced by WinGD. The main engine of the dual-fuel WinGD RT-flex50DF type was designed for use with natural gas (BOG) as the main fuel, in combination with low-sulphur marine gas oil (LSMGO) as the spare fuel in various ratios. A combination (gas/LSMGO) is usually used or only LSMGO during the manoeuvring itself for safety purposes. During the manoeuvring, the safest option will be used, depending on the ship's technical properties.

A common characteristic of all LNG feeder ships is the wheelhouse with all-round visibility (360°) and a flat deck.

In loaded condition, at mid draught of 8.10 m, the minimum freeboard of the reference ship is app. 8.60 metres, meaning the area for receiving or assistance of port tugboats along the entire length of the above-water part of the ship along the parallel body is possible and not limited by the freeboard height itself as is the case with smaller types of LNG bunker ships. Reinforced parts of the hull for docking, i.e. sideward tugboat action by thrust force, are specially marked on the ship's sides. The ships are also equipped with all the standard and mandatory equipment at the ship's bow and stern, enabling use of tugboats, i.e. tug ropes on the ship's ends (bow and stern) and safe ship berthing.

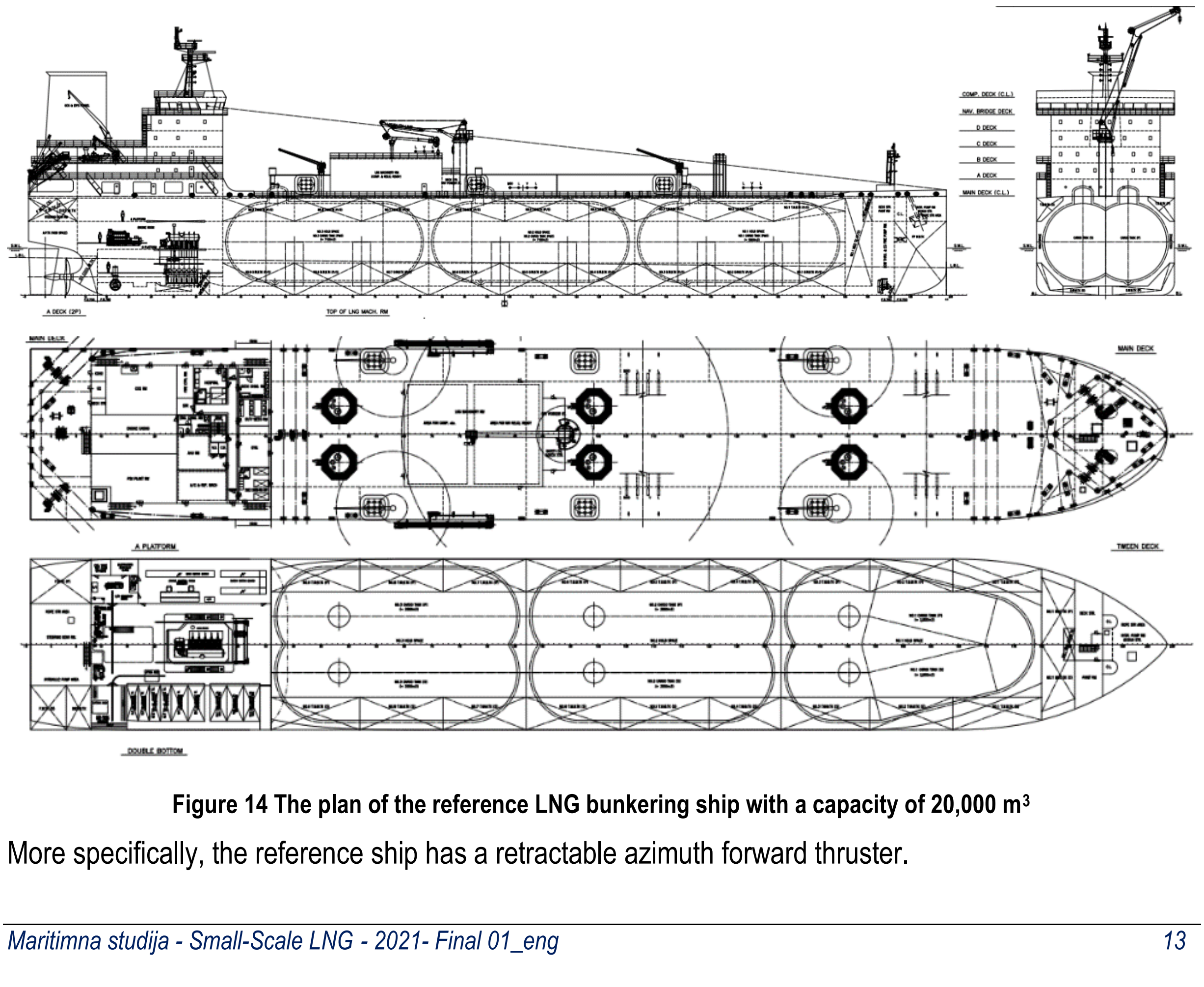

Figure 14 The plan of the reference LNG bunkering ship with a capacity of 20,000 m^3

More specifically, the reference ship has a retractable azimuth forward thruster.

Figure 15 ***Retractable type bow thruster***

The ship's cargo system consists of 3 (three) IMO C type LNG tanks (of the so-called "Bilobe" type for cryogenic cargo) with a temperature of up to -163 C, longitudinally divided into two parts.

The total cargo capacity of the reference ship is 20,000 m^3, that is, 19,600 m^3 under the maximum loading height of cargo in tanks which makes up 98,5 % of the volume of all cargo tanks.

The capacities of the cargo tanks are as follows: tank no. 1 - 6,000 m^3, tanks no. 2 and 3 - 7,000 m^3, that is, 5,880 m^3 and 6,860 m^3, respectively, at 98 % filling level.

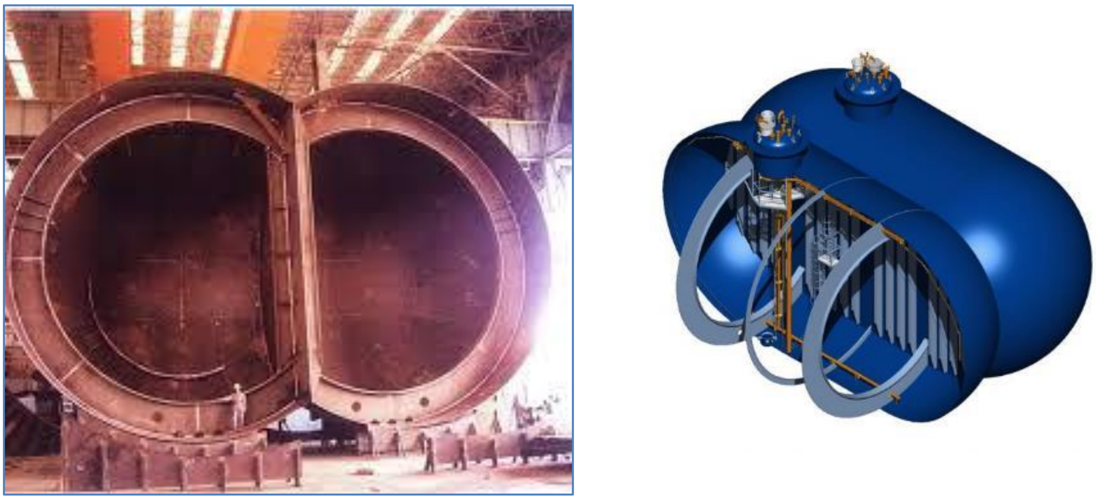

Figure 16 IMO ¨C¨ type cargo tank of the „Bilobe" type

Each cargo tank is equipped with 2 (two) deepwell cargo pumps with a capacity of 350 m^3/hour and two spray or stripping pumps with a capacity of 2 m^3/hour. The cargo system also includes the compressor room on the deck equipped with 2 gas-phase compressors with a capacity of 949 kg/h for gas return during cargo reloading operations and the partial reliq plant.

The cargo system also includes the GCU located on deck C of the ship's superstructure with the exhaust pipeline in the ship's funnel casing.

The reference ship is designed with three reloading flexible hoses on each side of the ship, one of which is closer to the bow, the second one to the centre, and the third one is closer to the stern, giving the ship flexibility during fuel reloading operations for various dimensions of receiving ships.

The ship is equipped with fenders (one or two sets of two fenders each) on each side of the ship with their own lowering and lifting system.

The crane located in the centre of the ship enables manipulation of flexible hoses and it is big enough to reach both sides of the ship. The crane is composed of flexible hoses for the liquid and gas phase of gas return with all the necessary valves.

Just as with the ships described above, the fender system is designed for their automatised lowering and lifting which in the end facilitates the ship's preparedness for connection to the other ship in case of reloading of LNG onto a ship that uses LNG as engine fuel. The fenders are of optimized size allowing, during the stay of the LNG ship, safe stay by the receiving ship in terms of maintaining a safe distance either in protected areas or on external anchorages where the condition of the sea, i.e. wave height significantly affects the safety of the stay and the operations.

Figure 17 LNG feeder ship with a capacity of 30,000 m^3

Ships with a capacity of 30,000 m3 are used, as a rule, only for feeder transport of LNG between terminals, which is why they use fenders at the terminal or fenders of the LNG FSRU ship.

The berthing and anchoring equipment of the reference LNG ship consists of hydraulic combined winches: 4 anchoring winches and 2 capstans.

This leads to the following conclusion:

(1) LNG feeder ships means LNG ships with a capacity of up to 30,000 m^3. Ships are intended for transportation of smaller quantities of LNG at shorter distances, that is, within one region, and for supplying fuel to ships which use LNG as fuel. Ships of the said sizes are called *”Small-Scale LNG Ships*”.

(2) The reference ships in this study are ships with a capacity of 3,500 m^3, 7,500 m^3, 20,000 m^3 and 30,000 m^3, with technical and technological characteristics as indicated in the study.

(3) The reference LNG feeder ships, according to prior experience, shows very good manoeuvring abilities and are usually equipped with a bow thruster.

(4) LNG ships with a capacity of up to 20,000 m^3 usually have fenders (one or two sets of two fenders each) on both sides of the ship with their own system for lowering and lifting, enabling berthing to other ships.

(5) On LNG feeder ships, cargo is usually transported in separate tanks of cylindrical shape, IMO type C.

3 MARITIME SAFETY MEASURES

Maritime safety measures include measures enabling a sufficient level of safety during the berthing and unberthing manoeuvre, as well as during the LNG ship's stay by the FSRU ship. An assessment of the safety during the manoeuvring and the ship's stay at the berth begins by determining the impact of external forces on the ship, the LNG FSRU ship and the minimum number and power of tugboats and the manoeuvring procedure.

3.1 DEPTH ASSESSMENT

For a safe manoeuvre and the stay of the largest LNG ships, the "Maritime Study for the LNG FSRU Terminal Krk"[3] envisages the deepening/dredging[4] of shallow waters in front of the terminal to a depth of at least -15 m.[5] The dredging of the shallow waters guarantees safe berthing and departure of ships of the maximum planned size in all the conditions of sea tides, waves and atmospheric pressure. In fact, the maximum draught of the observed LNG feeder ships is 8.5 metres which enables safe manoeuvring in all circumstances, that is, the UKC would be much higher than 1.0 metre at any moment, meaning the UKC can be considered safe for manoeuvring and berthing of an LNG feeder ship.

Accordingly, the sea depth is safe for manoeuvring of the largest LNG feeder ships and thus also of the reference, i.e. small-scale LNG feeder ships.

3.2 AN ASSESSMENT OF EXTERNAL FORCES

In assessing the meteorological and oceanological impacts on ship safety during manoeuvring and berthing, the reference LNG feeder ships were considered as described in the previous chapter.

The impact assessment is based on the following presumptions:

- the biggest forces from the least favourable wind directions are taken into consideration during the manoeuvring;
- only the most significant winds: bura (NNE), westerly wind (WNW) and lebić (SW) are taken into consideration during the berthing; the other winds are disregarded because of their much lower speed, frequency and smaller influence on the ship due to berth position and land configuration;
- the reference ship is an object of relatively high inertia; it is presumed that short bursts of wind cannot cause a sufficiently fast response that would result in an adequate force exerted on the ship's berthing system; therefore, 20-second average wind speeds and the generated forces are taken into consideration.
- resistance coefficients are those obtained by investigating reference LNG ship models; [6]
- the total wind force is broken down into the longitudinal and transverse component.

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3 The Maritime Study was prepared by the Faculty of Maritime Studies pursuant to the agreement entered into with EKONERG d.o.o. within the scope of the Public Tender for preparing "Services of preparation of the design and permitting documentation for the construction of the LNG FSRU terminal Krk and consulting services related to obtaining of all necessary permits and approvals: FEED preparation and main design preparation for Krk LNG FSRU and obtaining of the construction permit and LNG FSRU power supply system documentation" from 2017.

4 The dredging works are under way and planned to be completed in May 2021.

5 Pursuant to the Environmental Impact Study for the Liquefied Natural Gas Terminal on the Island of Krk, Oikon d.o.o. Applied Ecology Institute, 2013, Zagreb

6 According to the OCIMF Predictions of Wind & Current Loads on VLCC's, 1994 and the SIGTTO Prediction of Wind Loads on Large Liquefied Gas Carriers 2007. Since no data are available on the investigation of the impact of external force on small-scale LNG feeder ships, the coefficients of larger LNG ships of similar properties, that is, cross-section, were taken over.

3.2.1 Wind impact

The transverse and longitudinal wind forces *Fv* at which wind impacts the LNG feeder ship are assessed based on the formula:

$$F_v = C_{v(\alpha)} \cdot \left(\frac{\rho_v}{7600}\right) \cdot V_v^2 \cdot A$$

where:

- F_v – Wind force [t],[7]
- $C_{v(\alpha)}$ – Wind resistance coefficient of the object exposed to the impact of wind (special values for ships with prismatic tanks under different angles of wind incidence),
- ρ_z – Wind density [kg·sec²/m⁴][8],
- V_v – Wind speed [m/s][9],
- A – Surface of the vessel above the water [m²].

The LNG ship yaw moment under the influence of wind is assessed based on the following expression:

$$M_z = C_{vz(\alpha)} \cdot \left(\frac{\rho_v}{7600}\right) \cdot V_v^2 \cdot A \cdot LPB$$

where:

- M_z – Ship yaw moment [tm],
- $C_{vz(\alpha)}$ – Yaw moment coefficient under wind impact (especially for ships with spheric and prismatic tanks),
- Lpp – Ship length between perpendiculars [m].

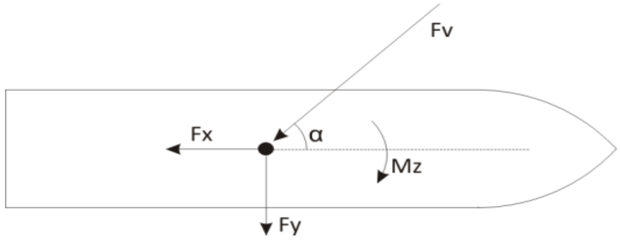

Figure 18 Longitudinal (F_x) and transverse (F_y) component of the wind force on the ship and the yaw moment (M_z)

The calculation of forces and the yaw moment was carried out for a 25-knots wind (≈13 m/s, that correspond to 6 Beaufort) which is presumably the strongest wind during which the berthing manoeuvre is allowed.

7 Wind force is expressed in tonnes in order to preserve the traceability to used sources.

8 Wind density is 0.1248 kg·sec²/m⁴ at a temperature of 20˚C.

9 The value of wind speed measured 10 m above sea surface is added to the expression.

Table 5 Wind and yaw moment forces under different angles of wind incidence

	Reference ship 1 – 3,500 m^3				Reference ship 2 – 7,500 m^3			
Angle	Fx [t]	Fy [t]	Fv [t]	Mz [tm]	Fx [t]	Fy [t]	Fv [t]	Mz [tm]
0˚	-2.7	0.0	2.7	1.0	-3.9	0.0	3.9	1.9
30˚	-2.3	5.0	5.5	-42.1	-3.3	8.2	8.8	-84.0
60˚	-0.9	9.9	9.9	-30.6	-1.3	16.0	16.1	-61.1
90˚	-0.3	11.0	11.0	51.6	-0.4	17.7	17.7	103.1
120˚	1.3	9.5	9.6	146.2	1.8	15.3	15.5	292.1
150˚	2.6	5.0	5.7	137.6	3.7	8.2	9.0	274.9
180˚	2.5	0.0	2.5	0.0	3.6	0.0	3.6	0.0
	Reference ship 3 – 20,000 m^3				**Reference ship 3 – 30,000 m^3**			
Angle	Fx [t]	Fy [t]	Fv [t]	Mz [tm]	Fx [t]	Fy [t]	Fv [t]	Mz [tm]
0˚	-6.5	0.1	6.5	4.3	-8.5	0.1	8.5	6.3
30˚	-5.5	14.0	15.1	-189.0	-7.2	17.7	19.1	-276.4
60˚	-2.2	27.5	27.6	-137.4	-2.9	34.7	34.8	-201.0
90˚	-0.7	30.5	30.5	231.9	-0.9	38.4	38.4	339.2
120˚	3.0	26.4	26.6	657.2	4.0	33.2	33.5	961.0
150˚	6.2	14.0	15.4	618.5	8.1	17.7	19.5	904.5
180˚	6.1	0.1	6.1	0.0	8.0	0.1	8.0	0.0

The charts show the results of the wind and yaw moment forces of the reference LNG feeder ships according to the following key:

- blue - ship with a capacity of 3,500 m^3,
- red - ship with a capacity of 7,500 m^3,
- purple - ship with a capacity of 20,000 m^3 and
- green - ship with a capacity of 30,000 m^3.

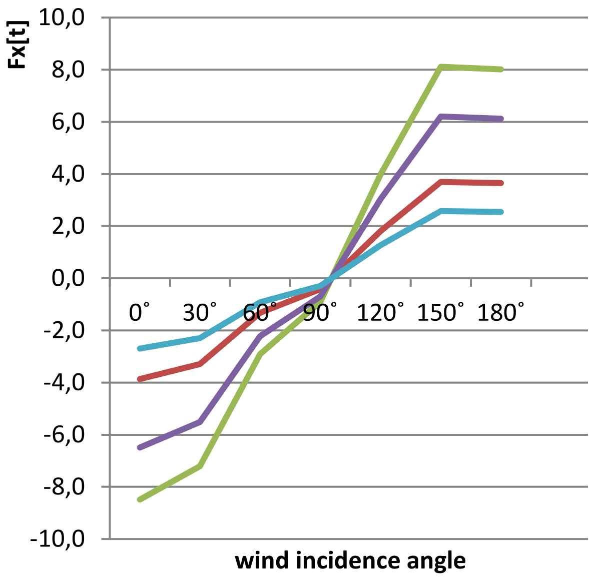

Figure 19 Longitudinal components of wind force

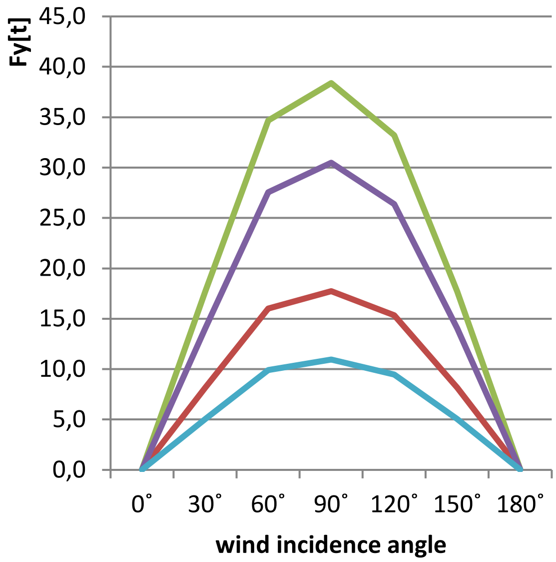

Figure 20 Transverse components of wind force

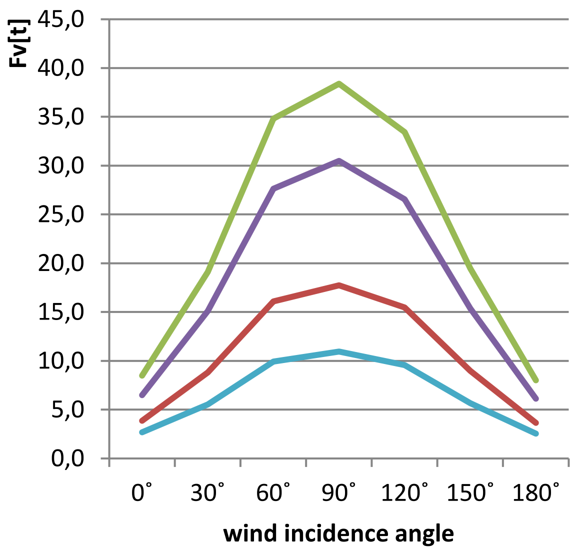

Figure 21 Total wind force

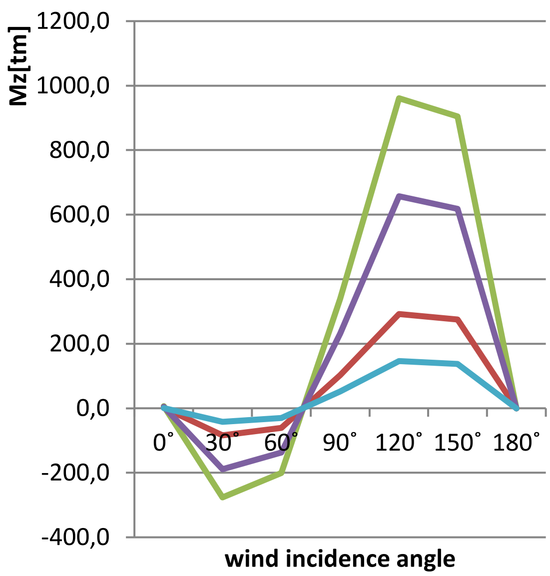

Figure 22 Ship yaw moments

According to obtained data, the maximum total wind force on the observed ships is obtained in case of side wind where the largest windage area is exposed to the wind. Longitudinal wind component is most expressed in case the wind angle is 0˚, i.e. blowing straight into the bow. The greatest yaw moment is achieved when the angle of wind incidence is 120˚, that is, when the wind blows into the aft quarter, which can in fact be expected since in these ships the exposed surface is greater in the aft part of the ship because of the exposed superstructure surface which is expressed in relation to the exposed surface of the tank area.

Accordingly, for the smallest reference ship with a capacity of 3,500 m^3, the maximum total wind force is app. 11 t, the maximum longitudinal wind component is app. 2.7 t, while the maximum yaw moment is app. 146.2 tm.

For the reference ship with a capacity of 7,500 m^3, the maximum total wind force is app. 17.7 t, the maximum longitudinal wind component is app. 3.9 t, while the maximum yaw moment is app. 292.1 tm.

For the reference ship with a capacity of 20,000 m^3, the maximum total wind force is app. 30.5 t, the maximum longitudinal wind component is app. 6.5 t, while the maximum yaw moment is app. 657.2 tm.

Furthermore, for the reference ship with a capacity of 30,000 m^3, the maximum total wind force is app. 38.4 t, the maximum longitudinal wind component is app. 8.5 t, while the maximum yaw moment is app. 961 tm.

During the manoeuvre, when the ship is in the direct vicinity and positioned with its port-side parallel to the FSRU and during its stay at the berth, the ship will be positioned on a 225˚ course. Angles of incidence and the estimated forces for the winds from significant directions (bura - NNE, lebić - SW and west wind - WNW) are presented in the table below.

Table 6 Estimated total forces for 25-knots wind from significant directions for a ship berthed port-side

Wind direction and app. angle of wind incidence to the ship	Reference ship 1 (3,500 m^3)	Reference ship 2 (7,500 m^3)	Reference ship 3 (20,000 m^3)	Reference ship 4 (30,000 m^3)
NNE / 160°	4.7 t	7.2 t	12.3 t	15.7 t
WNW / 70°	10.2 t	16.6 t	28.5 t	36.0 t
SW / 0°	2.7 t	3.9 t	6.5 t	8.5 t

According to these calculations, at a 25-knots wind speed, LNG feeder ships will be most affected by a west wind since such a wind acts on the ship's side and largest exposed surface almost perpendicularly. In case of winds from the first quadrant, especially bura and levant, the LNG feeder ship, while berthed by the FSRU ship, will mostly be sheltered by the FSRU ship and the wind force acting on the LNG feeder ship will be much smaller than the one indicated here.

When wind exceeds 6 Beaufort (> 25 kts), weather conditions do not allow the berthing manoeuvre. However, in case the ship is on berth, wind forces affecting it should be considered. Please find below the estimated wind force on the reference ships for a side wind (least favourable) and for the most significant directions for different wind speeds.

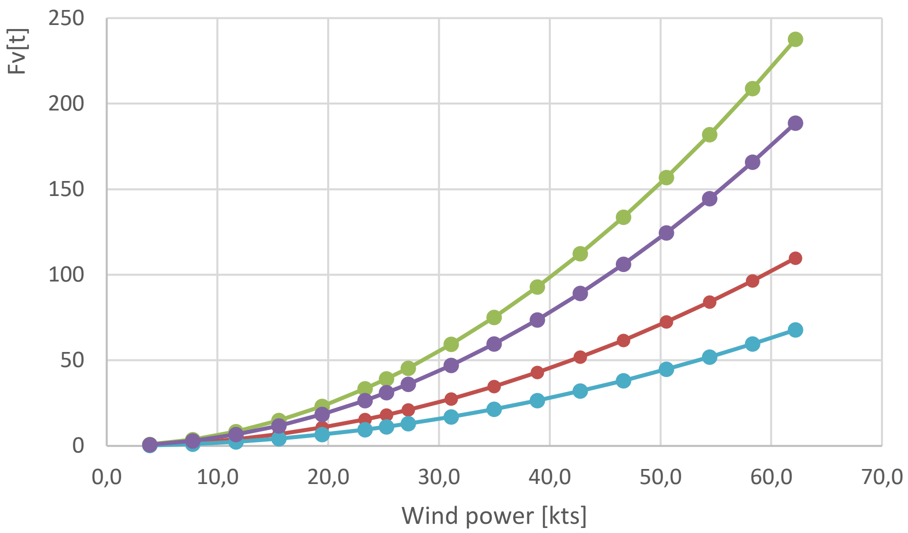

Figure 23 Side wind force (angle of incidence of 90˚) for different wind speeds (blue - ref. ship 1; red - ref. ship 2, purple - ref. ship 3, green - ref. ship 4)

Table 7 Total force for winds exceeding 6 Bf from a significant directions - reference ship 1 (3,500 m³)

Wind direction and angle of incidence	30 kts (15m/s – 7Bf)	40 kts (20m/s – 8/9 Bf)	50 kts (25m/s – 10 Bf)	58 kts (30m/s – 11 Bf)
NNE 160 ˚	6.7 t	11.9 t	18.6 t	24.9 t
SW 0˚	3.9 t	6.9 t	10.8 t	14.5 t
WNW 70˚	14.8 t	26.2 t	41.1 t	55.3 t

Table 8 Total force for winds exceeding 6 Bf from significant directions - reference ship 2 (7,500 m³)

Wind direction and angle of incidence	30 kts (15m/s – 7Bf)	40 kts (20m/s – 8/9 Bf)	50 kts (25m/s – 10 Bf)	58 kts (30m/s – 11 Bf)
NNE 160˚	10.4 t	18.5 t	28.8 t	38.8 t
SW 0˚	5.6 t	10 t	15.5 t	20.8 t
WNW 70˚	23.9 t	42.6 t	66.5 t	89.5 t

Table 9 Total force for winds exceeding 6 Bf from significant directions – reference ship 3 (20,000 m³)

Wind direction and angle of incidence	30 kts (15m/s – 7Bf)	40 kts (20m/s – 8/9 Bf)	50 kts (25m/s – 10 Bf)	58 kts (30m/s – 11 Bf)
NNE 160˚	17.7 t	31.5 t	49.1 t	66.2 t
SW 0˚	9.3 t	16.6 t	26.0 t	34.9
WNW 70˚	41.1 t	73.2 t	114.3 t	153.8 t

Table 10 Total force for winds exceeding 6 Bf from significant directions - reference ship 4 (30,000 m³)

Wind direction and angle of incidence	30 kts (15m/s – 7Bf)	40 kts (20m/s – 8/9 Bf)	50 kts (25m/s – 10 Bf)	58 kts (30m/s – 11 Bf)
NNE 160˚	22.5 t	39 t	62.6 t	84.3 t
SW 0˚	12.2 t	21.7 t	34 t	45.7 t
WNW 70˚	51.8 t	92.1 t	144 t	193.7 t

While a wind is blowing directly into the bow or stern, and to a lesser extent into the bow or stern quadrant, attention should be paid to balancing the berthing because of the wind. between the feeder ship and the FSRU ship. Such a longitudinal wind can cause one side of the smaller ship to move away and the other to move closer depending on the wind direction. Movement can be prevented by occasionally checking the condition of the "Yokohama" fenders and of the mooring lines, that is, by balancing the forces on the mooring lines.

3.2.2 The impact of the sea current

The force applied by the sea current on the berthed ship is determined according to the following expression:

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

where:

- F_{ms} – Force of the sea current acting on the vessel [N],
- $C_{ms(\alpha)}$ – Water resistance coefficient of the object exposed to the action of the sea current,
- ρ_v – Density of sea water in which the vessel is located [kg/m³],
- v_{ms} – Sea current speed [m/s],
- A_{ms} – Surface of the underwater part of the vessel [m^2].

The following applies in case of reference ships:

- For reference ship 1, the exposed underwater ship surface ranges from 430 m^2 (side) to 70 m^2 (front).
- For reference ship 2, the exposed underwater ship surface ranges from 700 m^2 (side) to 100 m^2 (front).
- For reference ship 3, the exposed underwater ship surface ranges from 1,250 m^2 (side) to 190 m^2 (front).
- For reference ship 4, the exposed underwater ship surface ranges from 1,300 m^2 (side) to 280 m^2 (front).
- While staying at the terminal, the ship is moored to FSRU ship and can only be exposed to the action of a coastal current;
- The speed of the sea current during favourable weather will not exceed 0.5 knots (0.3 m/s) whereas during the strongest winds it may be 1.5 knots (0.8 m/s) maximum;
- The resistance coefficient for smaller ships under consideration (reference ships 1 and 2) was taken to be 1.0 and it is equal to the value of the maximum measured lateral resistance coefficient for tankers in loaded condition and in case the ratio between sea depth and draught is 2.
- The resistance coefficient for larger ships under consideration (reference ships 3 and 4) was taken to be 1.7 and it is equal to the value of the maximum measured lateral resistance coefficient for loaded tankers and in case the ratio between sea depth and draught is 1.5.

The total force of the sea current under the following assumptions is as follows:

Table 11 Total forces of the sea current - reference ship 1 (3,500 m³)

Sea current speed	Sea current lateral force	Sea current longitudinal force
0.2 kts	0.2 t	0.04 t
0.5 kts	1.9 t	0.3 t
1.5 kts	14.1 t	2.3 t

Table 12 Total forces of the sea current - reference ship 2 (7,500 m³)

Sea current speed	Sea current lateral force	Sea current longitudinal force
0.2 kts	0.3 t	0.05 t
0.5 kts	3 t	0.5 t
1.5 kts	21.7 t	3.4 t

Table 13 Total forces of the sea current - reference ship 3 (20,000 m³)

Sea current speed	Sea current lateral force	Sea current longitudinal force
0.2 kts	1.1 t	0.1 t
0.5 kts	9.8 t	1.5 t
1.5 kts	69.7 t	10.6 t

Table 14 Total forces of the sea current - reference ship 4 (30,000 m³)

Sea current speed	Sea current lateral force	Sea current longitudinal force
0.2 kts	1.1 t	0.2 t
0.5 kts	10.2 t	1.6 t
1.5 kts	72.5 t	11.7 t

When the LNG feeder ship is berthed to the FSRU terminal both vessels are only affected by the coastal current. In that case, the only force to be observed is the longitudinal force of the sea current of 0.5 knots (maximum expected speed of the sea current) which acts on the particular berthed LNG feeder ship. The lateral sea current force on the ship hull can only act on the ship during its approach, that is, manoeuvring.

In general, it can be concluded that the impact of the sea current is extremely low.

3.2.3 The impact of waves

The force applied by waves on ships acts in a very complex manner, so a highly accurate assessment of the impact of waves requires a calculation of uncertain applicability to a number of presumed limit conditions. Therefore, the empirical expression verified upon the assessment of the necessary force is used for the assessment.

Accordingly, the force of the waves which act perpendicularly to the vessel's longitudinal axis can be presented using the following expression:

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

where:

F_{val}	–	The force applied by the wave [N],
$C_{val(\varphi)}$	–	Empirical coefficient,
ρ_v	–	Water density [kg/m³],
g	–	Gravity constant [m/s²],
L	–	Ship length on the water line [m],
H_s	–	Significant wave height [m].

The following applies in case of reference ships:

- The significant wave height during which manoeuvring is allowed is presumed to be 0.5 m (maximum wave height is app. 1 m) for the smallest ship under consideration, that is 1 m (maximum wave height is app. 1.7 m) for the other ships under consideration.
- Perpendicular wave action on the berthed ship is presumed.
- An empirical coefficient of 0.7 is presumed where a factor of safety is 2.[10]

Based on the above, the total (permanent) force of the waves that acts perpendicular to the ship's longitudinal axis is:

Table 15 Total force of the waves on the ships under consideration

Significant wave height	Reference ship 1 (3,500 m³)	Reference ship 2 (7,500 m³)	Reference ship 3 (20,000 m³)	Reference ship 4 (30,000 m³)
0.5 m	1.9 t	2.6 t	3.4 t	4.0 t
1 m	7.7 t	10.4 t	13.6 t	15.8 t
1.5 m	17.4 t	23.4 t	30.6 t	35.6 t
2 m	30.9 t	41.7 t	54.5 t	63.3 t

It must be mentioned that due to the configuration of the coastal line, the probability of the presumed wave height at the terminal location is very low, especially taking into consideration the significant level of cross sea in the concerned area.

3.2.4 Manoeuvring limit conditions

Considering the position of the FSRU ship, the biggest forces are expected during strong winds, while the impact of the sea current and of the waves will be much smaller and, in general, will not affect safe berthing and staying of the ships.

The table below shows total forces which act perpendicular to the ship's longitudinal axis as follows: wind speed of 25 kts, sea current speeds of 0.5 kts and significant wave heights of 0.5 m (maximum wave height 1 m) for reference ship 1 and significant wave heights of 1 m (maximum wave height of 1.7 m) for other ships.

Table 16 Total forces for the reference ship under boundary manoeuvring conditions

Reference ship		Force perpendicular to the longitudinal axis			
		Wind force [t]	Sea current force [t]	Wave force [t]	Total force [t]
Ship 1	**Loa = 94 m**	11.0	1.9	1.9*	**14.8**
Ship 2	**Loa = 123 m**	17.7	3	10.4	**31.1**

[10] Source: Hensen, H., Tug use in port – a practical guide, The Nautical Institute, London, 1997. According to the source above, the empirical coefficient for the force of short-period waves is 0.35.

Ship 3	**Loa = 160 m**	30.5	9.8	13.6	**53.9**
Ship 4	**Loa = 185 m**	38.4	10.2	15.8	**64.4**

*** Force based on significant wave height of 0.5 m.**

According to the limitations of LNG ships berthing onto the LNG FSRU ship laid down by the Maritime Study for the LNG FSRU terminal and the calculated forces of the action of wind, waves and sea current onto the reference LNG ships as well as their technical and technological characteristics, limit conditions for manoeuvring during the berthing can be determined as follows:

- maximum wind speed of 25 kt for a 20-second average, and
- significant wave height of 0.5 m for a ships with length up to 110-metre , that is, significant wave height of 1.0 m (maximum wave height of 1.7 m) for ships with a length of more than 110 m.

For the above limit conditions, the maximum sea current speed is presumed to be 0.5 kts.

In addition, the manoeuvring must be allowed only when horizontal visibility is more than 1 M.

According to the said assessment of external forces and the dynamics of reference ships as well as the standards used on other existing LNG FSRU terminals during manoeuvring (in regular weather conditions) mandatory use of the tugboat is presumed as follows

For LNG ships with a length of up to 110 metres:

- at least one (1) tugboat with a bollard pull force not less than 350 kN (35 t) during the berthing and
- at least one (1) tugboat with a bollard pull force not less than 350 kN (35 t) during the unberthing.

For LNG ships with a length from 110 metres up to 160 metres:

- at least two (2) tugboats with a bollard pull force not less than 350 kN (35 t) each during the berthing and
- at least one (1) tugboat with a bollard pull force not less than 350 kN (35 t) during the unberthing, that is, at least 2 tugboats with a bollard pull force not less than 500 kN (50 t) in case the ship is not equipped with a bow thruster.

For LNG ships with a length from 160 metres to 190 metres:

- at least three (3) tugboats with a bollard pull force not less than 500 kN (50 t) each during the berthing and
- at least two (2) tugboats with a bollard pull force of not less than 500 kN (50 t) each during the unberthing.

For the above ships, the total bollard pull force of one mandatory tugboat was estimated taking into consideration the largest transverse wind and wave force under the allowed weather conditions for berthing and the biggest sea current force that can be expected in the observed area with at least an additional 25 % of the force for manoeuvring purposes and taking into consideration the specificity of the manoeuvre of ship-to-ship berthing and the possible risk of damage to both ships as well as specific safety standards applied in the LNG industry. Use of a tugboat with the azimuth stern drive (ASD) propulsion is also mandatory, that is, tugboats with equivalent technical and technological properties ("fit for purpose"[11]).

[11] "*Fit for purpose*" is a designation in the LNG industry which signifies the type of tugboat constructed with all the necessary properties to provide efficient and safe services to LNG ships pursuant to high safety standard applied in

If a ship longer than 160 metres has good manoeuvring characteristics, such as azimuth stern drive and one or more bow or stern thrusters of appropriate power, the unberthing may be carried out using one tugboat in favourable weather conditions. Use of one tugboat on these ships is allowed following agreement of the captain of the LNG ship, the pilot and Harbour Master Office.

3.3 THE BERTHING AND DEPARTURE MANOEUVRE OF THE LNG FEEDER SHIP

The FSRU ship is berthed port-side to the terminal jetty, bow facing toward the open part of the Sapan bay. Since the FSRU ship is able to manoeuvre and seaworthy and must maintain this ability constantly, its orientation is adjusted accordingly and, in case of forced departure from the berth in emergency situations, the FSRU departure manoeuvre is much easier.

The terminal's orientation affects the orientation of the LNG feeder ship berthing. In general, LNG ships and thus also the FSRU ships can have the cargo reloading manifold at different distances from the ship's centre, but these are mostly located somewhat up the stern from the centre. As a rule, due to the levelling and connection of the manifold, the ships are usually berthed to the FSRU ship in the same orientation (bow to bow). It is therefore presumed that the reference LNG feeder ships will be berthed port-side to the FSRU ship.

The frequency of calling of particular ships in terms of size and/or properties and the experience with the complexity of manoeuvre during berthing or unberthing in can affect the adjustment, that is, the change of the orientation of LNG ship berthing.

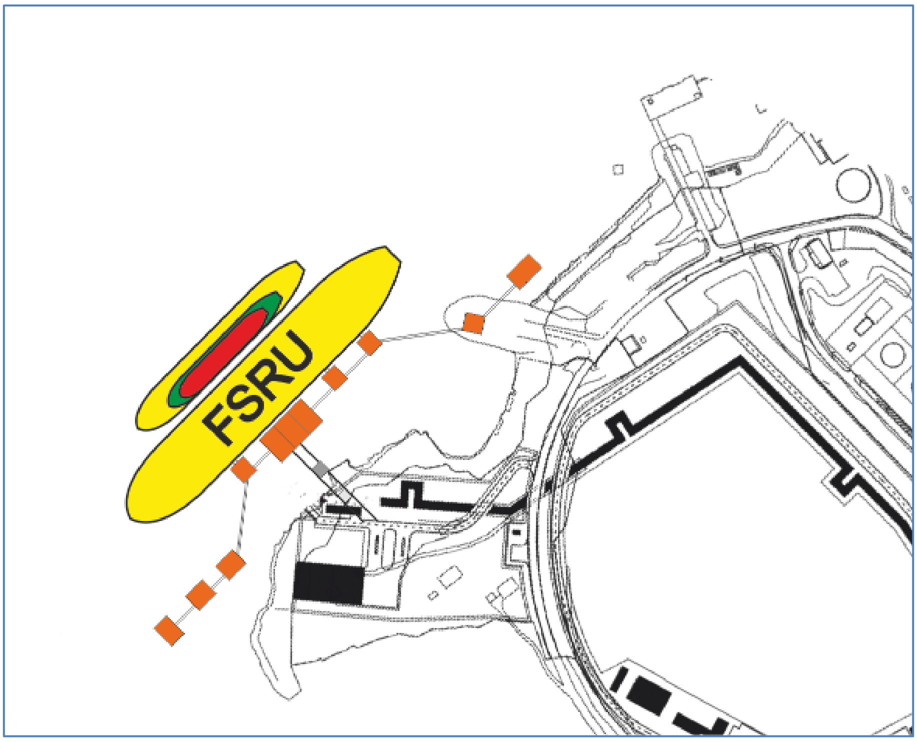

Figure 24 LNG feeder ships (red, green and yellow) berthed port-side to the FSRU ship

Berthing and unberthing of LNG feeder ships without a tugboat is not acceptable. In addition, in case of emergency situation during LNG feeder ship's stay on berth by the FSRU ship, one stand-by tugboat is

the LNG industry. "*Fit for purpose*" does not relate only to the power of the tugboat's propulsion machinery or the bollard pull force, but also to the combination of all other factors and properties which condition the tugboat's operation (structure, size, width, propulsion type). These are usually tugboats with ASD or Voiht Schneider propulsion, but they can also be tugboats with other types of propulsion which meet all the required criteria.

mandatory in the direct vicinity of the LNG FSRU ship. The tugboat must be berthed at a distance allowing, at the request of the captain of the LNG FSRU ship or the responsible person of the Port, the tugboat to be available to the ship in its full gear within not more than 10 minutes.

Please find below the general berthing and departure manoeuvres in the following cases.

- LNG ship using 1 tugboat during the berthing (length up to 110 m),
- LNG ship using 2 tugboats during the berthing (length from 110 m up to 160 m),
- LNG ship using 3 tugboats during the berthing (length from 160 m up to 190 m),
- LNG ship using 1 tugboat during departure (length up to 110 m and ship from 110 m up to 160 m if it is equipped with a bow thruster),
- 2 tugboats during the departure (length from 160 m up to 190 m and ship length from 110 m up to 160 m if it is not equipped with a bow thruster),

Manoeuvres performed with the other reference ships and a different number of tugboats have not been specifically described. In fact, the course of the manoeuvre itself can be similar to the depicted one, while the manner and exact location of receiving the tugboat will depend on current weather conditions and the ship's properties.

In general, a stern tugboat is usually used, connected through the centre lead by using tow ropes pursuant to OCIMF requirements. The strongest tugboat is usually placed at the stern. A pushing tugboat is received at the bow and stern outside the bow and stern curvature, at approximately 1/5 of the ship's length from the bow and stern[12]. The choice of the manner of manoeuvring and the manner, sequence and place of receiving the tugboat in each particular case is agreed between the pilot and the captain, depending on the technical and technological properties of the ship and the currently prevailing weather conditions.

It is important to emphasize that, before the dredging works in front of the terminal planned for end of May 2021 are completed, the berthing and departure manoeuvres will be performed in the manner laid down in the amendment to the basic Maritime Study "Amendment to the Maritime Study for LNG FSRU Krk" prepared by the Faculty of Maritime Studies in October 2020, while applying boundary conditions and the minimum number and power of the tugboats indicated herein.

3.3.1 Berthing manoeuvre

The berthing manoeuvre means the arrival of the ship approaching with its bow almost directly toward the LNG FSRU ship from the approximate direction NNW toward the stern of the FSRU ship, at a reduced speed. At a distance of at least 1 M from the LNG FSRU ship on the LNG ship's starboard side, the tugboat is connected by its side, in front of the superstructure. One to two ship lengths in front of the terminal, using its own thrust and with the help of the tugboat, the ship is almost completely halted and starts rotating 90˚ sidewise.

The rotation is mostly enabled by the power of the bow thruster and the tugboat at the stern side for pushing. The ship's main thruster system is used for limiting the speed of the ship's rotation and its halting. When the ship is positioned parallel to the terminal its sidewise pushing to the terminal begins. The final sidewise approach to the terminal and berthing takes place as in the above case.

12 The curved part of the ship's hull, at the bow and stern, outside the area of the parallel midbody does not allow to receive the tugboat if the tugboat is intended for pushing. When pushing the ship, tugboats must lean onto the part of the ship's hull which is structurally designed for the purpose. This part of the hull is reinforced and marked with the letter "T" or "TUG".

When the ship is close enough to the terminal, ship's berthing lines are placed: as a rule, first the spring lines and then the breast lines followed by the bow and stern lines. Ships of the reference size do not use lines for drawing the ship nearer, but only the tugboat and bow thruster which pushes the ship by the FSRU ship.

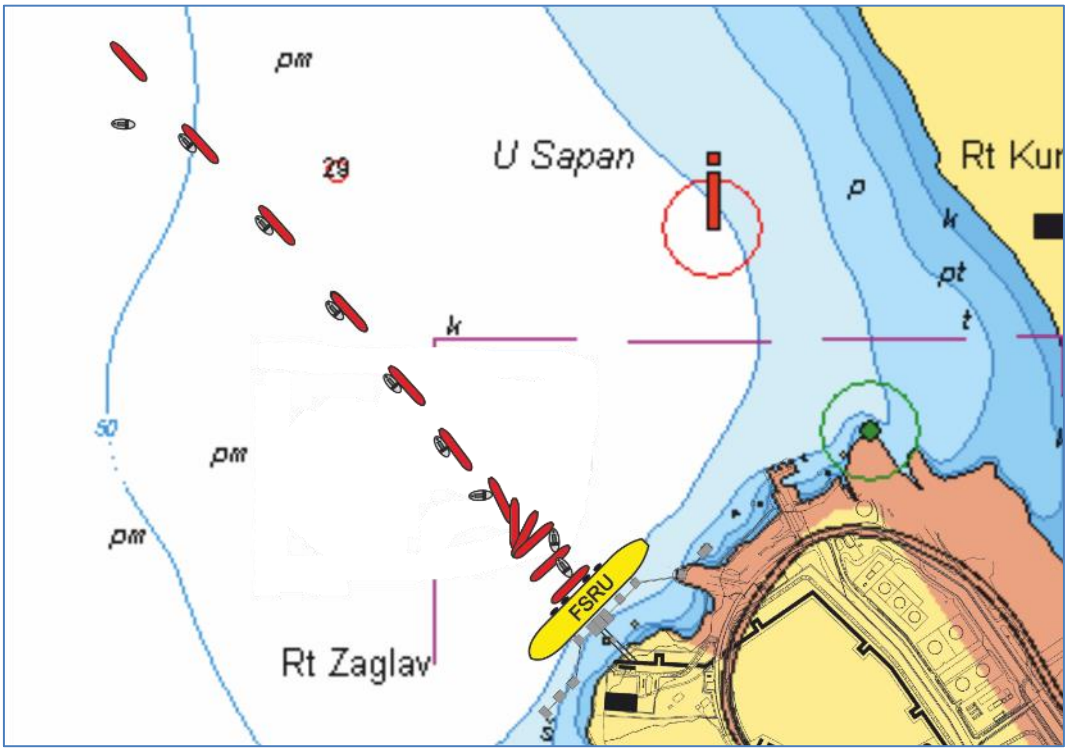

Figure25 Port-side berthing manoeuvre by direct arrival to the terminal, using 1 tugboat (the arrival route can be slightly different from the one shown here)

When two tugboats are used for the berthing manoeuvre, the same approaching manner is used, except that the ship's rotation and pushing, that is, keeping the LNG ship in place is carried out using a second tugboat. The second tugboat is attached by the ship's starboard side, directly in front of the forecastle.

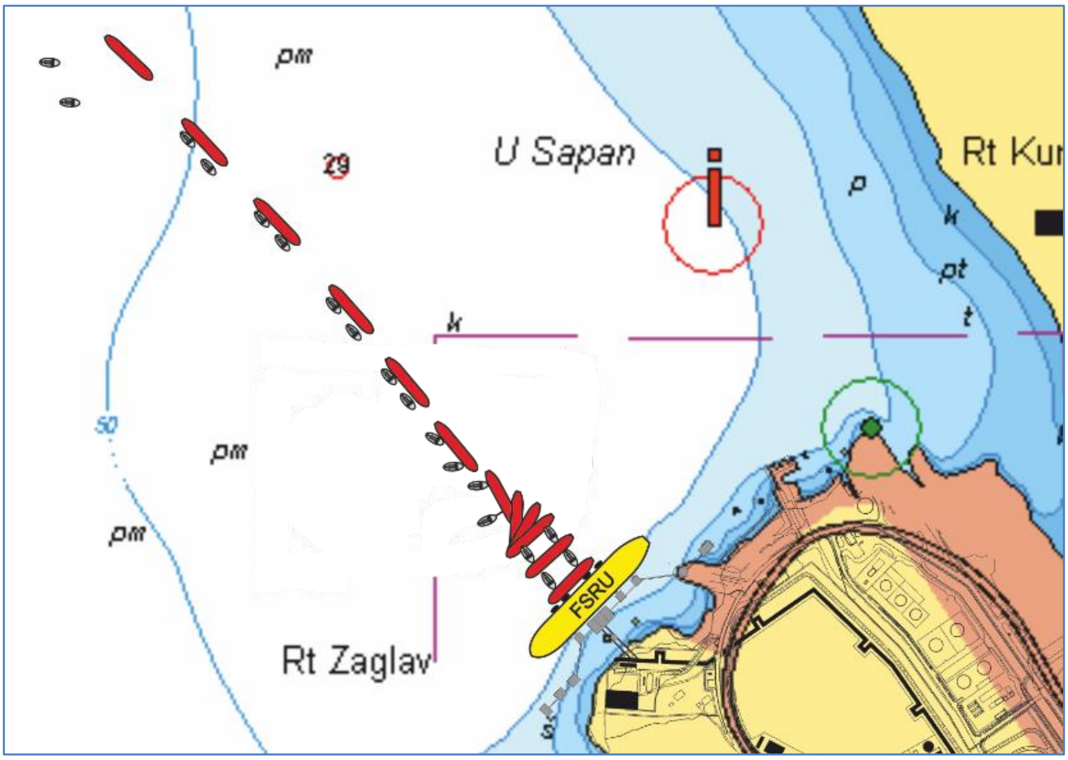

Figure26 Port-side berthing manoeuvre by direct arrival to the terminal, using 2 tugboats (the arrival route can be slightly different from the one shown here)

Three tugboats are used for the berthing manoeuvre of the largest reference ship. The additional third tugboat is positioned at the ship's stern and tied through the centre lead at the stern. The tugboat is used to halt and rotate the ship. The berthing takes place similarly as with smaller vessels, but the approaching speed must be reduced, and the halting and rotation of the ship must be carried out at 3 to 4 ship lengths before the terminal. Also, the ship approaches the FSRU ship directly and turns by 90˚ at the indicated location, with its bow in SW direction.

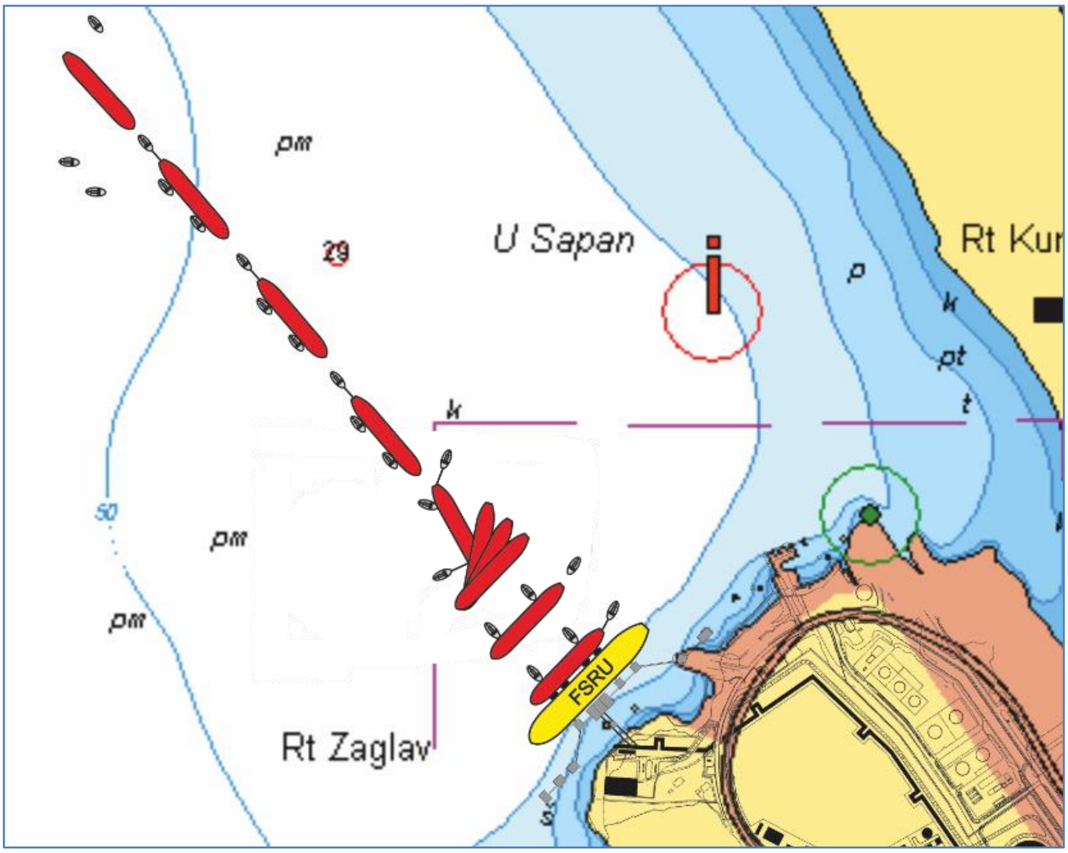

Figure27 Port-side berthing manoeuvre by direct arrival to the terminal, using 3 tugboats (the arrival route can be slightly different from the one shown here)

3.3.2 Departure manoeuvre

For the unberthing and departure manoeuvre, all general notes indicated in the part on the ship's docking and berthing apply, and the basic factor which determines the departure manoeuvre is the currently prevailing wind direction and speed.

The manner of performing the unberthing and departure manoeuvre is presented using one and two tugboats. The unberthing and departure manoeuvre using one tugboat in favourable weather conditions is performed by receiving the tugboat at the stern in front of the superstructure and using it to pull the ship's stern. The bow thruster is used to push the bow.

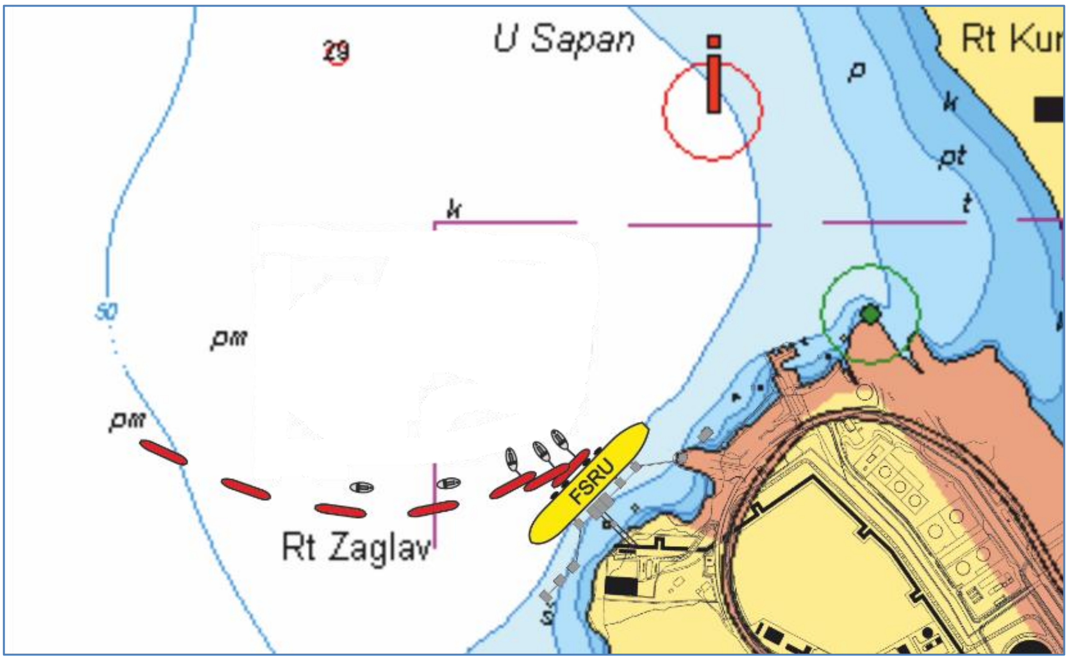

Figure28 Departure manoeuvre of a ship berthed port-side (1 tugboat used)

When two tugboats are used, the second tugboat is positioned by the ship's side, directly in front of the forecastle and it is also used to pull the ship.

Unlike arrival, the departure manoeuvre of a ship berthed port-side is very simple since there are no obstacles in front of the bow and in the departure direction and the ship need not be rotated. After the berthing lines have been released, the ship is moved away from the terminal by the tugboat attached at the stern part and by using the bow thruster or front tugboat. At a safe distance from the terminal, at least two ship widths, using the main ship engine and the rudder, the ship sails ahead and thus distances and positions itself at the adequate departure angle. In favourable weather conditions, tugboats can be released immediately after leaving the safe zone, i.e. after a distance of 3-4 ship lengths from the FSRU ship.

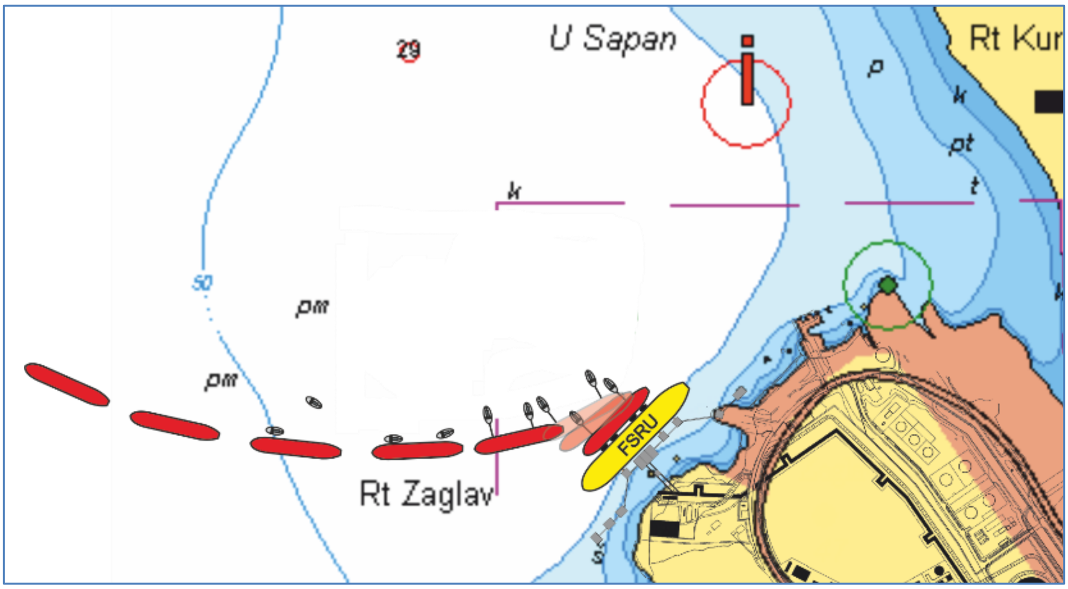

Figure29 Departure manoeuvre of a ship berthed port-side (2 tugboats used)

This leads to the following conclusion:

(6) The sea depth at the terminal and in the approach waterway is safe for manoeuvring of the largest LNG ships and thus also of the reference, i.e. small-scale LNG feeder ships.

(7) Boundary conditions for the berthing of an LNG feeder ship by the FSRU ship are constant wind speed of 25 knots for a 20-second average or a significant wave height of 1.0 m (max. wave height of 1.7 m). For ships of 110 m or less, the boundary condition of the significant wave height is 0.5 m. For all boundary cases of wind speed and wave height, the maximum sea current speed is presumed to be 0.5 kts.

(8) Manoeuvring is allowed only when horizontal visibility is more than 1 M.

(9) During the manoeuvring of LNG feeder ships, tugboats should be used as follows: For ships of up to 110 m, at least one (1) tugboat with a tow force of not less than 350 kN (35 t) during the berthing and unberthing manoeuvre; For ships from 110 m to 160 m, at least two (2) tugboats during the berthing manoeuvre and at least one (1) tugboat during the unberthing manoeuvre with a tow force of not less than 350 kN (35 t) for each particular tugboat; For ships from 160 m to 190 m, at least three (3) tugboats during the berthing manoeuvre and at least two (2) tugboats during the unberthing manoeuvre with a tow force of not less than 500 kN (50 t) for each particular tugboat.

(10) In case a ship with a length between 110 and 160 metres does not have a bow thruster, during the unberthing the ship will have to use at least 2 tugboats with a tow force of not less than 500 kN (50 t) each.

(11) In case the LNG feeder ship with a length between 160 metres and 190 metres has good manoeuvring abilities (properties as indicated in the study), the unberthing manoeuvre can be performed using one tugboat in favourable weather conditions. Use of one tugboat on these ships is allowed following agreement of the captain of the LNG ship, the pilot and Harbour Master Office.

(12) In all the cases, it is mandatory to use a tugboat with the azimuth stern drive (ASD) propulsion, that is, a tugboat with equivalent technical and technological properties (“fit for purpose”).

(13) The LNG feeder ship is generally berthed port-side, bow facing toward the open sea.

(14) The manner of manoeuvring, i.e. berthing and unberthing is performed, as a rule, in the manner described in the study, with use of the prescribed number of tugboats.

(15) Before the completed dredging works in front of the terminal planned for end of May 2021, the berthing and unberthing manoeuvres will be performed in the manner laid down in the amendment to the basic Maritime Study “Amendment to the Maritime Study for LNG FSRU Krk” prepared by the Faculty of Maritime Studies in October 2020.

4 BERTHING AND STAY OF THE LNG SHIP

4.1 BERTHING FENDERS

The approach of the LNG feeder ship relates to the part of the manoeuvre of approaching the berthing location by using the tugboat and leaning of the ship onto the FSRU terminal, after which the ship goes into rest (stay at the berth).

The berthing of the reference ship is achieved by leaning onto fenders located on the starboard, outer side of the FSRU ship.

The properties of the fender are determined first and foremost by the peak energy during the berthing, that is, rest of the ship. This energy is usually determined using the method recommended by PIANC[13] which generates satisfactory results. The calculation below was made for two reference ships:

- ship with a capacity of 7,500 m^3 (123 m long) and
- ship with a capacity of 30,000 m^3 (185 m long).

The presumptions for the calculation for the indicated small-scale LNG ships are very conservative because they are based on approach speeds of 300 mm/s, which is higher than those expected (200 mm/s), and include a significant factor of safety (1.5). The results are indicated in the table below.

[13] Permanent International Association of Navigation Congresses.

		LNG ship of 7,500 m^3	LNG ship of 30,000 m^3
Tonnage	DWT	3,800 t	16,400 t
Displacement	MD	8,100 t	36,000 t
Length	LOA	123.0 m	185.0 m
Length between perpendiculars	LBP	118.0 m	180.0 m
Width	B	18.60 m	28.1 m
Draught	D	5.60 m	7.4 m
Block coefficient	CB	0.63	0.93
BERTHING			
Type of shore		Full shore (ship)	
Calculation of eccentricity		Full calculation	
Approach angle	a	5.00 º	5.00 º
Contact point (from the bow) %	x	25.00 %	25.00 %
Rotation radius	K	27.40 m	51.88 m
Contact point from the centre of gravity	R	30.93 m	47.14 m
Under keel clearance	UKC	9.00 m	6.00 m
Additional weight coefficient	CM	1.50	1.50
Coefficient of eccentricity	CE	0.52	0.61
Coefficient of jetty configuration	CC	1.0	1.0
Coefficient of softness	CS	1.0	1.0
BERTHING ENERGY			
Berthing conditions		Good exposed berthing	
Approach speed	VB	300 mm/s	300 mm/s
Berthing energy	EN	284 kNm	1,482 kNm
Factor of safety	FS	1.5	1.5
Peak energy	EA	426 kNm	2,223 kNm

Table 17 Collision Impact energy

Fenders must absorb all the forces generated by the ship's stopping. This case presumes the stopping of reference ships onto fenders which meet the calculation presented above.

Accordingly, it is presumed that, for a reference ship with a capacity of 30,000 m^3, at least 2 pneumatic fenders will be placed on the parallel midbody of the FSRU ship with an absorption energy of at least 2,500 kNm (each) and of a sufficient surface to guarantee the pressure on the ship hull is within the allowed limits.

A reference ship with a capacity of 3,500 m^3 ship requires at least 2 pneumatic fenders to be placed on the parallel midbody with an absorption energy of at least 500 kNm (each) and of a sufficient surface to guarantee the pressure on the ship hull is within the allowed limits.

The FSRU LNG Croatia ship is equipped with four pneumatic so-called Yokohama fenders with dimensions of 9.0 x 4.5 m and absorption energy of 4,750 kNm, which meets the indicated condition of the minimum absorption energy for reference LNG feeder ships. In addition to the above, the FSRU ship is equipped with two smaller pneumatic fenders on the end points of possible contact, so-called baby fenders with dimensions of 3.5 x 2.0 m and absorption energy of 310 kNm. Baby fenders are positioned at the height of the bow and stern of the ship being received where the parallel midbody ends. Their main purpose is to prevent the impact of the LNG ship during the arrival and berthing manoeuvre laterally to the LNG FSRU ship, if not parallel to the FSRU ship.

Figure 30 FSRU “LNG Croatia” with “Yokohama” fenders on the LNG ship berthing side

“Yokohama” fenders are positioned at approximate distances of 33 and 48 metres from the centre of the manifold toward the bow and stern of the FSRU LNG Croatia, while baby fenders are positioned approximately 98 metres along the stern and 63 metres along the bow from the centre of the manifold.

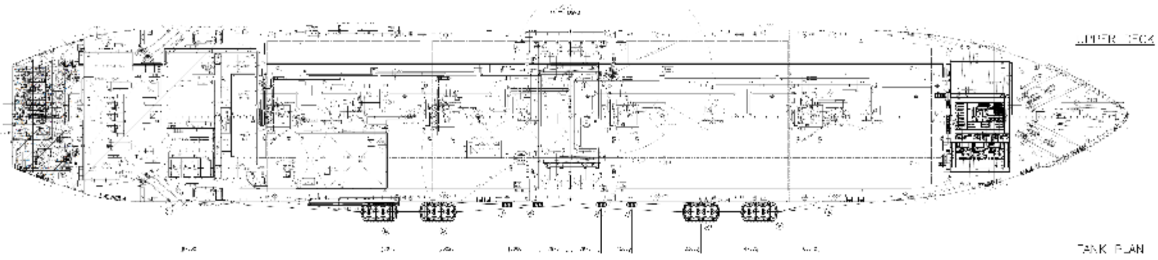

Figure 31 Arrangement of “Yokohama” fenders on the FSRU “LNG Croatia”

In addition to the above, it is common for LNG feeder ships which are also designed for fuel supply operations (e.g. ships with a capacity of app. 15,000m^3) to include fenders of appropriate absorption energy. The ships use these fenders for berthing by the ships which do not have the foreseen fenders. Fenders are usually of smaller dimensions, and their absorption energy meets the maximum berthing energy requirements. The reference ship with a capacity of 7,500 m3 has fenders with dimensions of 4.5 x 3.3 m and energy absorption of 1,175 kNm at 60 % deflection which completely meets the maximum berthing energy requirements. The fenders must be positioned at least 15 metres from the centre of the manifold.

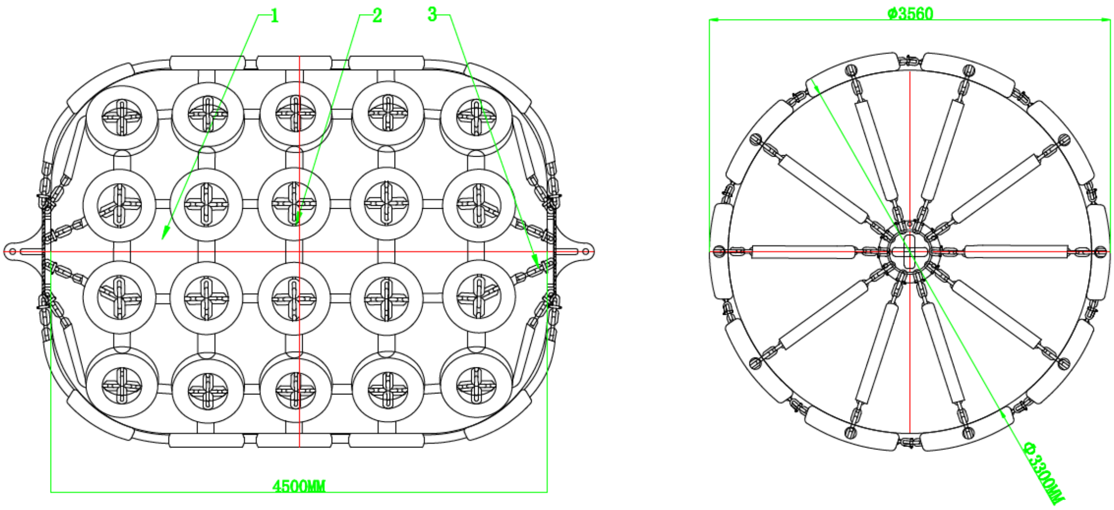

Figure 32 Pneumatic fenders of the reference ship of 7,500 m³

During the docking of the reference LNG ship, since the fenders are positioned on the FSRU ship's side, it is expected that the existing "Yokohama" fenders of the FSRU terminal will be used which completely meet the energy absorption requirements and which must be arranged so that the LNG feeder ship can completely lean on the parallel midbody. Because the Yokohama fenders are quite large, they must be positioned closer to of farther from each other, depending on the length of the arriving ship, but taking care not to position below the loading platform for cargo manipulation.

The adjustment of ship fenders and their inspection is carried out before each LNG ship berthing. As a rule, the position must be in accordance with the Compatibility Study, that is, the calculation of forces on particular berthing lines. Based on the data, the minimum number of berthing lines is determined to enable safe berthing to the FSRU ship (Optimoor Mooring Study). Accordingly, the position for LNG feeder ships will be determined on a case-by-case basis.

Baby fenders in case of smaller LNG feeder ships are usually not used because their position is beyond the reach of LNG ship hulls.

4.2 BERTHING SYSTEM

The berthing system, especially the berthing lines, must ensure, throughout the LNG feeder ship's stay and in all the allowed circumstances of the wind, wave, sea current and other, that the ship is berthed by the FSRU ship in a manner guaranteeing that none of the significant LNG feeder ship's functions or LNG FSRU ship's equipment are at risk.

As regards the equipment, it is presumed that equipment will be used which is in accordance with the requirements indicated in the *Mooring Equipment Guideline*s, 4th edition, OCIMF, and with the recommendations from the *International Safety Guide for Oil Tankers and Terminals*, (ISGOTT), 5th edition.

Satisfactory berthing is achieved by placing a sufficient number of berthing lines of appropriate properties, and the following principles are presumed:

- the berthing lines must be placed as symmetrically as possible to the centre of the ship as this facilitates a better distribution of stress on individual lines;
- bow and stern berthing lines must be placed as close to the bow and stern as possible and at an angle of approximately 45° to the edge of the shore (if possible).

– spring lines must be placed as parallel as possible to the ship's longitudinal axis (horizontal angle in relation to the ship's longitudinal axis should not exceed 10°), and these must be placed from the berthing points placed at approximately 1/4 of the ship's length from the bow or stern;
– berthing lines of the same type and strength must be used in all berthing points; if not possible, the ropes placed for the same purpose and the same point, e.g. all the spring lines, all breast lines, all bow lines and all stern lines must be of equal or similar properties;
– the length of the berthing lines must be between 35 and 50 m.

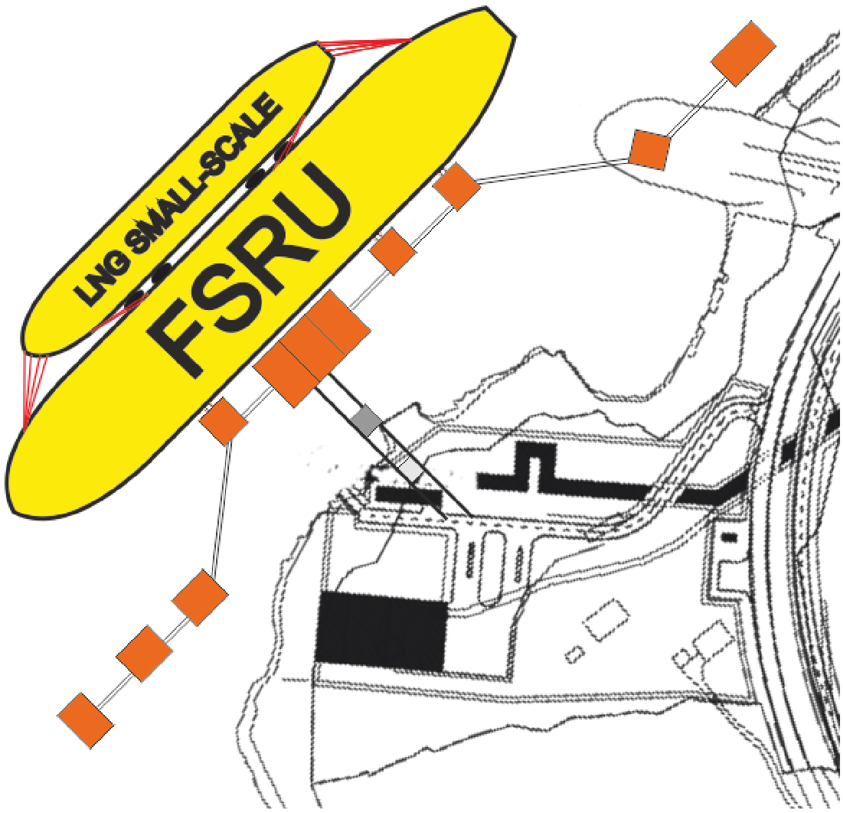

Figure 33 General distribution of berthing lines of the LNG feeder ship to the FSRU ship (the figure shows an LNG ship with a capacity of 30,000 m³)

Each particular berthing line used for berthing of the LNG tanker to the berthing system must be in accordance with the allowed safe strength of line rails on the FSRU ship (according to the OCIMF Mooring Equipment Guidelines). Records of their regular maintenance and the pertaining certificates must be available during each berthing.

The berthing lines from the LNG feeder ship are placed on quick-release hooks on the FSRU ship according to the previously performed and agreed sequence by exchange of information between the LNG ship and the FSRU ship characteristic of the STS operation.

Accordingly, for the berthing of LNG feeder ships, the FSRU ship must use at least the following number of berthing lines:

– 4 bow lines,
– 2 bow spring lines,
– 2 stern spring lines,

– 4 stern lines.

Regardless of the above, if the Optimoor Study for the particular ship show that safe berthing is possible even with a smaller number of lines, a different arrangement and number of lines is also acceptable, but only for ships of up to 160 m. In any case the total number of lines must not be less than 8.

As already mentioned, the determination of the exact manner of berthing and the final number of berthing lines is determined under the Optimoor Mooring Study, i.e. calculation of forces exerted on particular berthing lines. The data obtained from this study are used to determine the minimum number of berthing lines necessary to enable safe berthing to the FSRU ship in each particular case of berthing of the LNG feeder ship.

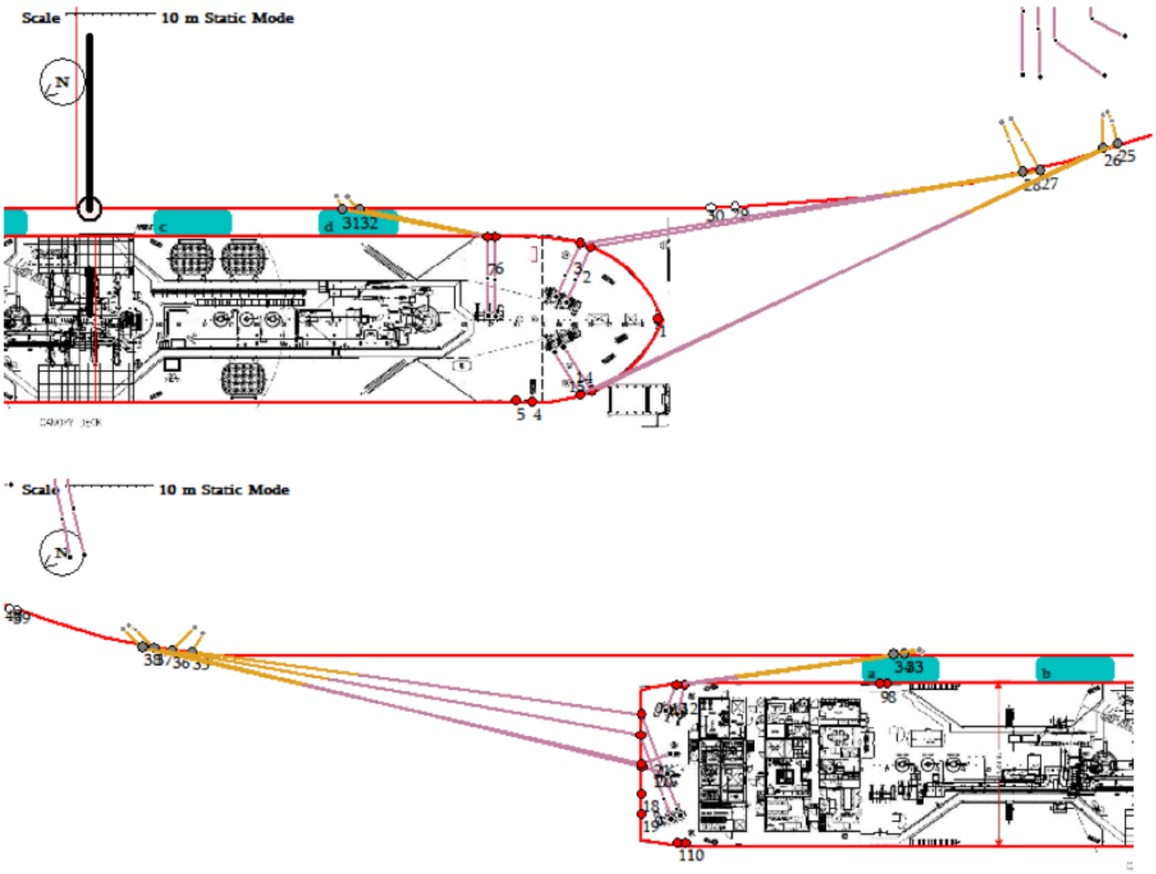

Figure 34 Berthing of LNG feeder ships with a capacity of 7,500 m³ to the FSRU ship (arrangement of berthing lines at the bow and stern of LNG ships) [14]

Throughout the LNG feeder ship's stay, fire wire-lines of appropriate breaking strength must be placed at appropriate points at the bow and stern to allow for the berthing of a tugboat in case of emergency.

This leads to the following conclusion:

14 Taken over from the Optimoor Mooring Study for the LNG ship "Avenir Accolade" with a capacity of 7,500 m³ for the STS operation on the FSRU ship "LNG Croatia" prepared for the company "Golar".

(16) During the berthing of the LNG feeder ship, FSRU ship's fenders or LNG feeder ship's fenders (if any) must be used. The adjustment of ship fenders and their inspection is carried out before each LNG ship berthing. The exact position of the fenders is determined by the Compatibility Study, that is, by calculating the forces on certain berthing lines for each particular case of LNG feeder ship berthing.

(17) LNG feeder ships with a length of up to 160 m must be berthed to the FSRU ship using at least 8 berthing lines, while ships with a length of over 160 m must be berthed using at least 4 bow lines and 4 stern lines as well as 2 bow and 2 stern spring lines each. The exact manner of berthing and the final number of the berthing lines is determined by the Optimoor Mooring Study, that is, by calculating the forces on particular berthing lines for each particular case of LNG feeder ship berthing.

(18) Throughout the LNG feeder ship's stay, fire wire-lines of appropriate breaking strength must be placed at appropriate points at the bow and stern to allow for the berthing of a tugboat in case of emergency.

5 SAFETY MEASURES IN EMERGENCY SITUATION PROCEDURES

Emergency situation means all circumstances during the ship's berthing or staying at the terminal which might put at risk the FSRU, the berthed LNG feeder ship, the nearby ships, the terminal and the onshore plant or the immediate environment. An emergency event is an event that was not foreseen, that is, that was not knowingly and intentionally carried out and/or approved by the ship's crew and/or responsible persons at the Port or on the terminal related to the berthing or loading/unloading activities on the ship.

Below is presented the safety measures undertaken during the ship's stay in case of bad weather conditions. Other safety measures in case of emergency apply as laid down by the Maritime Study.

During the ship's stay, considering the presented meteorological and oceanographic properties of the observed area, special attention should be paid to cases of sudden local storms from the W-SW direction, especially during the summer season. Reference values are 20-second averages.

During the LNG feeder ship's stay at the terminal, the captain of the LNG ship, the captain of the FSRU and the Port's responsible person must receive and monitor the weather reports of the Croatian Hydrological and Meteorological Service (DHMZ) and the data from the terminal's weather station. As is typical for the local relief, storms from W-SW and bura wind from NE appear suddenly and leave much less time for preparation, unlike the south winds. Therefore, if the weather forecast foresees bura or storms, it is reasonable to continuously monitor the weather reports and follow the natural indications of incoming wind.

During the LNG feeder ship's stay on berth, if the wind intensifies >21 knots (>10.8 m/s) or waves of significant height over 1 metre appear, the Port's responsible person or the captain of the FSRU ship must declare a condition of preparedness due to a possible emergency and notify thereon the captain of the LNG feeder ship and the Rijeka Port Authority. In this case, preparation for stopping of cargo operation is considered, and in case of probable intensification of the wind, tugboats are called to standby and prepare for possible unberthing of the LNG ship.[15]

The FSRU ship and its crew are obligated to monitor incessantly the ship's condition and the stress on berthing hooks and lines. Weather reports and instruments must be monitored incessantly. Condition of preparedness must be in force until the wind weakens (<10.8 m/s), and the weather forecast does not indicate any worsening of the weather.

If an intensification of the wind over 27 knots (>13.8 m/s) has been announced, further accident prevention measures must be undertaken which include the preparation for disconnecting the cargo hoses between the LNG feeder ship and the FSRU ship, preparation for disembarking from the LNG feeder ship of all the persons of the FSRU terminal. After a wind of over 27 knots (>13.8 m/s) has started blowing, an emergency situation has occurred, the cargo hoses between the LNG ship and the FSRU ship are disconnected, the pilot and tugboats are called and position the tow lines on the LNG feeder ship: one at the stern and one at the bow, as close as possible to the ship's end points (in case of a ship with a length of less than 110 metres, one tugboat is called). If the ship is being pushed, the tugboats are positioned in the part of the ship marked for pushing by the tugboat. In case the weather forecast foresees that the wind will intensify to over 38 knots (20.0 m/s), the LNG feeder ship starts preparing for unberthing and, after the wind has intensified to over 38 knots (20 m/s), it leaves the berth and heads to the anchorage.

In general, depending on the foreseen, that is, measured wind speed, the following activities must be undertaken:

15 Limited operation due to the wind's impact on the crane used for transfer of cargo hoses does not constitute extraordinary circumstances.

- >21 kts (10.8 m/s) Condition of preparedness is declared, preparations start to abort cargo transfer, the pilot and tugboats are notified on the possibility that their help might be required.
- >27 kts (13.8 m/s) Emergency situation is declared, cargo hoses are disconnected, the pilot is on the ship, tugboats are placing towing lines.
- >38 kts (20.0 m/s) LNG feeder ship leaves the berth.

The Port's responsible person, , the captain of the FSRU ship or the captain of the LNG feeder ship may bring a decision to abort cargo reloading, disconnection of cargo hoses and leaving the berth in other circumstances as well, that is, at any moment if they assess that the safety of any ship is at risk.

Since the weather front bringing storm from western direction comes very suddenly, in case of its arrival, tugboats must be placed in tow and other measures must be carried out as soon as possible, i.e. before the front with the strong wind reaches the terminal area.

An emergency situation is in force until wind drops to below 27 kts (13.8 m/s) or until significant wave height drops to below 1.0 metre.

This leads to the following conclusion:

(19) The study presents safety measures applied in case bad weather that constitutes an emergency occurs during the stay of an LNG feeder ship. Other safety measures for emergency situations apply as laid down in the main Maritime Study.

(20) A condition of preparedness occurs when wind blows at a speed of more than 21 kts necessitating to stop operation and notify the pilot and tugboat on the possible need to assist the LNG ship.

(21) An emergency situation occurs in case of wind of over 27 kts necessitating to disconnect cargo hoses, for the pilot to board the ship, and for the tugboats to place berthing lines and provide support to the LNG ship in the manner described in the study.

(22) In case of wind of more than 38 kts, the LNG feeder ship must leave the berth.

(23) The Port's responsible person, , the captain of the FSRU ship or the captain of the LNG feeder ship may bring a decision to abort cargo reloading, disconnect the cargo hoses and leave the berth also in circumstances different from the ones foreseen above, at any moment, if they assess that the safety of any ship is at risk.

(24) It is recommended to observe all the recommended safe navigation measures during the berthing of the first 6 LNG feeder ships and, after that, to review as necessary the recommended safety measures.

6 CONCLUSION

The basic conclusions of this Study are as follows:

(1) LNG feeder ships means LNG ships with a capacity of up to 30,000 m^3. Ships are intended for transportation of smaller quantities of LNG on shorter distances, that is, within one region, and for supplying fuel to ships which use LNG as fuel. Ships of the said sizes are called *"Small-Scale LNG Ships*".

(2) The reference ships in this study are ships with a capacity of 3,500 m^3, 7,500 m^3, 20,000 m^3 and 30,000 m^3, with technical and technological characteristics as indicated in the study.

(3) The reference LNG feeder ships, according to prior experience, shows very good manoeuvring abilities and are usually equipped with a bow thruster.

(4) LNG ships with a capacity of up to 20,000 m^3 usually have fenders (one or two sets of two fenders each) on both sides of the ship with their own system for lowering and lifting, enabling berthing to other ships.

(5) On LNG feeder ships, cargo is usually transported in separate tanks of cylindrical shape, IMO type c.

(6) The sea depth at the terminal and in the approach waterway is safe for manoeuvring of the largest LNG ships and thus also of the reference, i.e. small-scale LNG feeder ships.

(7) Boundary conditions for the berthing of an LNG feeder ship by the FSRU ship are constant wind speed of 25 knots for a 20-second average or a significant wave height of 1.0 m (max. wave height of 1.7 m). For ships of 110 m or less, the boundary condition of the significant wave height is 0.5 m. For all boundary cases of wind speed and wave height, the maximum sea current speed is presumed to be 0.5 kts.

(8) Manoeuvring is allowed only when horizontal visibility is more than 1 M.

(9) During the manoeuvring of LNG feeder ships, tugboats should be used as follows: For ships of up to 110 m, at least one (1) tugboat with a tow force of not less than 350 kN (35 t) during the berthing and unberthing manoeuvre; For ships from 110 m to 160 m, at least two (2) tugboats during the berthing manoeuvre and at least one (1) tugboat during the unberthing manoeuvre with a tow force of not less than 350 kN (35 t) for each particular tugboat; For ships from 160 m to 190 m, at least three (3) tugboats during the berthing manoeuvre and at least two (2) tugboats during the unberthing manoeuvre with a tow force of not less than 500 kN (50 t) for each particular tugboat.

(10) In case a ship with a length between 110 and 160 metres does not have a bow thruster, during the unberthing the ship will have to use at least 2 tugboats with a tow force of not less than 500 kN (50 t) each.

(11) In case the LNG feeder ship with a length between 160 metres and 190 metres has good manoeuvring abilities (properties as indicated in the study), the unberthing manoeuvre can be performed using one tugboat in favourable weather conditions. Use of one tugboat on these ships is allowed following agreement of the captain of the LNG ship, the pilot and the Harbour Master Office.

(12) In all the cases, it is mandatory to use a tugboat with the azimuth stern drive (ASD) propulsion, that is, a tugboat with equivalent technical and technological properties ("fit for purpose").

(13) The LNG feeder ship is generally berthed port-side, bow facing toward the open sea.

(14) The manner of manoeuvring, i.e. berthing and unberthing is performed, as a rule, in the manner described in the study, with use of the prescribed number of tugboats.

(15) Before the completed dredging works in front of the terminal planned for end of May 2021, the berthing and unberthing manoeuvres will be performed in the manner laid down in the amendment to the basic Maritime Study “Amendment to the Maritime Study for LNG FSRU Krk” prepared by the Faculty of Maritime Studies in October 2020.

(16) During the berthing of the LNG feeder ship, FSRU ship’s fenders or LNG feeder ship’s fenders (if any) must be used. The adjustment of ship fenders and their inspection is carried out before each LNG ship berthing. The exact position of the fenders is determined by the Compatibility Study, that is, by calculating the forces on certain berthing lines for each particular case of LNG feeder ship berthing.

(17) LNG feeder ships with a length of up to 160 m must be berthed to the FSRU ship using at least 8 berthing lines, while ships with a length of over 160 m must be berthed using at least 4 bow lines and 4 stern lines as well as 2 bow and 2 stern spring lines each. The exact manner of berthing and the final number of the berthing lines is determined by the Optimoor Mooring Study, that is, by calculating the forces on particular berthing lines for each particular case of LNG feeder ship berthing.

(18) Throughout the LNG feeder ship’s stay, fire wire-lines of appropriate breaking strength must be placed at appropriate points at the bow and stern to allow for the berthing of a tugboat in case of emergency.

(19) The study presents safety measures applied in case bad weather that constitutes an emergency occurs during the stay of an LNG feeder ship. Other safety measures for emergency situations apply as laid down in the main Maritime Study.

(20) A condition of preparedness occurs when wind blows at a speed of more than 21 kts necessitating to stop operation and notify the pilot and tugboat on the possible need to assist the LNG ship.

(21) An emergency situation occurs in case of wind of over 27 kts necessitating to disconnect cargo hoses, for the pilot to board the ship, and for the tugboats to place berthing lines and provide support to the LNG ship in the manner described in the study.

(22) In case of wind of more than 38 kts, the LNG feeder ship must leave the berth.

(23) The Port’s responsible person, , the captain of the FSRU ship or the captain of the LNG feeder ship may bring a decision to abort cargo reloading, disconnect the cargo hoses and leave the berth also in circumstances different from the ones foreseen above, at any moment, if they assess that the safety of any ship is at risk.

(24) It is recommended to observe all the recommended safe navigation measures during the berthing of the first 6 LNG feeder ships and, after that, to review as necessary the recommended safety measures.

REPUBLIKA HRVATSKA
Ministarstvo mora, prometa i infrastrukture
Uprava sigurnosti plovidbe
Lučka kapetanija Rijeka
Senjsko pristanište 3

P / 5890748

KLASA: UP/I-350-05/21-01/28
URBROJ: 530-04-5-2-21-2
Rijeka, 29. travnja 2021. godine

LUČKA KAPETANIJA RIJEKA nadležna temeljem članka 1. Zakona o lučkim kapetanijama (NN br. 118/18), temeljem članka 96. Zakona o općem upravnom postupku (NN br. 47/09), povodom zahtjeva Lučke uprave Rijeka u predmetu prihvaćanja i potvrđivanja maritimne studije, donosi

R J E Š E N J E

Prihvaća se i potvrđuje dopuna maritimne studije 'Maritimna studija - LNG FSRU Krk' naziva 'Privez small-scale LNG brodova na LNG FSRU Krk', izrađene u Rijeci, travanj 2021. godine od Pomorskog fakulteta u Rijeci, Studentska 2, Rijeka za potrebe naručitelja LNG Hrvatska d.o.o, Radnička cesta 80, 10000 Zagreb.

O b r a z l o ž e n j e

LNG Hrvatska d.o.o, obratila se dana 14. travnja 2021. ovom tijelu sa zahtjevom da se prihvati i potvrdi dopuna 'Maritimne studije - LNG FSRU Krk' naziva 'Privez small-scale LNG brodova na LNG FSRU Krk', izrađene od Pomorskog fakulteta u Rijeci za potrebe naručitelja LNG Hrvatska d.o.o.
Uvidom u navedenu dopunu Maritimne studije utvrđeno je da ista, u cjelini s Maritmnom studijom – LNG FSRU Krk, formalno udovoljava uvjetima propisanim člankom 54a. stavkama 4, 5. i 6. Pomorskog zakonika (NN 181/04, 76/07, 146/08, 61/11, 56/13, 26/15 i 17/19), odnosno da sadržajno udovoljava osnovnim mjerama maritimne sigurnosti u predmetnoj luci posebne namjene.

Slijedom iznesenog riješeno je kao u izreci. Upravna pristojba u iznosu od 35,00 kuna naplaćena je po Tar. br. 1. i 2. Tarife Zakona o upravnim pristojbama (NN br. 8/96 s izmjenama) u korist Državnog proračuna RH.

LUČKI KAPETAN

dr. sc. Darko Glažar dipl. inž. kap.

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.

DOSTAVITI:

1. LNG Hrvatska, Radnička cesta 80, 10000 Zagreb
2. Za spis