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# Breakthrough LNG Deployment in Inland Waterway Transport

**Activity 1.2 Development of standardised components for best available LNG technologies; 1.2.3 LNG bunker stations**

**Activity 1.3 Defining a total configuration of a vessel-bunker station solution; bunker station solution**

**Activity 1.4 Adoption of the standard configuration by the competent authorities**

**Activity 6.2 Design of an optimal bunkering station for IWT LNG fuel supply**

## Report

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Erik Büthker    Adriano van der Kleij  
Pitpoint.LNG    Pitpoint.LNG

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## 1 Executive summary

The mission of the consortium is to reduce the investment barrier for the ship owners with the aim to facilitate large scale implementation of LNG in Inland Waterway Transportation (IWT), thus forcing a breakthrough in the LNG market. A firm base LNG supply network will contribute and show commitment and confidence in the IWT sector for switching to LNG as fuel.

The IWT sector is facing new demands to drastically reduce air pollutant emissions like NO<sub>x</sub> and PM. The transition to LNG as alternative fuel provides the opportunity to attain this goal while at the same time improving the competitiveness of IWT.

Not all vessels are suitable to switch to LNG due to the higher investments costs for LNG equipment and therefore particular vessels which have a relatively high fuel consumption to have a positive business case as the savings in fuel costs can compensate the additional investments in LNG equipment.

The use of LNG in IWT is however still under development, and LNG conversion is still a custom solution (case by case) and therefore requires high investments.

Also, there are other uncertainties like the lack of LNG bunker infrastructure, technology development and standards for LNG propulsion equipment for IWT vessels. Most important is the emission regulations that will come into force and how policymakers in the different countries will support LNG as a transport fuel in the long term.

In practice, these uncertainties prevent ship owners from switching to LNG as fuel and from investing in this transition.

One of the particular uncertainties is the lack of LNG bunker infrastructure along the Rhine-Alpine corridor, the corridor which encompasses the Rhine river as the key inland waterway river in Europe. This study will try to stimulate the further deployment of LNG bunker infrastructure by analysis on standardization of LNG bunker stations, its components and overall design, which will help to reduce the investment costs.

## 2 Revision History and Statement of Originality

Revision	Date	Author	Organization	Description
V0.0	16-4-2019	Erik Büthker	PitPoint.LNG	Processing draft document
V0.1	28-5-2019	Erik Büthker	PitPoint.LNG	Processing draft document
V0.2	15-7-2019	Adriano van der Kleij	PitPoint.LNG	Processing draft document
V0.3	5-8-2019	Salih Karaarslan	EICB	Restructuring
V1.0	5-8-2019	Adriano van der Kleij	PitPoint.LNG	Final document

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### **Statement of originality:**

*This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.*

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### 3 Abbreviations

ARA	Amsterdam Rotterdam Antwerp
CEF	Connecting Europe Facility
IWT	Inland Waterway Transport
LNG	Liquefied Natural Gas
STS	Ship to Ship
PTS	Pipe (shore) to Ship
TTS	Truck to Ship

## 4 Introduction

The study encompasses the development of standardized components for LNG bunker stations, their integration into a bunker station configuration, its approval by competent authorities and the design of an optimal bunkering station for IWT LNG fuel supply.

The objective is to have certificated standardized components integrated into a configuration with a corresponding optimal design which will be location-independent and possible to apply at various locations. This study will make it possible for others to deploy similar bunkering stations at various sites in Europe, significantly reducing the time required for the necessary pre-work and thus reducing the investment costs. This will contribute to the further development of LNG infrastructure for inland waterway transport

The study will cover the following specific subjects:

- LNG bunker station technology standardization
- LNG bunker station LNG bunkering process standardization
- LNG bunker station LNG storage tank refilling process standardization
- Bunker components
- Adoption by competent authorities
- Design of an optimal bunkering station for IWT LNG fuel supply
- Common ESD system



## 5 LNG bunker station technology standardization

The bunkering station standardization is an important prerequisite to realize safe bunkering operations and to create interoperability. In the past years a lot of activities have resulted in several standards for LNG bunkering. Standards are now available for the LNG bunkering operation as well for the technical installations.

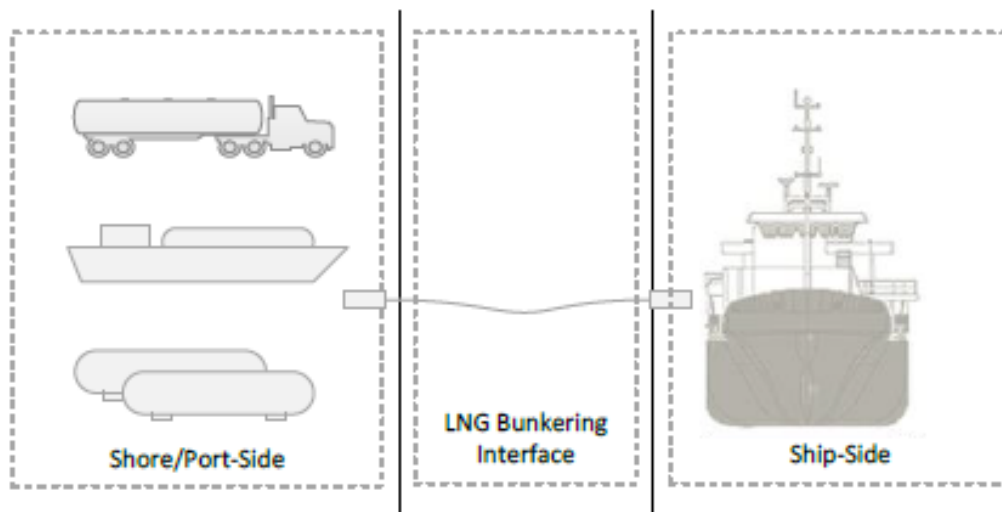


Figure 1 Interface between bunkering station and ship

Standards are today available for specific LNG components, but also the safety measures and minimal safety requirements are described in several standards. Some interfaces between ship and bunkering station however are still missing and can be defined as “grey areas”. This chapter will give some guidance for these “grey areas”

There are four items to consider as regards standardization of the LNG bunkering station:

- The interface for the LNG supply to the storage tank of the LNG bunkering station;
- The interface between the LNG bunkering station and the ship;
- The design of the ESD system of the supply of LNG to the LNG bunkering station;
- The design of the ESD system of the LNG bunkering station in relation to the ship.



For larger LNG installations like LNG terminals the standardization is carried out by CEN/TC 282 Installations and equipment for LNG. The scope of this standardization group can be quoted as follows:

“Standardization in the field of plant and equipment used for production, transportation, transfer, storage and regassification of LNG. Drafting of product standards specific to LNG when such standards are not included in the programme of work of another TC. Coordination of questions concerning LNG in the technical work of TC dealing with cryogenic equipment. Standardization begins at the inlet to the liquefaction plant and ends at the outlet from the regassification plant.”

The activities are also focusing on marine applications like LNG transfer systems, but mainly related to LNG regassification plants. The standard EN 13645 can be also applied for LNG bunkering stations however the EN ISO 16924 is more detailed in operational aspects. See below an overview of the published standards by CEN TC 282. Where the in 2017 published EN 20519 and the EN 23645 are the most relevant for LNG bunkering.

CEN/TC 282 Published Standards	
Reference, Title	Publication date
<b>EN 12065:1997</b> (WI=00282005) Installations and equipment for liquefied natural gas - Testing of foam concentrates designed for generation of medium and high expansion foam and of extinguishing powders used on liquefied natural gas fires	1997-09-17
<b>EN 12066:1997</b> (WI=00282006) Installations and equipment for liquefied natural gas - Testing of insulating linings for liquefied natural gas impounding areas	1997-09-17
<b>EN 12838:2000</b> (WI=00282008) Installations and equipment for liquefied natural gas - Suitability testing of LNG sampling systems	2000-01-19
<b>EN 13645:2001</b> (WI=00282009) Installations and equipment for liquefied natural gas - Design of onshore installations with a storage capacity between 5 t and 200 t	2001-12-12
<b>EN 1473:2016</b> (WI=00282022) Installation and equipment for liquefied natural gas - Design of onshore installations	2016-05-18
<b>EN 1474-2:2008</b> (WI=00282015) Installation and equipment for liquefied natural gas - Design and testing of marine transfer systems - Part 2: Design and testing of transfer hoses	2008-12-03
<b>EN 1474-3:2008</b> (WI=00282016) Installation and equipment for liquefied natural gas - Design and testing of marine transfer systems - Part 3: Offshore transfer systems	2008-12-03
<b>EN ISO 16903:2015</b> (WI=00282023) Petroleum and natural gas industries - Characteristics of LNG, influencing the design, and material selection (ISO 16903:2015)	2015-06-17
<b>EN ISO 16904:2016</b> (WI=00282021) Petroleum and natural gas industries - Design and testing of LNG marine transfer arms for conventional onshore terminals (ISO 16904:2016)	2016-03-16
<b>EN ISO 20088-1:2016</b> (WI=00282024) Determination of the resistance to cryogenic spillage of insulation materials - Part 1: Liquid phases (ISO 20088-1:2016)	2016-10-05
<b>EN ISO 20519:2017</b> (WI=00282025) Ships and marine technology - Specification for bunkering of liquefied natural gas fuelled vessels (ISO 20519:2017)	2017-02-22
<b>EN ISO 28460:2010</b> (WI=00282019) Petroleum and natural gas industries - Installation and equipment for liquefied natural gas - Ship-to-shore interface and port operations (ISO 28460:2010)	2010-12-15

The EN 13645 is now reviewed again. This standard is applicable for plants with a storage capacity from 5 ton – 200 ton. So bunkering stations for inland shipping will fall under this scope. However, the EN-ISO 16924 is more specific in procedures and safety distances and there for good applicable for LNG bunkering stations.


CEN/TC 282 Work programme						
Project reference	Status	Initial Date	Current Stage	Next Stage	Forecasted voting date	
<b>prEN 1473</b> (WI=00282027) Installation and equipment for liquefied natural gas - Design of onshore installations	Under Approval	2016-09-21	2018-06-28	2019-02-28	2019-02-28	
<b>prEN 1474-2</b> (WI=00282032) Installation and equipment for liquefied natural gas - Design and testing of marine transfer systems - Part 2: Design and testing of transfer hoses	Under Approval	2018-05-16	2019-03-06	2019-05-30	2020-02-15	
<b>prEN ISO 20088-2</b> (WI=00282031) Determination of the resistance to cryogenic spill of insulation materials - Part 2: Vapour release (ISO/DIS 20088-2:2019)	Under Approval	2018-04-20	2019-04-10	2019-12-10	2019-12-10	
<b>prEN ISO 20088-3</b> (WI=00282030) Determination of the resistance to cryogenic spillage of insulation materials - Part 3: Jet release (ISO 20088-3:2018)	Under Enquiry	2018-04-24	2019-04-11	2019-07-04	2020-03-04	
<b>prEN ISO 20257-1</b> (WI=00282026) Installation and equipment for liquefied natural gas - Design of floating LNG installations - Part 1: General requirements (ISO/DIS 20257-1:2018)	Under Approval	2016-01-26	2018-11-12	2019-07-12	2019-07-12	
<b>prEN ISO 21593</b> (WI=00282029) Ship and marine technology - Technical requirements for liquefied natural gas bunkering dry-disconnect/connect coupling (ISO/DIS 21593:2018)	Under Approval	2017-02-06	2019-03-28	2019-07-04	2019-03-28	

This CEN TC 282 group is closely working together with the international ISO standardization group ISO/TC 67/SC 9 LNG installations and equipment. Also, the activities of this group are focusing on LNG plants, but some standards like ISO 18683 are related to LNG bunkering, in this case for large sea going vessels and not applicable for inland shipping.


## ISO/TC 67/SC 9

### Liquefied natural gas installations and equipment


Filter: ☐ Published standards ☒ Standards under development ☐ Withdrawn standards ☐ Projects deleted

**Standard and/or project under the direct responsibility of ISO/TC 67/SC 9 Secretariat <sup>(4)</sup>** 


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 [ISO/NP TS 18683](#) [Under development]  
Guidelines for systems and installations for supply of LNG as fuel to ships


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 [ISO/DIS 20088-2](#) [Under development]  
Determination of the resistance to cryogenic spill of insulation materials -- Part 2: Vapour release

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 [ISO/DIS 20257-1](#) [Under development]  
Installation and equipment for liquefied natural gas -- Design of floating LNG installations -- Part 1: General requirements

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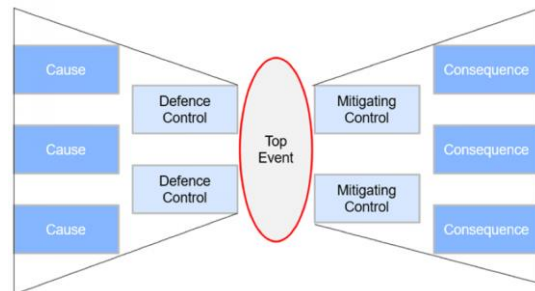
 [ISO/AWI 20257-2](#) [Under development]  
Installation and equipment for liquefied natural gas -- Design of offshore installations -- Part 2: Specific requirements for FSRU

## 5.2 Maximum filling level of a fixed storage tank of the land-based LNG bunkering station

To avoid incidents with LNG storage it is very important to control the maximum filling level of the LNG storage tank facilities. An extensive risk analysis has been carried out in the Netherlands for the standardization of LNG bunkering stations in the so-called bow tie method which can also be seen below.

All potential risks in the operation of an LNG station are identified and the possible risk and the mitigation options are discussed.

This risk analysis showed that transferring the LNG from a truck to an LNG storage is the activity with the greatest risk involved.



The most important finding is that over-filling of the storage tank shall be prevented. The risks involved are impacting the surroundings of the facility.

When LNG is stored in a tank and heats up, its density changes and therefore expands in volume and reaches its maximum level. Therefore, it is possible that liquid LNG is coming out through the vent stack. That is a situation that should be prevented in all circumstances.

To prevent this situation from happening a strict procedure is set up that will prevent the overfilling of the storage tank.

This procedure is described in EN-ISO 16924 Natural gas fueling stations -- LNG stations for fueling vehicles. The LNG storage tank shall be equipped with two independently working maximum level detectors. In all circumstances it shall be prevented that the LNG storage tank will be overfilled.

In case of reaching the maximum level, the Emergency Shut Down (ESD) system will be activated automatically. The ESD system will automatically stop the filling process, stops the pumps and closes automatically the safety valves.

The second important design parameter is the maximum filling capacity of the LNG storage tank. This maximum filling capacity is depending on the set-point of the mounted pressure relief devices.

The maximum filling capacity is set by the ADR Regulation. An LNG storage tank may not be filled more than 95% under any conditions. The maximum filling capacity is calculated as follows:

$$\text{maximum filling capacity} = 0.95 * \frac{\text{Density of the LNG at setpoint of the safety relief valves}}{\text{Density LNG at 1 bara}}$$

Example calculation:

The set point of the pressure relief of LNG storage tank safety valve is 1000 kPa (10 bar).

The density of LNG at set point of the pressure relief valve at 1000 kPa (10 bar) is 359.6 kg/m<sup>3</sup>.

The density of LNG at normal conditions: 100 kPa (1 bar) is 442.0 kg/m<sup>3</sup>

The maximum filling capacity of LNG storage tank according to ADR is 95%

The maximum filling capacity is then:

Max fill capacity =  $359.6/442 \times 0.95 = 77\%$

Interpretation: In this specific situation this LNG storage tank may not be filled more than 77%. This maximum filling level shall be clearly indicated on the tank and at the offloading point.

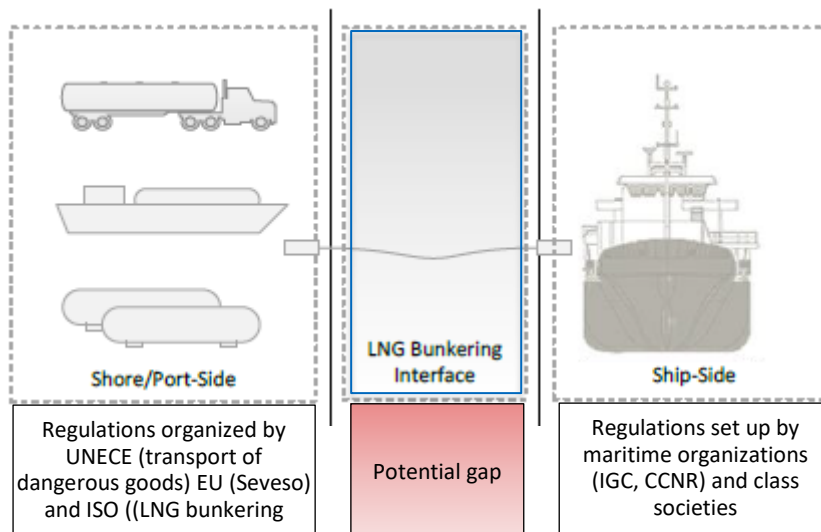
### **5.2.1 Filling instruction**

A detailed instruction is needed for the truck driver who delivers LNG from the tank trailer to the station. An example of the complete filling procedure of the LNG storage tank is described in the Dutch Regulation PGS33 for LNG filling stations.

Together with the EN-ISO 16924 and the ADR Regulation this set of standards describes a safe filling operation of the storage tank.

### 5.3 Interface between ship and shore

There have been a lot of activities carried out on standardization of the LNG components and LNG bunkering process. There are different regulatory frameworks in place for the ship itself and for the truck transporting the LNG to the ship. The important issue is the potential gap between different regulatory frameworks because the frameworks do have their own specific scope of activities and can cause potentially dangerous situations.



To overcome this problem of alignment of different standards a lot of organizations are involved in the developing of guidelines for LNG bunkering. Below several involved organizations are mentioned and this shows directly the complexity of the framework.



Society for Gas as a Marine Fuel (SGMF)



International Standardization Organization



World Port Climate Initiative (WPCI)







International Association of Classification Societies      European Commission (UNECE, Seveso III)



EMSA European Maritime Safety organization      International Maritime Organization (IGF)

All above mentioned organizations worked on the standardization of specific parts of the LNG bunkering process chain. All organizations were aware of this gap and worked together in the international standardization to set up a list of requirements to fill up this gap between the different regulations. This resulted in the publication of the ISO 20519 Ships and marine technology — Specification for bunkering of liquefied natural gas fueled vessels. With this standard in place the interface between ship and shore is well organized.

One of the key steps in safe LNG bunkering is verifying that the supplying vessel or facility and the receiving vessel are compatible. Compatibility covers a wide range of topics and because of the complexity of LNG bunkering, it is more important to confirm compatibility than for bunkering of conventional oil-based fuels. A vessel compatibility assessment should be carried out prior to LNG bunkering operations. Compatibility is normally agreed upon and confirmed in writing prior to the start of bunkering as part of the bunkering procedures. An easy way to do this is to fill out a checklist to confirm compatibility before each bunkering operation. CCNR have taken over the bunkering checklist from IAPC/WPCI.

There are three major precautions to prevent unsafe situations. The first important item for a safe connection between ship and shore is the mooring of the ship. Under no circumstances the ship may drift away during bunkering.

The second precaution is the use of a breakaway device which is mounted on the ship in combination with the ESD system which is described in the next chapter. Using a breakaway device prevents that LNG can be spilled in case of drifting away during bunkering.

The third precaution is the use of a dry quick connect coupling. During coupling and uncoupling it is not necessary to empty the hose with LNG. An example of such a coupling is shown in the figure below.

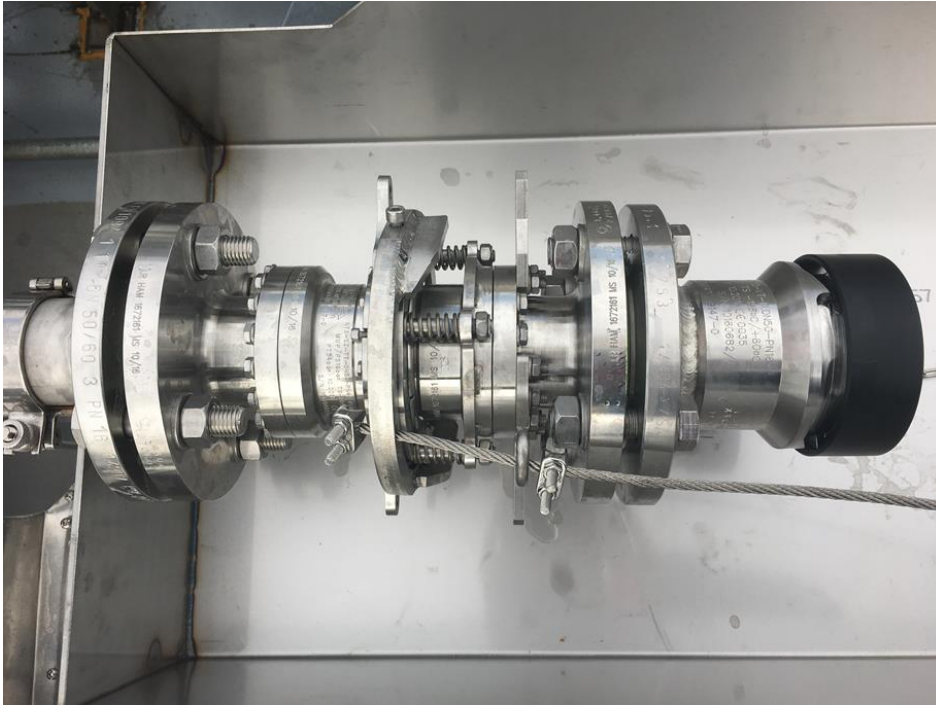


Figure 2 combined dry break breakaway LNG bunkering connection

This bunkering connection has both mentioned functions combined and therefore several advantages, it is a dry quick connect coupling combined with an integrated breakaway device. This breakaway device is activated by a steel cable which is connected with the shore. In case of drifting away of the ship during bunkering the breakaway device will be activated and no spillage of LNG will occur.

The last point to mention is the location of the bunker manifold on the ship. Standardization of the position of the bunker manifold will ease the mooring of the ship and the connection with the LNG bunkering hose. The table below shows the position of the bunker manifold of some of the current LNG powered inland ships. It shows that the majority has the bunker manifold located at 15-20 from bow or stern.

ship	Location bunker manifold	Length ship	Manifold position in m from bow	Manifold position in m from stern
Musketeer		110	16.5	93.5
Argonon		110	66	44
Ecoliner		110	108	2

Ecotanker 2x		110	95	15
Sirocco		110	16.2	93.8

## 5.4 The design of the ESD system

An ESD system is a system that safely and effectively stops the transfer of LNG between the facility and vessel in case of an emergency. It generates an automatic emergency stop between shipside and LNG trailer / bunker installation in case of one or more of the following sources:

- Gas detection / Fire detection
- Manual activation on ship side (receiving installation) as on trailer of bunker installation side (delivery installation)
- 'break away' detection
- Power failure
- High level detection in fuel tanks / over fill safety; / High pressure detection
- Low temperature in the drip tray
- Detection of high transfer flow
- Detection of LNG hose outside safe working area

And when activated there will be an initiate shutting down of the LNG transfer pumps and closing of the ESD valves as showed in the figure below

Actions of the ESD system are as follows:

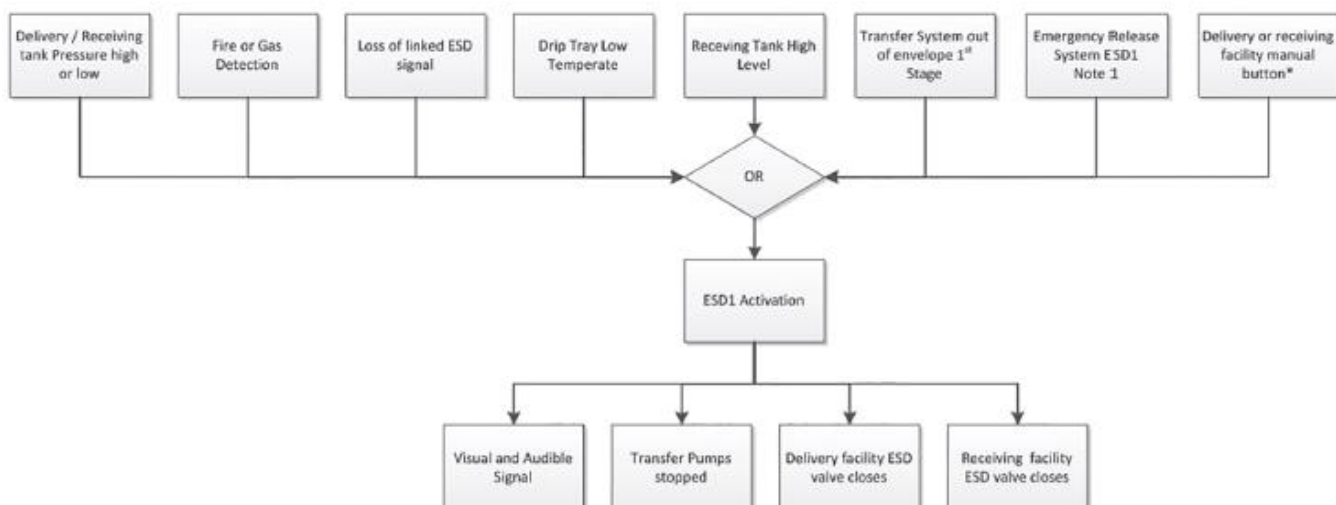


Figure 3 actions of the ESD system

The following incidents at the LNG bunkering station shall trigger an ESD activation as well:

- gas detection with a separate link to the control room (ROC)
- Instrument gas low pressure and power fail
- Temperature to detect spillage and fire
- Overfill and or overpressure of the tank
- Manual activation
- ESD from the truck and truck unloading system (from plant to truck and truck to plant)
- ESD from ship

The current situation is that a lot of different ESD configurations are present. For sea going vessels different systems are present, also for small scale activities and road transport different systems are in use, this can also be seen in the figure below.



With the expected 15 newbuild LNG driven inland tankers of Plouvier Transport it was decided to choose for a pneumatic ESD system as a standard. The main reason for this is that a pneumatic system is easy to operate, and the systems are reliable and cheap to install. A more detailed description of the system is given in chapter 8.

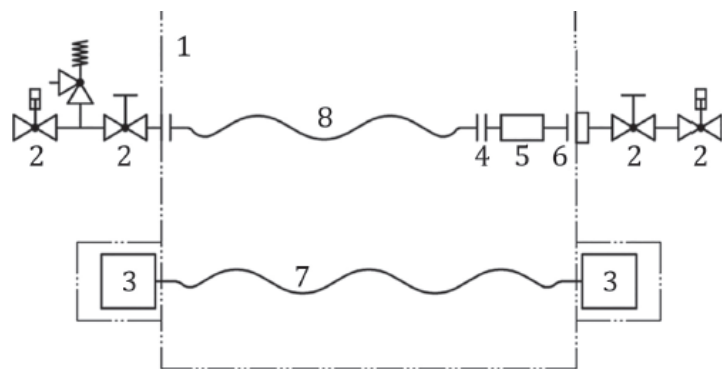
Before any export of LNG can start, an ESD link between the ship and the plant must be established.

The plant shall be equipped with a bidirectional pneumatic ESD link between ship and shore according applicable standards. The instrument air for this ESD will be supplied by the ship. The ESD on the shore side shall be triggered according to the process safety and legal requirements.

## 6 Bunker components

### 6.1 Technical drawings of bunker components

In the figure below a standard setup of an LNG transfer between shore and ship is displayed.



**LNG Provider**

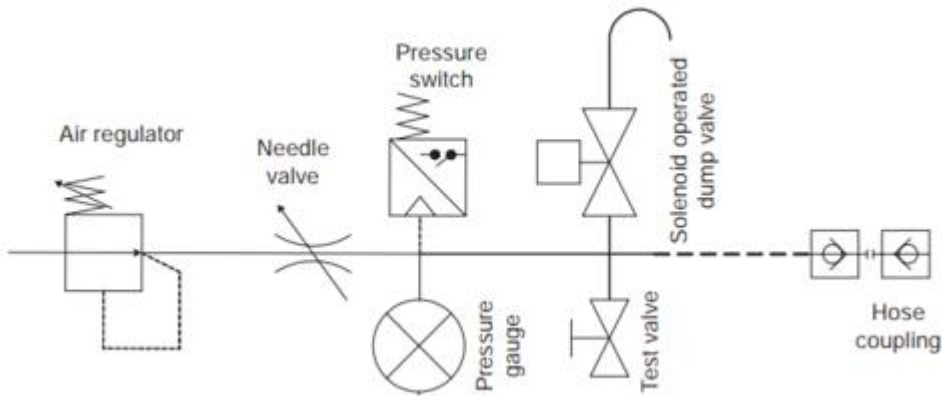
**LNG Receiving Vessel**

**Key**

- |   |                                 |   |  |
|---|---------------------------------|---|--|
| 1 | scope                           | 7 | ship/shore or ship/ship ESD link   |
| 2 | automatic and manual ESD valves | 8 | loading system (systems include: vessel to vessel transfer arms, articulated rigid piping and hoses) |
| 3 | ESD junction box                | 9 | vapour return system   |
| 4 | insulation flange               |   |  |
| 5 | emergency release coupling      |   |  |
| 6 | QC/DC (if used)                 |   |  |

## 6.2 Automatic ESD

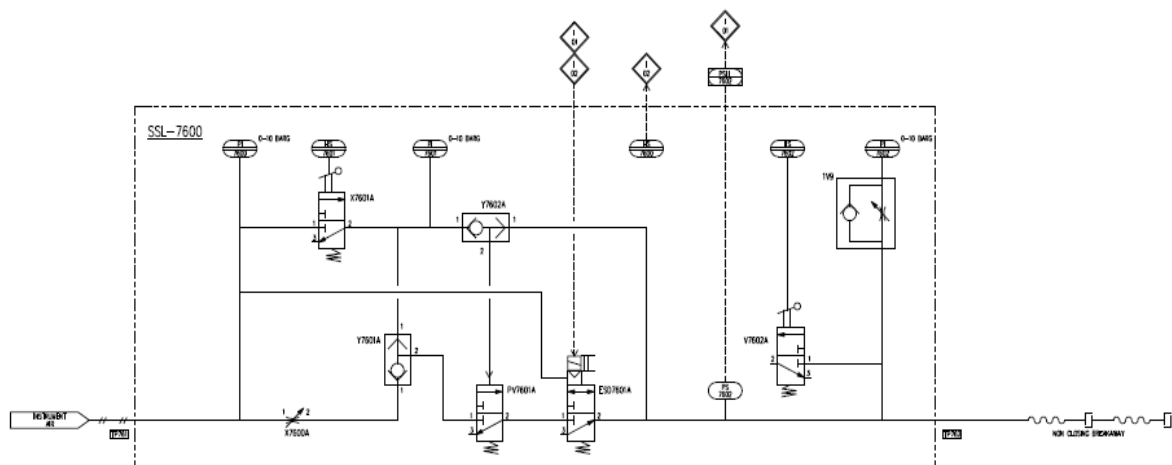
Below a setup of an ESD system is given.



Depressurizing of the system on either ship or shore side will initiate an ESD action.

Operating pressures vary between two and seven bar, the air being supplied from shore at some installations and from the ship at others. The normal set point should be about 80% of the supply pressure to ensure rapid tripping, commonly used is 2.7 barg supply pressure and 2.4 barg tripping pressure.

At least two types of connector are in use but the most common is the standard ½" MIL-C-51234 quick connector, available from the Snap-tite 'H' series, or its Nitta-Moore equivalent. Both manufacturers using the same ordering code. A nipple is fitted to the ship's fixed piping with the coupler fitted to the hose. The normal arrangement is for couplers at both ends of the hose so that it can be completely disconnected from the terminal's nipple when not in use.



### 6.3 Insulation flange

**Electrical Isolation:** Vessels transferring or receiving low flashpoint flammable liquids, such as LNG, need to take additional precautions against ignition resulting from electrical arcing. Two causes of arcing are static electricity build-up in the LNG bunker hose and differences in potential between the ship and bunker supplier's facility, including the quay or pier, trucks, bunker vessels, etc. It used to be common practice to connect a bonding cable between a ship carrying low flashpoint flammable liquids and the loading or offloading facility to physically ground the two objects together to equalize the difference in potential. However, it was noted that the bonding cable was not fully effective at equalizing the potential. Furthermore, if the cable accidentally broke or became detached, the chances of arcing would be greatly increased. An effective way of preventing arcing is to isolate the ship and the bunker supplier using an isolating (insulating) flange fitted at one end of the bunker hose only, in addition to an electrically continuous bunker hose. The isolating flange, an example of which is shown in the figure below, prevents arcs from passing between the ship and facility even if there is a difference in potential. Furthermore, because the hose is electrically continuous and one end is grounded to either the ship or the bunker supplier, static electricity will effectively be dissipated. An alternative method is to use one short section of insulating hose without any isolating flanges, but with the rest of the bunker hose string electrically continuous. To ensure that the ship is completely isolated from the supplier, it may be necessary to isolate mooring lines, gangways, cranes, and any other physical connections. This is typically done by using rope tails on mooring lines, insulating rubber feet on the end of gangways, and prohibiting the use of certain equipment that would otherwise pose an unacceptable risk of arcing

In each transfer system between shore and ship there should be an insulation flange installed according to the requirements of the International Oil Tanker and Terminal (ISGOTT) safety guide.

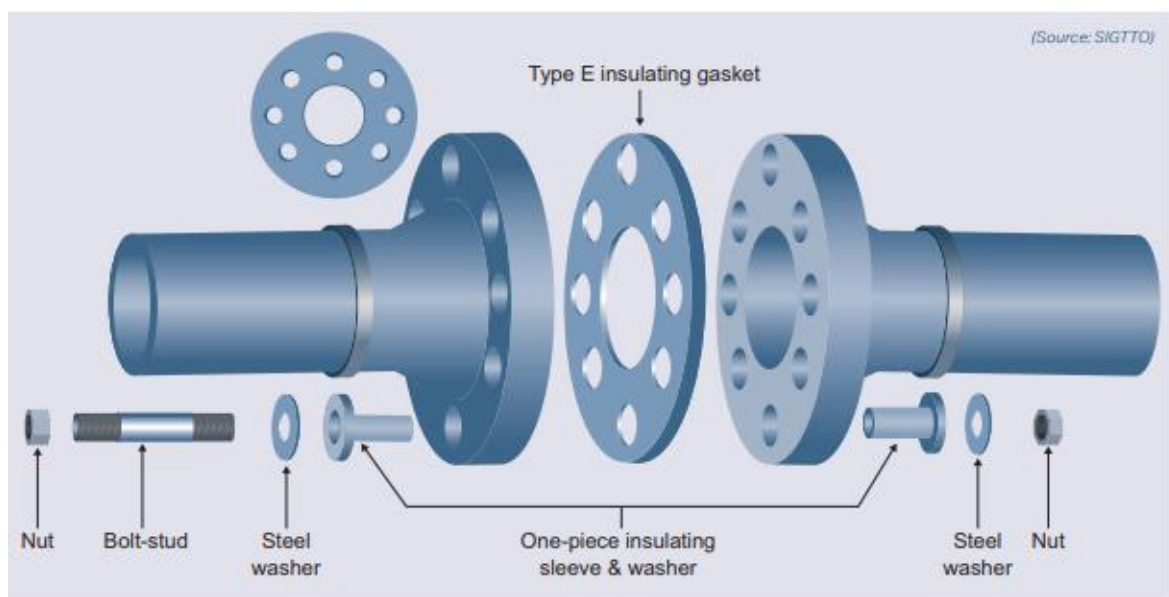
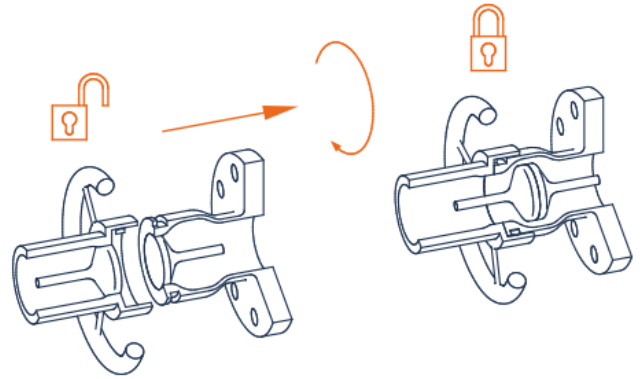
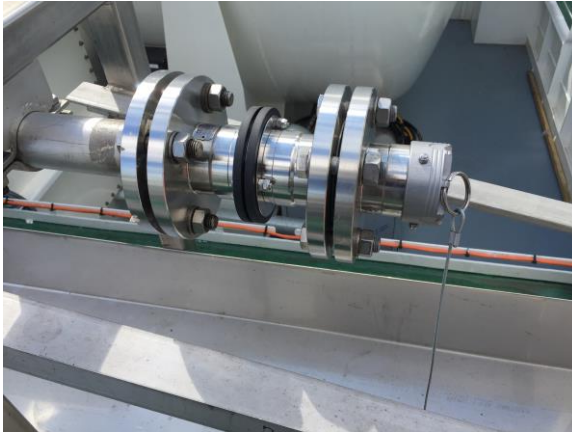


Figure 4. Typical Isolating Flange

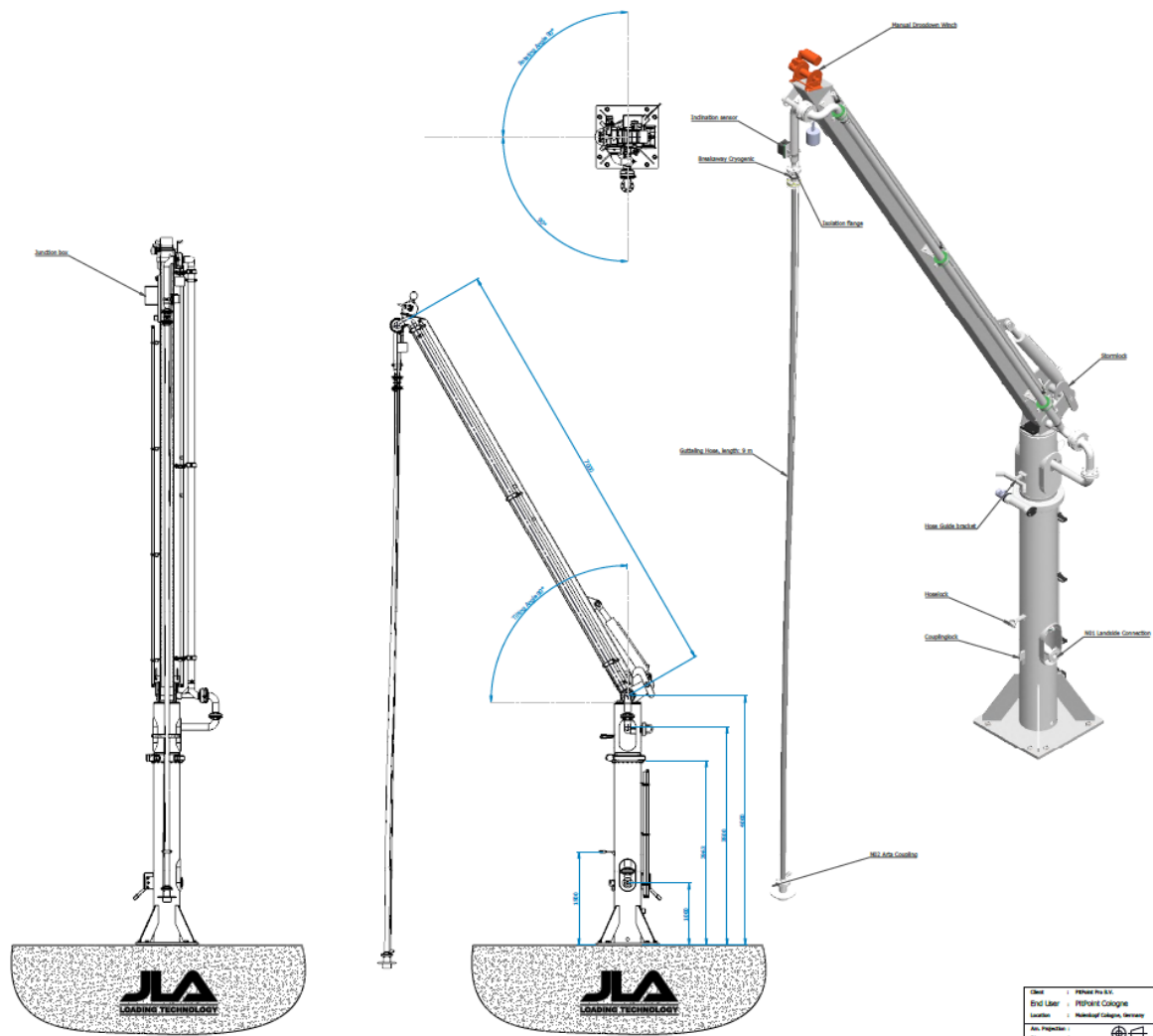


## 6.4 Quick connect disconnect coupling





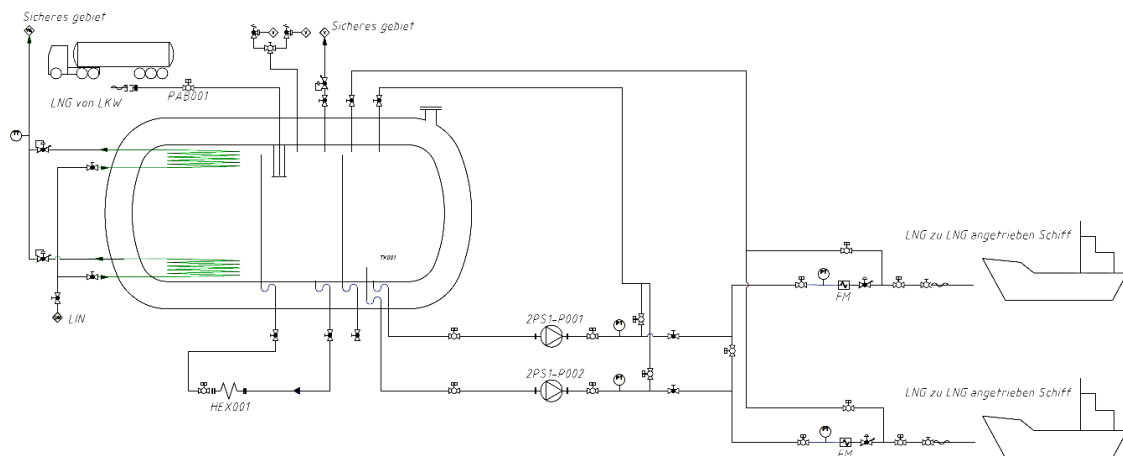
## 6.5 Hose



## 6.6 Drip tray



## 6.7 Total configuration of a station solution



## 7 LNG bunker station LNG bunkering process standardization

The standard LNG bunkering procedure can be considered to be well established today, with a significant number of LNG fuel bunkering operations to LNG fueled ships. Industry guidance outlines today the good practice procedures in bunkering operations, streamlining the processes and identifying the major relevant steps in the operation. The different LNG bunkering modes have, to some extent, all been put in practice and experience has been gained by operators.

The basis for this good day practice is the bunkering checklists prepared by the IAPH/WPCI. One of the main objectives of the working group was to create harmonized LNG bunker checklists for known LNG bunkering scenarios. These checklists reflect the extra requirements of ports regarding LNG bunkering operations in or near their port environment. By using bunkering checklists, a high level of quality and responsibility of the LNG bunker operators can be obtained.

Implementing harmonized bunker checklists in ports will also be of great benefit to the vessels (and their crew) bunkering LNG in other ports because it will reduce the potential confusion caused by having to comply with different rules and regulations in different ports. The working group has developed three bunkering checklists for implementation in ports:

- Bunkering checklist Truck to Ship
- Bunkering checklist Ship to Ship
- Bunkering checklist Bunker Station to Ship

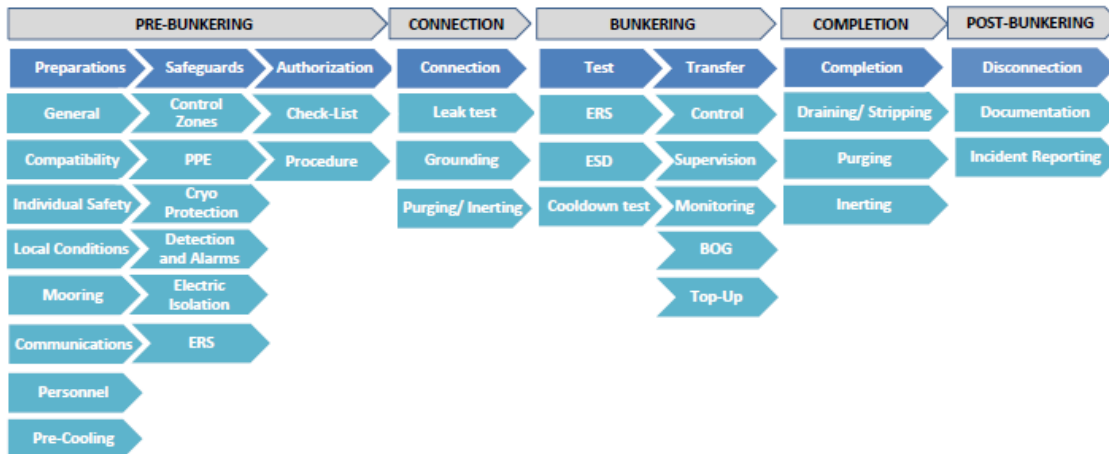
As the figure below shows that the LNG bunkering consist of a check of five important steps. For all these steps different checklists are available.

The pre bunkering list will check if the ship is compliant with the used equipment, if the safeguard systems are compatible and if all preparations have been made for a safe bunkering.

In the second step the physical connection of the bunkering hose and ESD system with the ship is made. The connection is checked for leaks and the ESD system is checked for proper operation. After cooling down the hose and other equipment, the actual bunkering starts and the pressure and level in the tank are well monitored. After completion of the bunkering the hose can be purged with nitrogen but is not always necessary when using a dry connect coupling. The bunker hose will in that case evaporate back to the storage tank and therefore it is not necessary to purge it with nitrogen. On the ship special requirements can require the purging of the bunkering pipework with nitrogen.

The final step in the bunkering checklist is to fill in the documentation with the delivered amount and to report any incidents.

With this bunkering checklist in place a safe operation of the bunkering process is guaranteed. The bunkering checklist is made publicly available<sup>1</sup>.



Another important aspect during bunkering is the so called 'Simops' or simultaneous operations during bunkering. This explains which activities can be performed during the LNG bunkering. This includes loading or unloading cargo, dangerous goods loading or unloading, passenger embarkation/disembarkation, bunkering of fuels other than LNG, and any other activity that can impact or distract from bunkering operations.

In such cases a specific risk analysis must be executed to identify the possible risks and to take the necessary measures. This will result in different areas around the LNG bunkering manifold in which certain activities cannot be executed. In the figure below an example is given of the unloading of a container ship. In the safety zone, no containers can be unloaded, in the hazardous zone no ignition sources may be present.



<sup>1</sup> <http://www.lngbunkering.org/lng/bunker-checklists>

## 8 LNG bunker stations LNG storage tank refilling process standardization

There are different options to supply a bunkering station with LNG. The most convenient way is transporting LNG to the bunkering station by truck. This will be the most feasible way for markets in their start-up phase with lacking demand. However, for the long-term with foreseen market growth other options should be taken into account.

For inland waterway vessels the LNG bunkering demand is approximately equal to the content of a tank trailer. Taking into consideration that there are approximately 12.000 ships sailing on the river Rhine. A yearly average consumption of an inland vessel is about 300-ton LNG/year, the average refueling with LNG per time is about 20 ton of LNG. When 10 % of all the inland ships changes over to LNG as fuel this means 18000 refilling's per year, or 50 refilling's/day which means that 50 trucks per day are bringing the LNG to the ships.



Besides the availability of the number of slots at the LNG Gate terminal in Rotterdam and the logistic organization of all the trucks, it is from a safety point of view not a desirable solution. Besides the environmental impact of all the truck on the road, the safety aspects in the harbor must be organized. Therefore, the development of fixed LNG bunkering stations with a fixed LNG storage along the river must be established.

In the case of such a station there are different options to fill LNG storage tank:

- Loading by tank trailer
- Loading of LNG by portable containers (ISO containers)
- Loading of LNG by Bunker vessel

### 8.1 Filling with tank trailers

As described above there is no difference in supply by tank trailer to a bunkering station or bring the tank trailer directly to the ship. The only advantage is that an LNG bunkering station has always a fixed storage of LNG available.

The logistics for a direct truck to ship filling are more complicated, the location of the ship and the time must match with the arrival of the truck. With a fixed LNG storage, the logistics can be arranged during the off-peak hours of the day.

A fixed storage results in a more safe and flexible option. The bunkering volumes are not limited to the capacity of a truck and the safety systems are more advanced than with a truck to ship solution.

Again, for the starting market the filling of the storage by tank trailer is an efficient and easy operation. When the demand is increasing, there is a need for a more efficient logistic process.

## 8.2 Filling with bunker barge

Then option 3 comes in place, delivery of LNG by bunker barge to the LNG bunkering station.



The build has been confirmed for a 3,000 m<sup>3</sup> LNG bunker-supply barge that can operate on inland waterways. It will be fitted with four Type C LNG tanks under a closed deck.

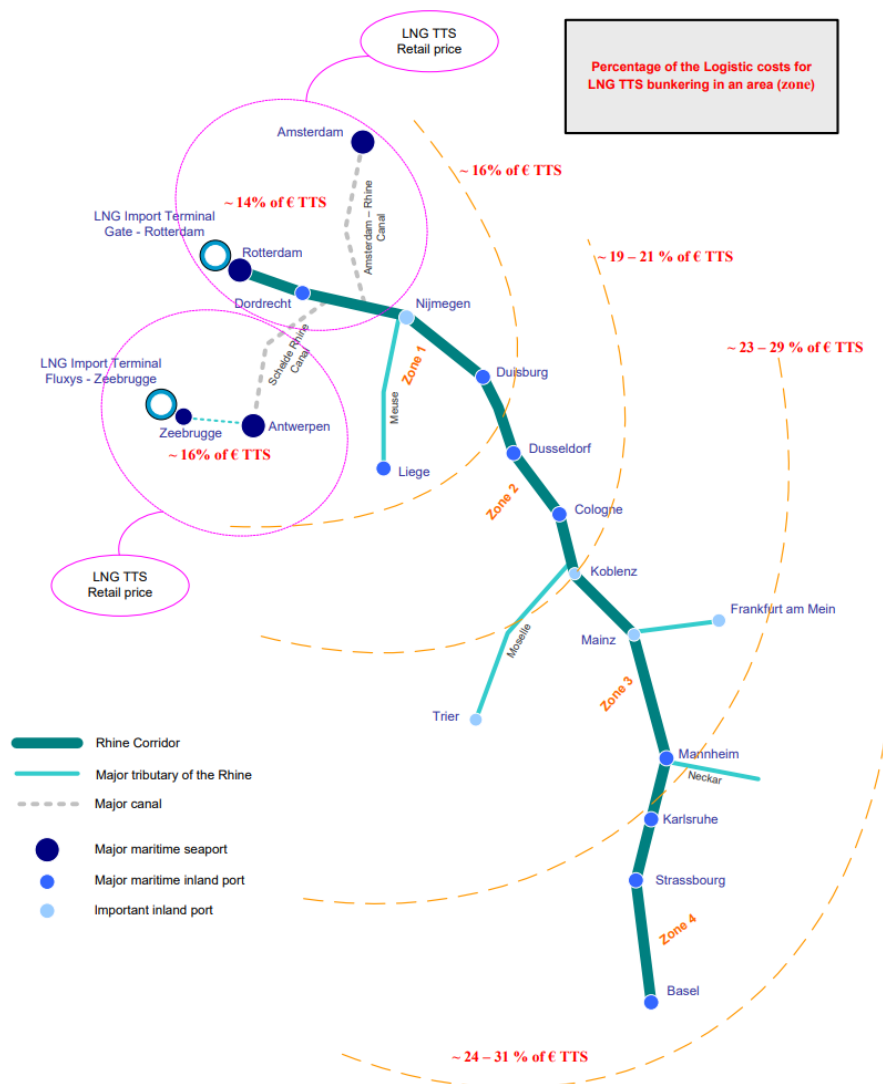
The challenge for such a configuration is that the operating costs are at the moment high due to the employability of the ship. There are three main reasons for this situation. First, the current LNG bunkering station has a storage capacity of 200 m<sup>3</sup>. The mentioned bunkering barge can supply 15 LNG bunkering stations in one round, while there are only a couple LNG bunkering stations in preparation this is not yet an economic solution. However, the demand for LNG for stationary industrial applications is increasing, so with a combination of both activities it can be an interesting option. When the demand for LNG increases, this will be a cheaper solution to bring LNG to different locations. The capacity of the ship is about 10.000 ton/year.

However, there is another drawback. The slot fee at the LNG terminal is currently very high for such a small ship in comparison to a truck loading. Costs for a slot fee for a truck loading is € 500, one truck load is about 18 ton so the price per ton will be approximately € 28/ton.

Costs for a slot fee for a bunker barge are € 25.600,- and in addition to the slot fee there is a fee for energy transfer of about € 1.10/MWh with a minimum of € 28.000, resulting in a tariff of approximately of € 45/ton.

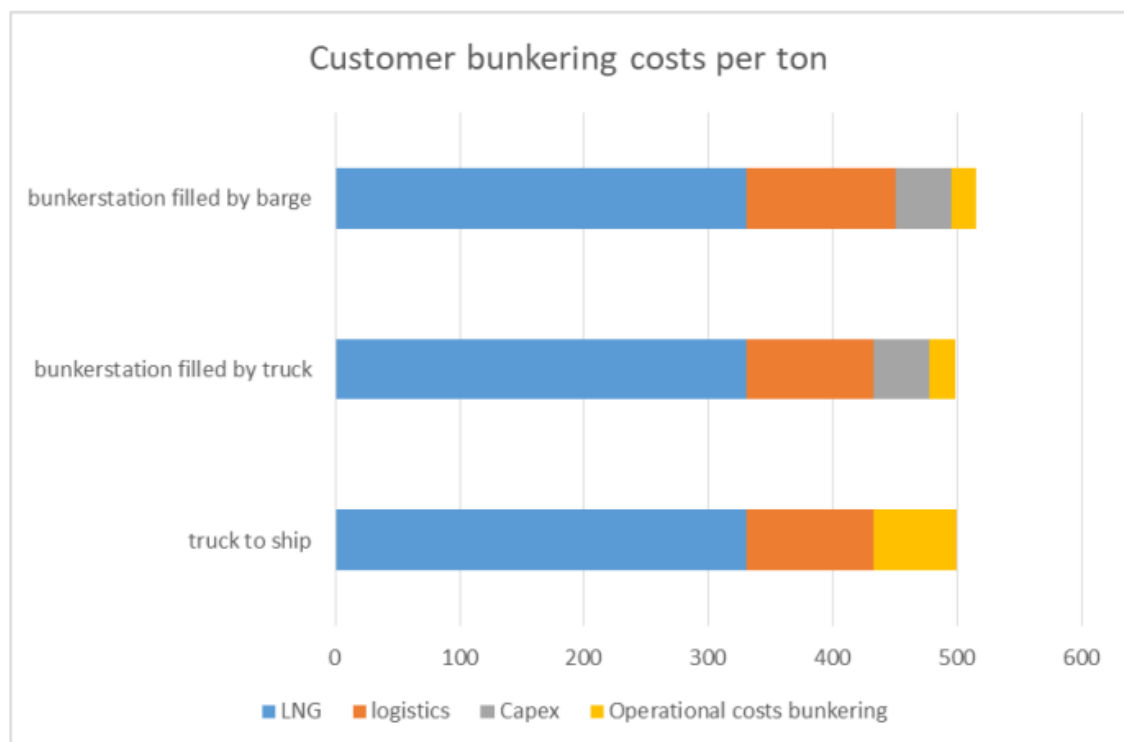
Only on the terminal fees the bunker barge pays the double price per ton in comparison to a tank trailer. In addition to these costs the operational cost of the ship versus the tank trailer has to be considered.

It is obvious that when the distance increase from the terminal the logistic costs for the truck will become relatively higher and as such there will be a break-even at some point. In a previous study this Action on best locations for LNG bunkering stations and on refilling of LNG bunker stations, an extensive analysis has been done on the logistic costs of a bunker barge versus tank trailer transport. The figure below shows the percentage of the cost price of LNG caused by logistic costs in relation to the distance from the terminal





The figure below shows the optimal situation for a fully utilised barge, in this situation the price difference is less. The purchase price in blue is the same for all options. The logistical costs are displayed in orange. The capital costs are displayed in grey, hereby assuming that the bunker barge is fully utilized. For truck to ship bunkering no capital expenditures are applicable. Finally, the operational costs are displayed in yellow. The figure shows that bunkering operations at a fixed bunkering station can be performed more efficiently, due to the larger bunker flows and more efficient (safety) procedures.





### 8.3 Filling with Tank containers

The final option to refill a bunkering station is to make use of tank containers. In respect to logistic costs there is not much difference between tank trailer transport or transport of a tank container by truck. The disadvantage is that the loading capacity of a tank container is less due to the extra weight of the container. However, the tank container is not equipped with an unloading pump, which saves weight but on the other hand needs an additional investment of a unloading pump at site.

By using tank containers there are three different options.

The first option is that the tank containers are used as storage system of the bunkering station itself and will be exchanged when empty. The advantage of such a system is that no investment has to be done in an expensive storage tank on site.

The disadvantage however is that the handling of containers result in additional cost. In addition, special attention must be giving to the handling of the boil of gas of empty containers. Before trailers and ISO containers can be loaded with LNG at Gate terminal, all combination components (truck, trailer as well as the container in the case of an ISO container) must be approved and authorized. This approval procedure focuses primarily on (statutory) safety requirements as well as compatibility with the terminal. Drivers also need to be registered in advance. In addition to a valid driving license, they should also have relevant ADR certificates and sufficient knowledge and experience to be able to load and transport LNG safely.



Picture: Standard 40' – 46000L 7/10 barg UN Portable T75 / ADR R14,3BN LNG tank.

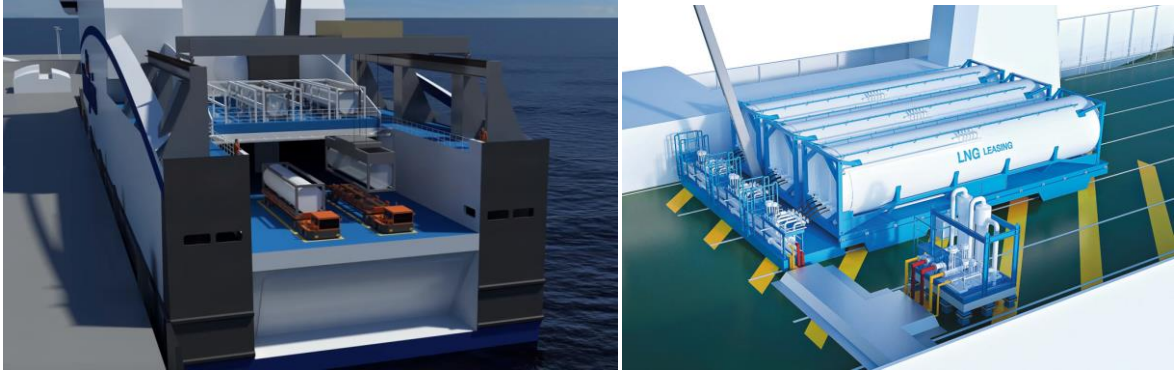


All the economic aspects of this solution are described in previous studies of this Action<sup>2</sup>, these studies conclude that tank containers are not an economical feasible solution at the moment.

The second option by using tank container is that the complete tank container is exchanged with the ship. The empty tank container is taken from the ship and replaced by a full container with LNG. The advantage of this option is that for the handling of a fuel container no additional permitting is needed for an LNG bunkering station in the harbour. It is comparable to loading a chemical container on a ship. The disadvantage is again the logistic costs of transporting the container to the location and the number of trucks needed. But the costs will increase more in comparison to direct truck to ship bunkering due to the handling of the full fuel container and

<sup>2</sup> <https://lngbinnenvaart.eu/files/1.2.1%20LNG%20fuel%20tank%20containers%20and%20non-containerised%20tanks.pdf>

empty container. However, this option is being used now for different seagoing vessels (see also illustrations below).



The last option is to transport containers by barge or by train to the bunkering location. Again, the handling of the containers adds additional cost to the process. The remarkable thing is that the transport of a container per barge is calculated per container. The same unit price is applicable for one container or ten containers. In comparison with transport of LNG by tank trailer, the costs are 15% higher to transport a tank container per barge.

Several solutions are available as regards transportation by train. To transport LNG to the harbour it is necessary that a rail track is available in the harbour. Again, the additional costs are involved by the handling of the container, or as shown in the right picture below dedicated LNG rail tankers are available. But to make efficient use of the rail tanker an unloading facility at the rail track must be available.



## 9 Adoption by competent authorities

As shown in the picture below it is not always easy to get a permit for LNG bunkering stations. Besides the technical description of the bunkering station a lot of other authorities are involved.



For the pilot bunkering station in Cologne the list below shows what additional information (besides the technical info like Hazop, risk assessment and explosion protection plan) had to be shared before the permit application was submitted:

- Noise report, while the harbour area is a noise controlled area a research has to be executed for the impact of noise produced by ships, the installation and the transport of LNG by trucks.
- Before the civil works could start a research has to be executed on the search of old remained 2<sup>nd</sup> world war bombs in the ground.
- Fire protection plan has to be set up and discussed with the local fire department. This includes a research on the capacity of the fire hydrants.
- A waste water plan has to be set up to show that no waste water will flow into the Rhine.
- A drainage plan, how the deal with rain water.
- A flooding plan, how to deal with high water levels in the river which can flood the area. All equipment shall operate in case flooding without causing unacceptable situations.
- a geotechnical investigation had to be carried out for the bearing capacity of the soil.
- Because the stored capacity is greater than 50 ton, the operation of the plant has to comply with the Seveso III act. This means a detailed description of the safety management plan needs to be set up and certified by the authorities.

- A plan of emission sources, light and a plan on how to prevent boil-off gas is emitted to the air.
- Building application.
- Nature, protection of species and landscape conservation plan has to be set up.

This list shows that besides the technical application a lot of other information had to be shared. Because this is the first LNG bunkering station in Germany a lot of additional questions were raised.

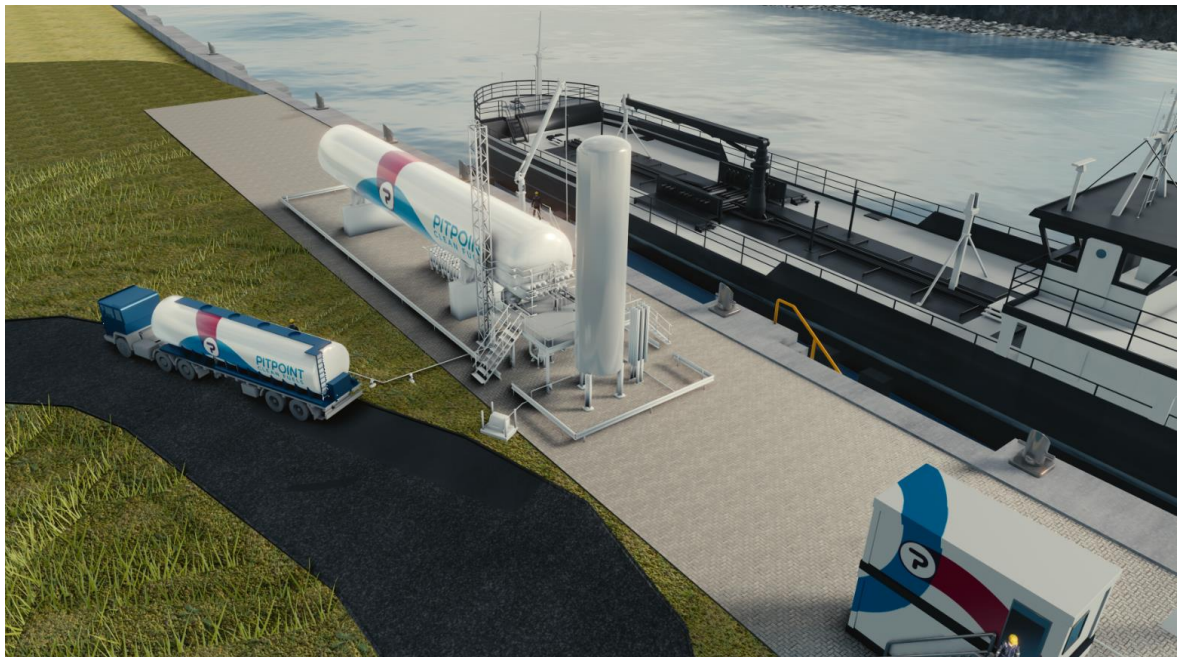
Regarding the technical part, a reference was made to the existing regulations on European and International level. That helped a lot to convince the local authorities.

With this first permit application fulfilled it will be easier in the future to apply for another permit.

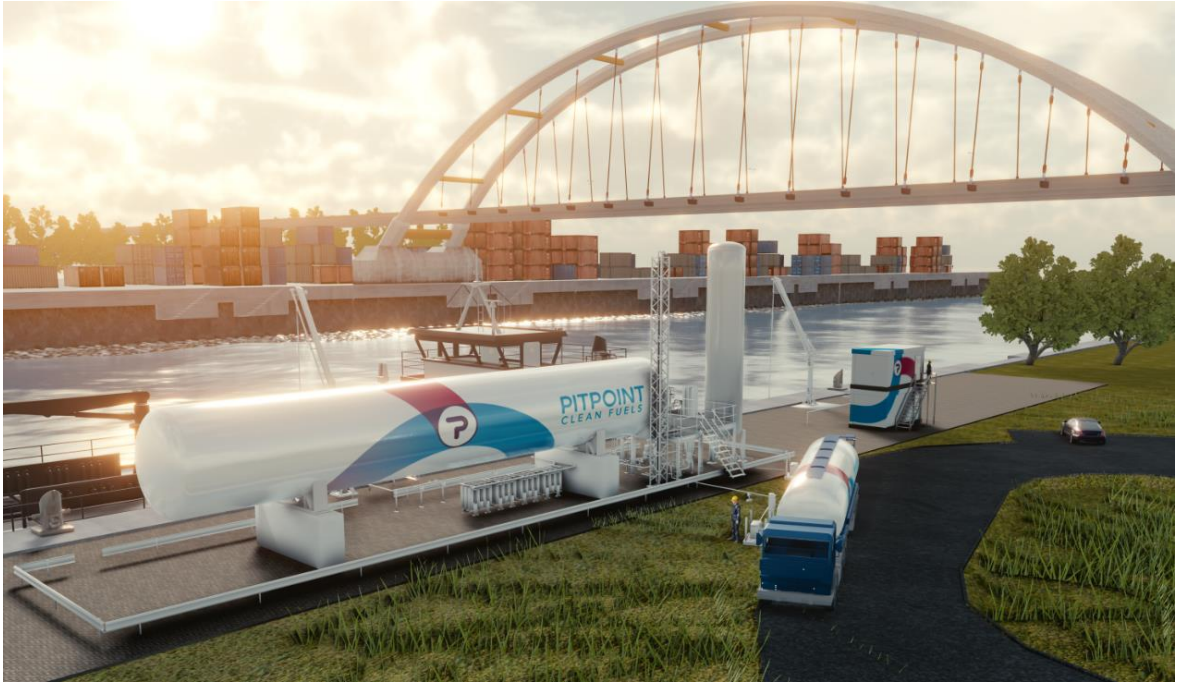
## 10 Design of an optimal bunkering station for IWT LNG fuel supply

The design was completed using full 3D modeling techniques. This made it possible to actually walk through the model before construction started. During the permitting phase the 3D model helped in making the installation more visual to the various permitting authorities.

This techniques made it also possible to optimize the design with regards to daily operations, maintenance and operability. This is a representative design which can easily be applied at other locations.

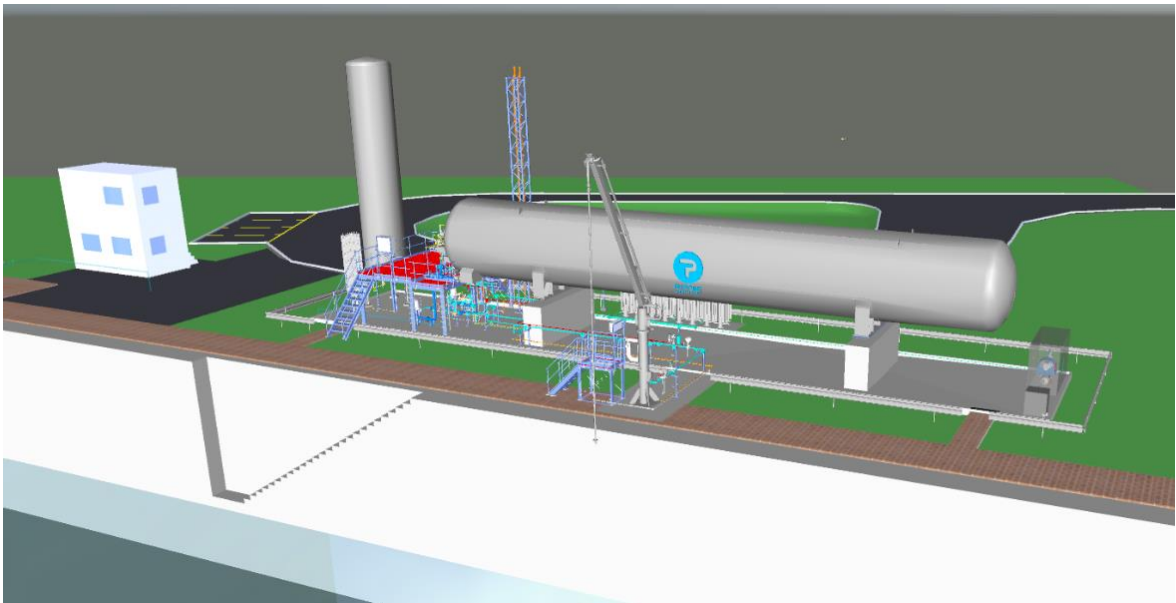














## 11 Conclusion

The objective of this study was to analyse and recommend on the overall standardization of LNG bunker stations for IWT. The overall standardization of an LNG bunker station includes the standardization of:

- The interface for the LNG supply to the storage tank of the LNG bunkering station.
- The interface between the LNG bunkering station and the ship.
- The design of the ESD system of the supply of LNG to the LNG bunkering station.
- The design of the ESD system of the LNG bunkering station in relation to the ship.
- Application of standardised bunker components.

Furthermore there needs to be an optimised design for a bunker station and the overall design and standard needs to be adopted by the competent authorities. The standardised technique and optimal design will contribute to lower investment. The most important findings of the analysis can be summarized with the following bullet points:

- The most relevant standards for LNG bunkering are:
  - EN 13645
  - EN ISO 16924
  - EN 20519
  - EN 23645.
  - EN 21593
- The Dutch regulation PGS33 for LNG filling stations, EN-ISO 16924 and The ADR Regulation can together be seen as a complete filling procedure for a safe filling operation of the storage tank.
- The ISO standard 20519 'Ships and marine technology—Specification for bunkering of liquefied natural gas fueled vessels' properly organised the interface between ship and shore.
- The bunker manifold should be located at 15-20 from bow or stern.
- The maximum filling capacity of an LNG storage tank is according to ADR 95%.
- Bunker stations should be equipped with a bidirectional pneumatic ESD link between ship and shore according to applicable standards. The instrument air for this ESD will be supplied by the ship. The ESD on the shore side shall be triggered according to the process safety and legal requirements. Pneumatic ESD system should be the standard, given the easiness to operate, their reliability and relatively low price.
- In each transfer system between shore and ship there should be an insulation flange installed according to the requirements of the International Oil Tanker and Terminal (ISGOTT) safety guide.

- There should be made use of a dry quick connect coupling, since during coupling and uncoupling it will not be necessary to empty the hose with LNG.
- Depending on the economic feasibility, the bunker station itself can be supplied with LNG in three ways:
  - Loading by tank trailer
  - Loading of LNG by portable containers (ISO containers)
  - Loading of LNG by Bunker vessel

The overall design and configuration of the bunker station are completed using full 3D modelling techniques. This made it possible to optimize the design with regards to daily operations, maintenance and operability. The end result is a representative design which can easily be applied at other locations.

## Annexe 1

### *Annex Procedure for filling the storage tank at an LNG delivery installation*

For offloading the LNG tanker, the driver shall follow the following procedure:

1. Park the LNG tanker in the direction of driving away, according to the specified distance to the reservoir to be filled (LNG storage tank), or as close as possible to the filling point.
2. Put on hand brake.
3. Check no other tanker is offloading fuels within 25 m of the offloading point and that offloading can take place safely.
4. The employees involved in offloading shall use suitable PPE.
5. Establish the contents of the stationary LNG storage tank and on this basis determine the maximum permissible quantity to be topped up.
6. Check the pressure in the LNG storage tank. This may not exceed the maximum filling pressure of the offloading pump. If possible the necessary steps shall be taken to obtain a feasible pressure (reduction).
7. The driver of the LNG tanker shall keep to the maximum filling capacity, as indicated in the filling instructions corresponding to that specific station. If these instructions are not present, filling may not take place.

Note:

Practical explanation in line with ADR 4.3.5 TU18.

8. Open the doors of the valve compartment of the LNG tanker, which enables the remote controlled shut-off valves and the pump to be put into operation.
9. Attach the cable to make a connection with the LNG filling station with the functions of making an equipotential connection and coupling the tanker emergency shutdown system with the emergency shutdown system of the LNG installation to be restocked.
10. Remove the blind flanges or blind couplings of the necessary shut-off valves of the LNG tanker and the filling point.
11. Couple the offloading hose between the shut-off valve of the LNG tanker and the filling point of the stationary reservoir (LNG storage tank) using flanges or hose couplings. Non-sparking tools shall be used for this.
12. Check the connections and open the necessary shut-off valves of the LNG tanker and of the filling point and/or the LNG storage tank and then check the tightness of connections.

**Note:**

The remote controlled shut-off valves on the reservoir connections of the LNG tanker may be opened in different ways (there is no standard for this yet). If these operations are not carried out properly the pump drive cannot be switched on.

13. Take measures so that the pump can be started and then start the pump.
14. Tighten connections, following shrinkage occurring because of the low temperature.
15. Continue to check constantly that offloading is taking place safely and in particular that the permissible filling capacity of the LNG storage tank is not exceeded.
16. Stop offloading upon reaching the maximum permissible filling capacity by stopping the pump and closing the shut-off valves of the LNG tanker.
17. Establish when the maximum permissible filling capacity is reached from the maximum level indication; a preliminary alarm can be given by setting the liquid level indicator at a lower level.

**Note:**

If the driver uses an approved remote control for pump and shut-off valves it is permitted to check the filling capacity of the stationary LNG storage tank on the spot.

18. Close the shut-off valves of the filling point and/or the LNG storage tank.
19. Degas the offloading hose according to the procedure for the LNG filling station.

**Note:**

When disconnecting the hose a small quantity of (L)NG is released. Connection and disconnection shall not be carried out during a thunderstorm.

20. Disconnect the hose and fit a blind flange or blind coupling to the hose shut-off valve.
21. Disconnect the earth connection and secure the filling point shut-off valve against unauthorised use.
22. Determine the quantity delivered.
23. Close the valve compartment of the LNG tanker which interrupts the servo-mechanism of the driving off alarm system, the remote controlled shut-off valves and the pump.
24. Check both the stationary LNG storage tank and the LNG tanker for irregularities or leakage and inform the customer of the delivery made by handing over or leaving the delivery note and report any irregularities to him and the client.
25. After closing the valve compartment of the LNG tanker, PPE, specifically for handling LNG, is no longer necessary.
26. Release the hand brake and leave the parking space.