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Breakthrough LNG deployment in Inland Waterway Transport

**Activity 1.2 Development of standardised
components for best available LNG technologies;
1.2.1 LNG fuel tank containers and non-
containerised tanks**

Report

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Revision history

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V0.1	29-01-2018	Edo Boerefijn	Cryonorm Systems	Completion of part for non-containerised fuel tanks and technical compatibility with other systems
V0.2	30-03-2018	Patrick Broeders	Trifleet Leasing	Completion of part for containerized fuel tanks
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V1.0	30-03-2018	Edo Boerefijn/ Patrick Broeders	Cryonorm Systems/ Trifleet Leasing	Final report

1 Introduction

This report covers the study to the development of standardized components for best available LNG technologies, and specifically the LNG fuel tank containers and non-containerised tanks. The corresponding sub-activity 1.2.1 prescribes a study to:

- Non-containerised fuel tanks
- Technical compatibility with other systems
- Fuel tank containers

The study to non-containerised tanks and technical compatibility with other systems, encompassing under which the tank connection space (TCS), is executed by Cryonorm. The study concerning tank containers is covered in the last chapter (chapter 20), and executed by Trifleet

2 Non-containerised fuel tanks & Technical compatibility with other systems

Design Basis

Units of measurement

Unit	Measurement
Temperature	°C
Pressure (gauge)	Barg
Mass	Kg
Volume	m ³
Length	Mm
Liquid / vapor density	kg/m ³
Flowing mass	kg/hr
Flowing vapor (gas)	Nm ³ /hr (at 0° and 1.013 bar)
Flowing vapor (steam)	kg/hr
Flowing liquid	m ³ /hr
Power	kW
Documents/correspondence	English / Dutch

General data and meteorological site data

Meteorological site data					
Pos.	Item	Description	Min.	Nor. (design)	Max.
1	Location	Netherlands			
2	Partners	Trifleet /EICB / CEF			
3	End user	-			
4	Type of system	CryoNorm LNG Distribution Manifold			
5	Altitude	M		Sea level	
6	Barometric pressure	mbara		1013	
7	Ambient temperature	°C	-25	20	35
8	Relative humidity	%		95 / 32	
9	Wind velocity	m/s		10	40
10	Minimum ambient temperature	°C		-25	
11	Min. design temperature	°C		-196	
12	Winterizing temperature	°C		-25	
13	Max temp for electrical equipm.	°C		65	

Applicable codes and standards

	Abbreviations, codes and standards
IGF Code	MSC 95/WP.7 dated 10 June 2015 or latest applicable version
IEC	International Electro technical Commission 92:/529
IMO resolution	MSC 86/26/Add. 1 Annex 11 MSC.285(86) (adopted on 1 June 2009) Interim guidelines on safety nor natural gas-fuelled engine installations in ships CCC 1/13/Add. 1 Annex 4
Class	Bureau Veritas
Tank	IMO IGC and IGF Type C independent fuel tank, MAWP 10 barg EN13458-2 Directive 97/23 CE class approved
CESNI	European Committee for drawing up Standards in the field of Inland Navigation Edition 2017
Experience	Cryonorm Systems experience with LNG Fuel Systems designed and built by Cryonorm Systems

2.1 Starting point

This part of the study is split into a few components:

- Compatibility with other systems
- Stationary storage tank
- The other systems beside the tanks

We will start with the compatibility between the different systems.

With the technical compatibility with other standard systems we have to investigate the following:

- Mechanical connection
- Control integration
- ESD integration

We have been asked to do the write a standard for the stationary vacuum insulated tank for the IWW.

The starting point from the GRA was to develop a standard vacuum insulated tanks with a type approval.

To create a standard for these types of tank is possible for 90% of the use in the IWW, but one type approval so it can be used in all ships is not possible. The class societies how will give an approval on an ship will demand their own (type) approval for the tank.

Therefore we worked out a standard which will be approved by the majority of the class societies.

For defining the interfaces we have to define the “other systems”. Therefore we did a study to define these standards for the components which will be connected to the container.

The other systems which must be defined are:

- Process area
- Bunkering station
- Control system
- ESD

2.2 Technical compatibility

We need to research what the technical compatibility is between the LNG container and the other systems.

The compatibility is based on:

- Mechanical connections
- Control connections
- ESD integration

We have to make sure all connections and integrations are in line with the required regulations.

Mechanical connections are:

- Outlet - Liquid out to product vaporizer
- Outlet - Liquid out to PB vaporizer
- Outlet - BOG to product vaporizer
- Inlet - NG from PB vaporizer
- PSV connection to general vent header

Control connections to tank are:

- Level tank
- Pressure tank

ESD integration:

- ESD action to automatic valves
- Gas and cold temperature detection

2.3 Mechanical connection

2.3.1 Definition

For the mechanical connections we need to connect several lines between the container and the process unit.

The mechanical connections are:

- Outlet - Liquid out to product vaporizer.
- Outlet - Liquid out to PB vaporizer.
- Outlet - BOG to product vaporizer.
- Inlet - NG from PB vaporizer.
- PSV connection to general vent header.
- Instrument air connection.

Outlet - liquid out to product vaporizer

LNG from the container to the product vaporizer for the regasification and creating of the NG.

Outlet - liquid out to the PB vaporizer

LNG from the container to the pressure built (PB) up vaporizer for the regasification and creating of the NG to increase the pressure in the container. The reason to increase pressure in an container is to make sure a flow can be created to the “outlet - liquid out to product vaporizer”.

Outlet - BOG to product vaporizer

BOG from the container to the product vaporizer.

Inlet - NG from PB vaporizer

From the PB vaporizer to the container. To increase the pressure in the container.

PSV connection to general vent header

The PSV's from the container must be connected to the central vent header of the process unit. This central header will be directed to a safe zone.

Instrument air connection

For the operating of the ESD valves on the container instrument air is required.

2.3.2 Connections

The connection must insure a safe and leak free transfer from LNG from the container to the process unit. There are different options to guaranty a safe and leak free transfer.

These connections can be done with:

- Fix piping.
- Flexible hoses.
- Break Away Coupling (BAC).
- “Normal” flanges.
- Dry Break Couplings (DBC).

2.4 Control connection

2.4.1 Definition

For the control connections we need to connect instruments between the container and the process unit.

The control connections are:

- Level tank.
- Pressure tank.

2.4.2 Connections

The signals from the instruments on the container must be directed to a local junction box with a Harting connection.

The local junction box must be connected with the process unit by means of a cable with a Harting connector.

2.5 ESD integration

2.5.1 Definition

For the ESD integration of the container in the total fuel gas system we need to make sure some actions will be integrated.

The ESD integrations are:

- ESD action to automatic valves.
- High pressure and level in the container.
- Gas and cold temperature detection.

2.5.2 Integration

For the integration of the ESD items we need to make several connections and secondary structural.

For the ESD action to the automatic valves instrument air or nitrogen must be foreseen. How do you get instrument air and/or nitrogen at the container. This can be done with the general instrument air heater of the ship or with a nitrogen bottle. Beside the instrument air or nitrogen also a ESD signal from the control system must be given to activate the valves. Looking at this it may be better to install an instrument air connection between the process unit and the container. With this connection in case of ESD the valves on the container can be activated.

Gas detection at the container area is mandatory. The gas detection is also a parameter for the ESD system, so this must be connected to the TCS junction box.

The cold temperature detection must be placed by possible leakage point. These are the areas where there will be a mechanical connection.

The cold temperature detection must be placed on a stainless steel drip tray.

In case of filling the container without a swap, high pressure and level in the container can be ESD trip when the values are too high.

2.6 Advantages and disadvantages mechanical connections

For the mechanical connections there are several options to make the connections or there are options which may can be for added value. The following mechanical connections or options can be used:

- Fix piping.
- Flexible hoses.
- Break Away Coupling (BAC).
- “Normal” flanges.
- Dry Break Couplings (DBC).

Fix piping

- | | |
|----------------|--|
| Advantages: | <ul style="list-style-type: none"> - Reliable. - Longer lifetime. |
| Disadvantages: | <ul style="list-style-type: none"> - Not flexible when the tie in points of the container are not the same. |

Flexible hoses

- | | |
|----------------|---|
| Advantages: | <ul style="list-style-type: none"> - Flexibility of connections. Distance and orientation of the tie in points are for 90% not the same. |
| Disadvantages: | <ul style="list-style-type: none"> - Shorter lifetime. |

BAC

- | | |
|----------------|--|
| Advantages: | <ul style="list-style-type: none"> - Stops flow by a safety action. |
| Disadvantages: | <ul style="list-style-type: none"> - Price. |

Normal flanges

- | | |
|----------------|---|
| Advantages: | <ul style="list-style-type: none"> - Price. - Reliable. |
| Disadvantages: | <ul style="list-style-type: none"> - Time relative longer than DBC. - Spill of LNG or NG. |

DBC

- | | |
|----------------|---|
| Advantages: | <ul style="list-style-type: none"> - Time relative shorter than normal flanges. - Dry break - so no or less spill of LNG or NG. |
| Disadvantages: | <ul style="list-style-type: none"> - Price. - Reliability is less than the normal flanges. |

For the mechanical connection our advice will be a combination from:

- Flexible hoses.
- Break Away Coupling (BAC).
- “Normal” flanges.

2.7 Sizes connections

The sizing of the connections are depending of several items:

- Required flow and pressure.
- NoBo regulations.
- Sizes valves.

So every standard system must be designed according the project specific requirements.

2.8 Solutions compatibility

For the mechanical connection we advise to use the combination:

- Flexible hoses.
- Break Away Coupling (BAC).
- “Normal” flanges.

The choice for this combination is made based on price/time/quality/fit for purpose.

For the control connection we advise to make a connection between the TCS and the container. The container will be equipped with a local junction box with a Harting connection. From the TCS a cable with a Harting connection will be connected to the container. In this way the control signals will be sent from the container to the TCS.

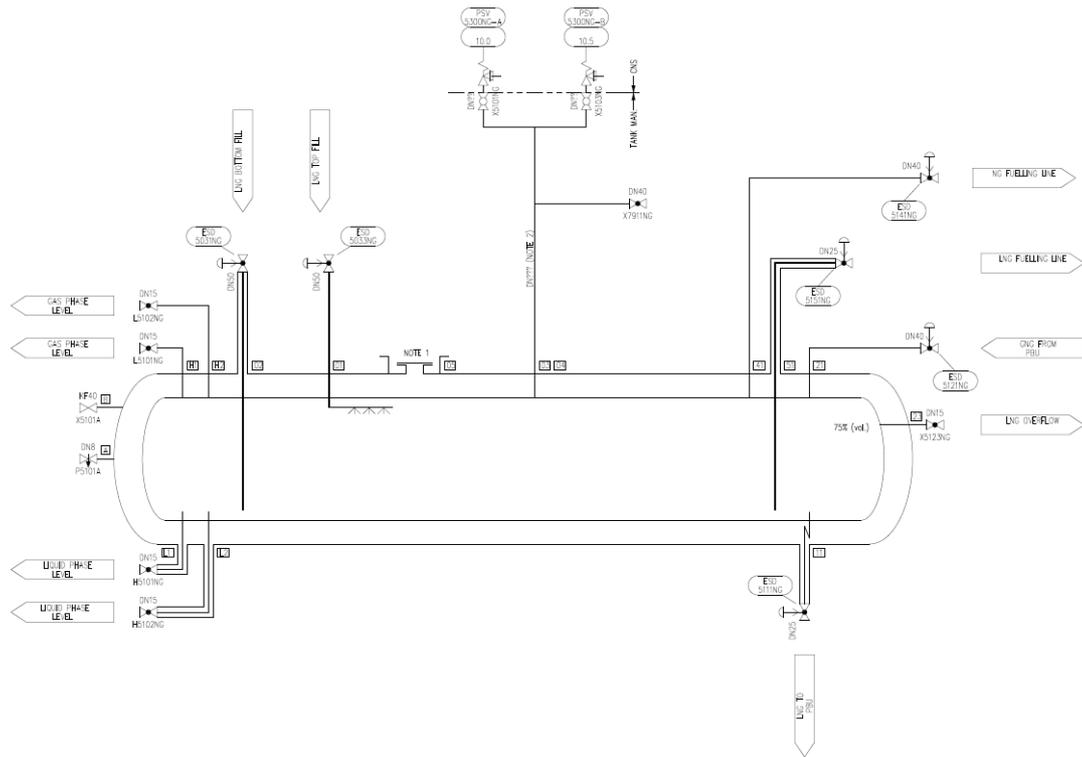
For the ESD integration we can advise three items. First is the direct instrument air connection between the TCS and the container. In this way the valves will be supplied with air when there is a ESD by the solenoid box.

For the gas detection we advise to make fix gas detection systems in the tank area which can be moved when a new container is places.

For the cold temperature detection we recommend the use of drip trays and TT in the mechanical connection area.

2.9 P&ID LNG storage tank

After working on the several possibilities and discussions with the several class societies we came to the following P&ID.



2.10 Starting point LNG storage tank

At the start we need to define the technical specifications for a standard tank.

Subjects that needs to be define are:

- Medium properties
- Operation properties
- Design data
- Code requirements
- Materials
- Valves & nozzles
- Surface treatment
- Tank Connection Space position

2.11 Technical specifications

2.11.1 General

Service:	Liquid Natural Gas (LNG) Fuel storage
Ambient conditions:	Marine environment, North-West Europe, Inland Waterways
Area classification:	Zone 1, Group IIA
Location(s):	Below or on deck
Sheltered:	Yes or no

2.11.2 Medium properties

Fluid:	Liquid Natural Gas (LNG)
Critical pressure:	56 bar(a)
LNG temperature:	-162°C
LNG density:	444 kg/m ³
Gas density:	0,76 kg/Nm ³

2.11.3 Operation properties

Gross capacity:	40 - 90 m ³
Net volume required (@95%):	38 - 85,5 m ³
Operating pressure:	approx. 7,0 bar(g)
Operating temperature min/max:	-162/-120°C
Operating density min/max:	444/377 kg/m ³

2.11.4 Design data

Orientation:	Horizontal
Medium:	Inner vessel - LNG / Outer vessel - vacuum
Design pressure:	Inner vessel - 10 bar(g) / Outer vessel -1 bar(g)
MAWP:	Inner vessel 9 bar(g) / Outer vessel *
Hydraulic test pressure:	Inner vessel Acc. design code / Outer vessel NA
Design temperature min/max:	Inner vessel -196°C/+20°C / Outer vessel -196°C/+50°C

Type support:	2 pcs. saddles
Manhole:	NA
Electrical earthing:	Yes, both saddles
Tank connection space (TCS):	Yes, tank to be supplied with TCS. TCS shall be gastight to 0,2 bar(g) on lower half of tank, between saddles. Space for vaporizer shall be reserved.
Allowable evaporation losses:	Acc. code.
Helium leak test:	Yes

2.11.5 Code requirements

Design code:	According ES-TRIN Cesni (15)12 Rev.1 Annex 8, §2.1.4
Design regulations:	CCR: ES-TRIN Cesni (15)12 Rev.1 Ch.30 & Annex 8 Class society
Inspection authority:	Class society
Collision load:	According class society
Dynamic load:	According class society
Impact test:	According class society
Corrosion allowance:	0 mm
Test pressure:	According class society
Weld test plate:	According class society
Radiographic examination:	According class society
Other NDE:	According class society
Material certificates:	According class society

2.11.6 Materials

Manufacturer / supplier:	Depended of class society
Heads inner / outer:	SS304(L)
Shell inner / outer:	SS304(L)
Internal parts:	SS304(L)
Supports / skirts /saddles:	SS304(L)
Lifting lugs / trunnions:	SS304(L)
Piping:	SS304(L)
Valves:	SS304(L)
Stiffening rings:	SS304(L)
Flanges:	SS304(L)
Welding fittings:	SS304(L)
Insulation supports:	SS304(L)
Reinforcing pads:	SS304(L)
Support tank connection space:	SS304(L)
Tank connection space:	SS304(L)

2.11.7 Valves & nozzles

Valves:	By tank manufacturer
Required certificates:	Yes, material & test inspection certificate (3.1 or 3.2 depending on requirement of class society) and fire safe certificate
Positions of the connections:	Depending on position of tank connection space
Nozzle 01 - Top fill:	ESD-5033 / DN50 - PN16 / Pneumatic act.
Nozzle 02 - Bottom fill:	ESD-5031 / DN50 - PN16 / Pneumatic act.
Nozzle 03a - Safety relief line:	X-5101 / * - PN16 / Sized by manufacturer, acc. IGF 6.7.3.2
Nozzle 03b - Safety relief line:	X-5103 / * - PN16 / Sized by manufacturer, acc. IGF 6.7.3.2
Nozzle 04 - PSV By-Pass:	X-7911 / DN40 - PN16
Nozzle 05 - Pressure safety device:	
Nozzle 11 - Liquid to PBU:	ESD-5111 / PN25 - PN16 / Pneumatic act.
Nozzle 21 - Gas from PBU:	ESD-5121 / PN40 - PN16 / Pneumatic act.
Nozzle 41 - Gas product discharge:	ESD-5141 / PN40 - PN16 / Pneumatic act.
Nozzle 51 - Liq. product discharge:	ESD-5154 / PN25 - PN16 / Pneumatic act.
Nozzle L1 - Lev. transm. liq. Ph.:	H-5101 / PN15 - PN50
Nozzle H1 - Lev. transm. gas Ph.:	H-5101 / PN15 - PN50
Nozzle L2 - Lev. transm. liq. Ph.:	H-5101 / PN15 - PN50
Nozzle H2 - Lev. transm. gas Ph.:	H-5101 / PN15 - PN50
Nozzle A - Vacuum measurement:	P-5101
Nozzle B - Vacuum evacuation:	X-5101

2.11.8 Surface treatments

Internal surface inner vessel:	Pickled and passivated, clean & dried for O ₂ service (dew point <-40°C.). Delivered pressurized by N ₂ 0,5 barg
Internal surface outer vessel:	Pickled and passivated, clean and dry
External surface inner vessel:	Pickled and passivated
External surface outer vessel:	Marine coating

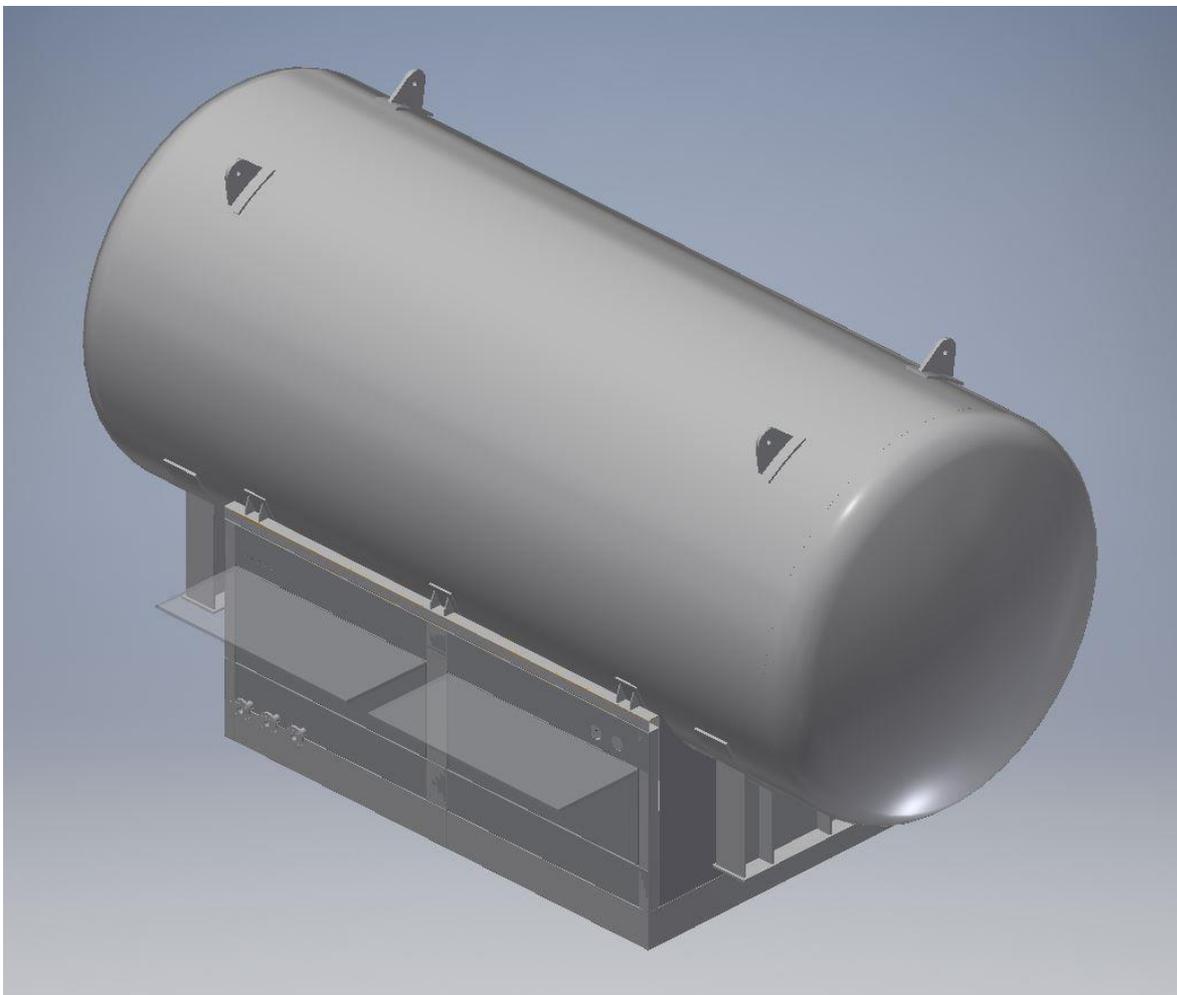
2.11.9 Tank Connection Space position

The tank connection space and the tank can be installed on different location on the ship. All has to do with the available space on or in the ship. Due to the available space the Tank Connection Space can be placed to different places of the tank.

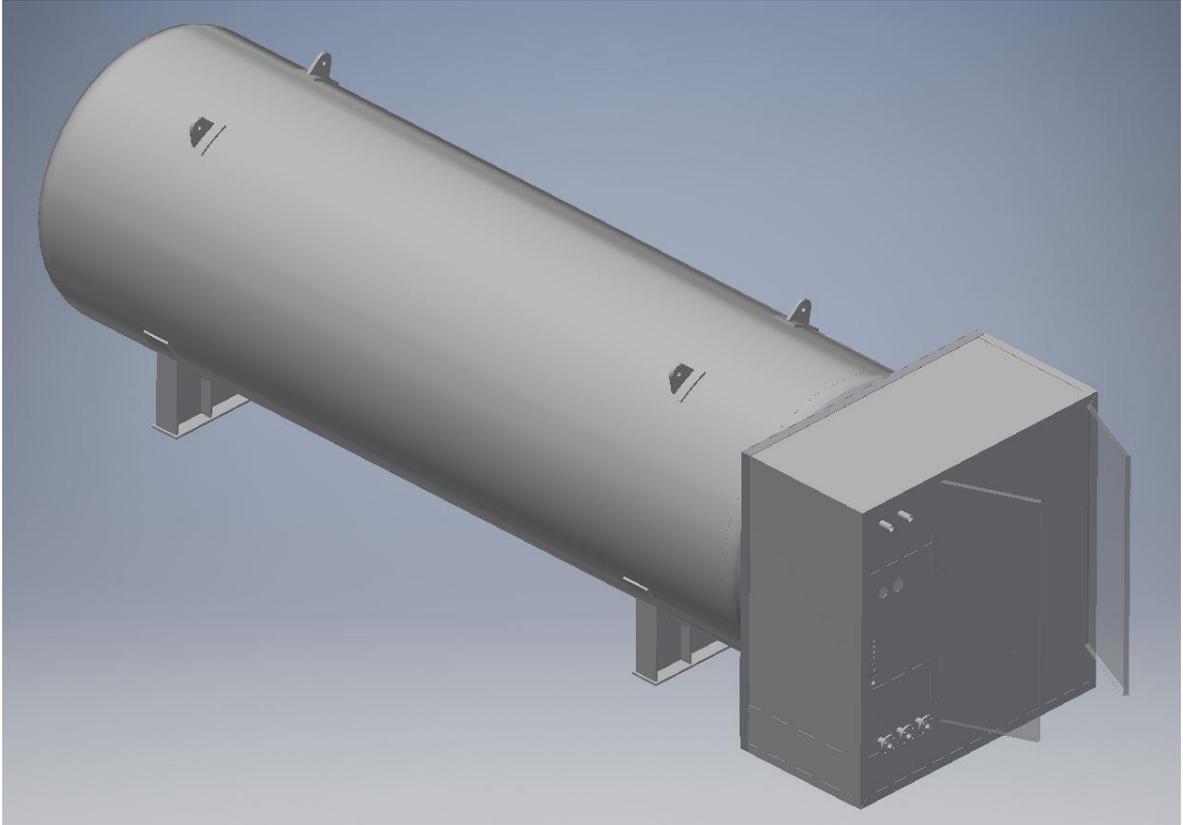
There are three ways to connect a TCS:

- Under the tank (UT model)
- Front of the tank (FT model)
- Side of the tank (ST model)

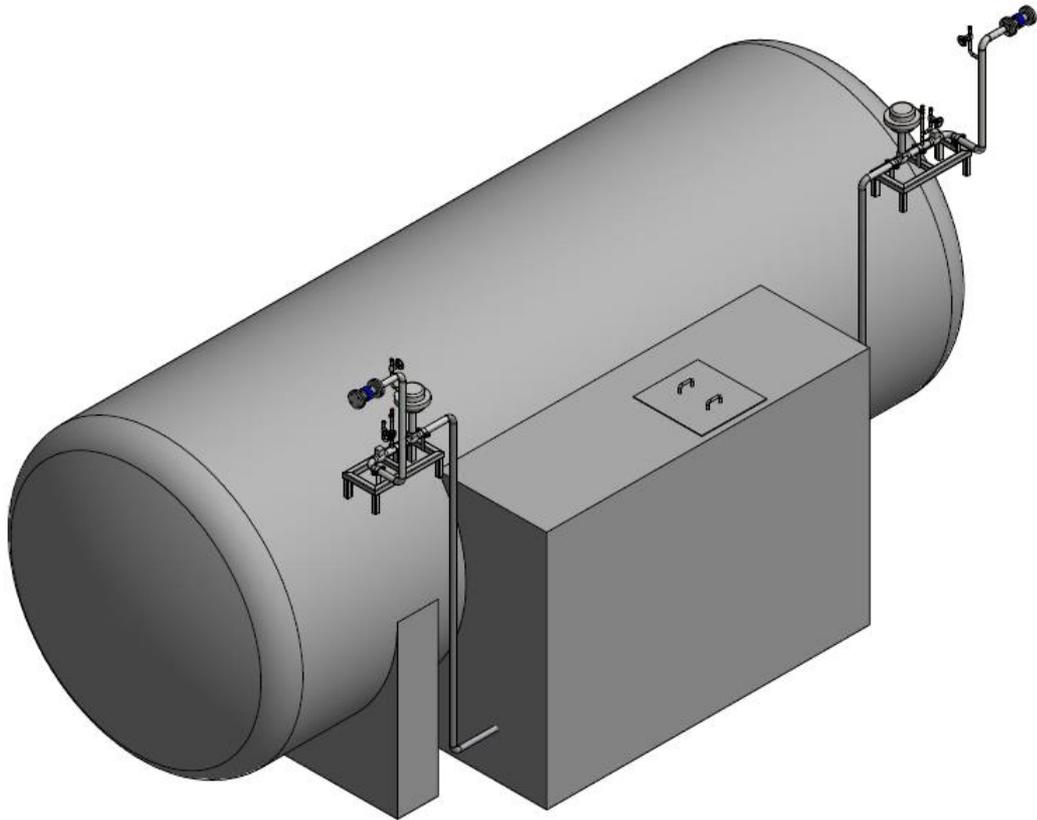
UT model



FT model



ST model



2.12 The other systems

For the defining of the compatibilities we did a study on what the other systems are and how they work. In this way we were able to create the outcome of the compatibility between the different systems and the container.

The other systems are the following:

- Process area
 - Vaporizer
 - Transfer lines
 - Valves and instruments
 - Junction box
 - Detection
- Bunker station
 - Transfer lines
 - Valves, break away coupling, dry quick coupling and instruments
 - Junction box
 - Detection
- Control system
- ESD

2.13 Process area

2.13.1 Equipment

In situations where there is a stationary storage tank the process area is called Tank Connection Space (TCS). This TCS is connected to the stationary storage tank. In the case of the TCS there are two types:

- Gas tight
- Natural ventilated

In case of a container tank the TCS (in this case process area) will be a separate unit which will be gas tight or natural ventilated. Due to the separate status of the container and the connections the interfaces are very important to swap containers quick and in a safe way.

The location of the process area on deck in a safe area will be a natural ventilated unit. When this is not the case the unit will be a gas tight installation which will be ventilated according to the rules and regulations.

The process unit will be made of stainless steel. The reasons for the choice of stainless steel is due to the corrosion and low temperature resistant qualities.

According to the rules and regulations the process area also needs a drip tray for LNG leakage. The size of the drip tray is defined by IGF. Because of the cryogenic temperatures and the perfect characteristics of stainless steel this is the material used for the process unit.

The process unit itself will become the drip tray. Therefore and for corrosion resistance we choose for a process unit of stainless steel.

The gas tight units must be resistant against an over pressure. Therefore the unit must be reinforced with stiffeners or it must be designed according to a pressure vessel. To insure the mechanical safety of the process unit, when there is pressure built up in the process unit, the unit is equipped with a PSV.

The accessibility of the process unit can be done with a door or manhole.

In the process unit the following is assembled:

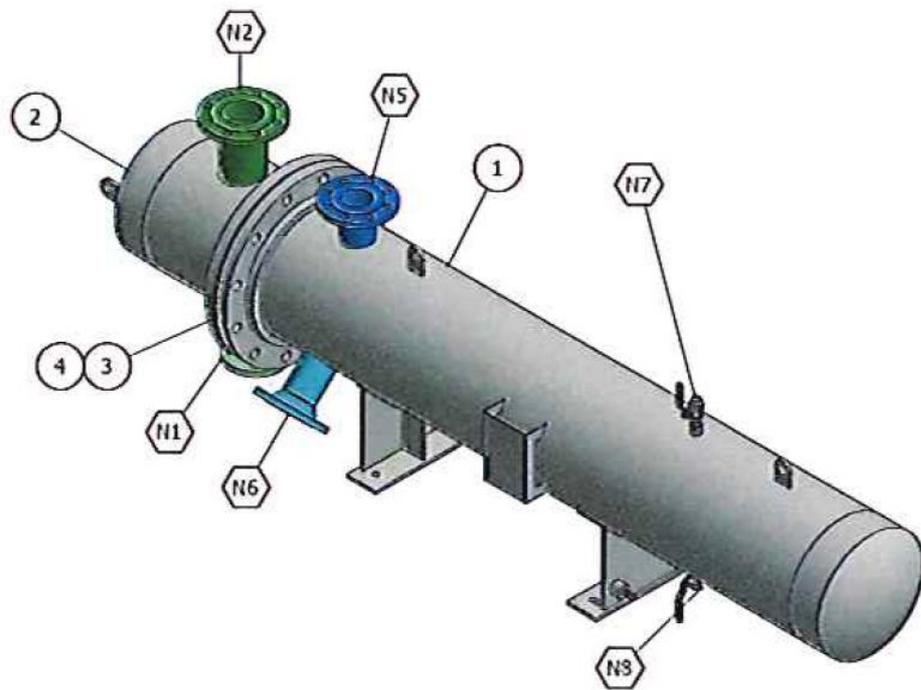
- Vaporizers
- Transfer lines
- Valves and instruments
- Junction box
- Detection

Vaporizers

To generate NG from LNG we need a heat transfer application. For this heat transfer application we made a choice for a vaporizer.

The vaporizer is of the shell and tube type. For the heat transfer a water/glycol mix from the engine cooling water system will be used.

The shell and tube will be made from stainless steel.



- Pos. 1 Vaporizer shell side
- Pos. 2 Vaporizer tube side
- Pos. 3 Gasket
- Pos. 4 Studbolts

- N1 Outlet tube side
- N2 Outlet tube side
- N5 Inlet shell side
- N6 Outlet shell side
- N7 Shell vent
- N8 Shell drain

General design data

	Tube side	Shell side
Capacity	TBD	TBD
Medium	LNG/NG	Water/glycol (50/50)
Design pressure	13.7 barg	10 barg
Nor. oper. pressure	2 - 7 barg	1 - 4 barg
Test pressure	20.6 barg	15 barg
Design temp.	-196/+100 °C	-30/+100
Working temp.	-155/+30°C (IN/OUT)	15/40 (IN/OUT)
Corrosion allowance (mm)	0	0
Certification	Acc. NoBo	
Design code	ASME VIII DIV.1+PED+NoBo	
Design code - heat exchanger	TEMA type BFU 2-pass	

There will be two vaporizers in the process unit. These are there for:

- NG for the engine (product vaporizer)
- NG for pressurization of the tank (pressure built vaporizer)

Transfer lines

The piping for the LNG, NG, nitrogen, air and water/glycol are mounted in the process unit.

For the lines >DN15 piping is used. The piping is made of stainless steel. After welding the piping will have a surface treatment, NDE, pressure test and leak test.

For the instrument, nitrogen and air connections stainless steel tubing will be used. After mounting the tubing will have a leak test.

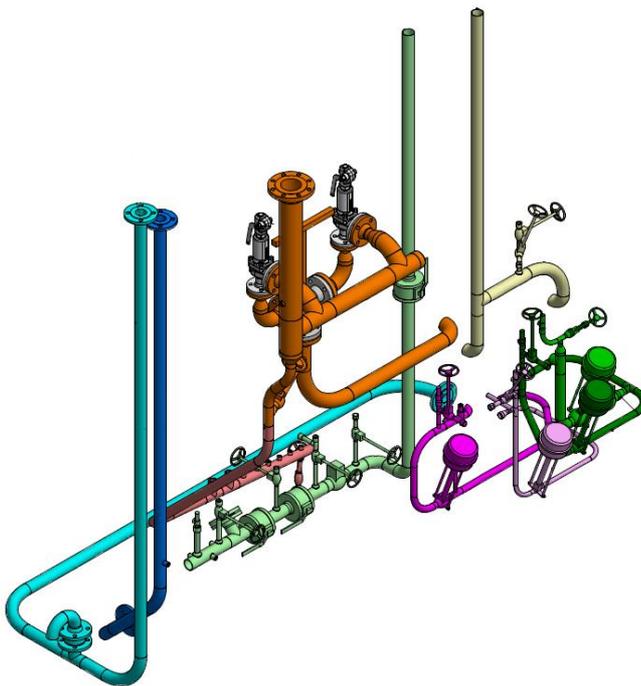
General design data piping

Capacity	TBD
Size	>DN15
Medium	LNG/NG/water/glycol
Design pressure	13.7 barg
Nor. oper. pressure	2 - 7 barg
Test pressure	20.6 barg
Design temp.	-196/+100 °C
Working temp.	-155/+40°C
Corrosion allowance (mm)	0

Certification	Acc. NoBo
Design code	ASME B31.3+PED+NoBo

General design data tubing

Capacity	TBD
Size	>DN15
Medium	LNG/NG/water/glycol/nitrogen/air
Design pressure	13.7 barg
Nor. oper. pressure	2 - 7 barg
Test pressure	20.6 barg
Design temp.	-196/+100 °C
Working temp.	-155/+40°C
Corrosion allowance (mm)	0
Certification	Acc. NoBo
Design code	NoBo



Picture: Lines for fuel system

Valves and instruments

All valve and instruments which are required to control the LNG/NG vaporization process are included in the process unit.

Medium	LNG/NG/water/glycol/Nitrogen/Air
Design pressure	13.7 barg
Nor. oper. pressure	2 - 7 barg
Test pressure	20.6 barg
Design temp.	-196/+100 °C
Working temp.	-155/+40°C
Corrosion allowance (mm)	0
Certification	Acc. NoBo
Design code	ASME B31.3+PED+NoBo

Junction box

On the outside of the process unit a junction box will be placed for the connection between the control system and the valves and instruments.

Ex marking	II 2 GD Ex e IIC T6
Zone	1 and 2
Operation temp.	-20°C ≤ Ta ≤ 55°C
IP coding	IP65
Material	GRP
Design code	EN60079
Cable glands	Plastic Ex e

Detection

There is gas and leakage detection in process unit to check the safety. In case of leakage a ESD will be activated.

2.13.2 Process

In the process area the LNG transfer from the tank to the vaporizer is controlled with the valves and instruments. From the vaporizer the NG transfer to the tie in point of the process unit is also controlled.

The pressure built vaporizer works in almost the same way. LNG from the tank to the vaporizer, but now the NG will go back in the tank to build up pressure.

From the NG phase there will be a separate line to the product vaporizer. This line is to decrease the pressure in the tank.

2.14 Bunker station

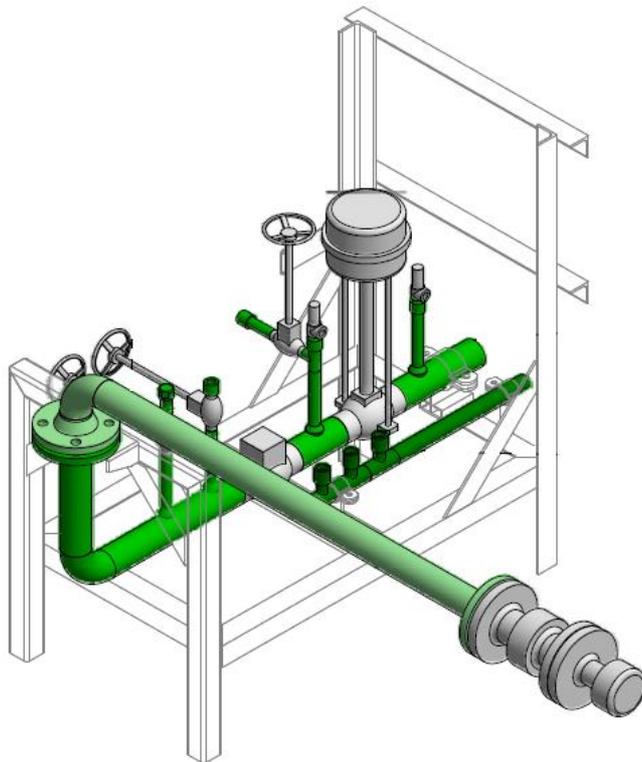
2.14.1 Equipment

The bunker station is located on deck or below deck. The bunker station will have drip tray against leakages.

The frame of the bunker station is made of stainless steel.

In the process unit the following is assembled:

- Transfer lines
- Valves, break away coupling, dry quick coupling and instruments
- Junction box
- Gas detection



Picture: Bunker station

Transfer lines

The piping for the LNG, NG, nitrogen and air are mounted on the frame of the bunker station.

For the lines >DN15 piping is used. The piping is made of stainless steel. After welding the piping will have a surface treatment, NDE, pressure test and leak test.

For the instrument, nitrogen and air connections stainless steel tubing will be used. After mounting the tubing will have a leak test.

General design data piping

Capacity	TBD
Size	>DN15
Medium	LNG/NG/water/glycol
Design pressure	13.7 barg
Nor. oper. pressure	2 - 7 barg
Test pressure	20.6 barg
Design temp.	-196/+100 °C
Working temp.	-155/+40°C
Corrosion allowance (mm)	0
Certification	Acc. NoBo
Design code	ASME B31.3+PED+NoBo

General design data tubing

Capacity	TBD
Size	>DN15
Medium	LNG/NG/nitrogen/air
Design pressure	13.7 barg
Nor. oper. pressure	2 - 7 barg
Test pressure	20.6 barg
Design temp.	-196/+100 °C
Working temp.	-155/+40°C
Corrosion allowance (mm)	0
Certification	Acc. NoBo
Design code	NoBo

Valves, break away coupling, dry quick coupling and instruments

All valve and instruments which are required to control the bunkering process are included in the process unit.

Medium	LNG/NG/Nitrogen/Air
Design pressure	13.7 barg
Nor. oper. pressure	2 - 7 barg
Test pressure	20.6 barg
Design temp.	-196/+100 °C
Working temp.	-155/+40°C
Corrosion allowance (mm)	0
Certification	Acc. NoBo
Design code	ASME B31.3+PED+NoBo

Junction box

On the bunker station a junction box will be placed for the connection between the control system and the valves and instruments.

Ex marking	II 2 GD Ex e IIC T6
Zone	1 and 2
Operation temp.	-20°C ≤ Ta ≤ 55°C
IP coding	IP65
Material	GRP
Design code	EN60079
Cable glands	Plastic Ex e

Detection

There is leakage detection on the bunker station to check the safety. In case of leakage a ESD will be activated.

2.14.2 Process

The bunker station will be the connection between the external bunkering installation and the LNG storage tank.

The bunker installation is equipped with a break away and dry quick coupling. In the process line a ESD and a check valve are placed to operate the flow and secure a safe operation.

In the bunker line a purge connection is placed. So that purging of the line is possible when required.

2.15 Control system

The control system is programmed on the outcome of the process engineering, such as PFD, P&ID, cause and effect chart, etc..

The control system will control all processes based on signals coming from the valves, instruments and detection devices.

Based on the signals, the program and the operator the system will work according the requirements.

The operation will be done with a HMI mounted on an central control cabinet. If required additional HMI's can be added.

Central control cabinet

Cabinet	Rittal
HMI	Siemens
PLC	Siemens S7
Zone	Safe zone



Picture: Control cabinet incl. HMI

2.16 ESD

The ESD system must secure the safety of the system. The ESD system is a combination of the following components:

- Control system.
- Automatic valves.
- Instruments.
- Detections.

The control system will control and react on ESD signals. When a ESD signal is given the total system will be shut down for operation.

In case of a ESD first the emergency must be managed before the system can be reset for normal operation.

2.17 Total operation

All equipment mentioned in this part together with a stationary or containerized storage tank can be classified as a fuel gas system for a IWW ship.

The interfaces between all different pieces of the system must be compatible so the integration of all different pieces can become one complete system, that can deliver NG at the right flow and pressure to the gas or dual fuel engine.

3 Fuel tank containers

3.1 Short history on containerised fuel tank

This paragraph shortly describes the history of this research of standardization of the fuel tank.

When we began this project in 2016 no specific rules were available for the design and approval of LNG transportable tanks. Our initial plan was to have a standard transportable tank which could be used for the transportation of LNG as well as fuel tank on board ships. Since the standard LNG transportable tanks (UN Portable T75) already comply with and approved according the international regulations it would be relatively easy to have an additional approval to use the tanks as an fuel tank on board inland waterway vessels.

The fact that there were no specific rules made it an interesting project so that we were able to be part of the development of the rules.

Unfortunately the call for involvement was not heard and during the course of 2016 and 2017 the rules were determined by means of the ESTRIN 2017 which under annex 8 makes a reference to the IGC for these fuel tanks.

In next chapter I will explain the pros and cons of these rules.

3.2 Regulations

When research started the goal of this project was to come to an standard tank container which could be used not only for transport and storage of LNG but also be used as an fuel tank on board internal waterway vessels.

In January 2016 when the project started there was no regulation in place for inland waterway vessels with LNG as a fuel. The general fear was that so called off-shore rules were going to be used by the classes (Bureau Veritas, Lloyd's Register, DNV etc.) with all disadvantages of the rather strict rules for off shore systems.

Some simple examples are, that those rules demanded top discharge tanks, and 3.2 certificates on the materials. Both examples would have a deep impact on the design and cost of the tanks.

During the course of 2016 several questions were asked about these issues but in the end didn't make any difference.

In 2017 the ESTRIN 2017 is published with annex 8 “SUPPLEMENTARY PROVISIONS APPLICABLE TO CRAFT OPERATING ON FUELS WITH A FLASHPOINT EQUAL TO OR LOWER THAN 55 °C”.

The initial Idea was to use tanks/UN portable tanks or ADR tanks already classified and designed for transport and storage of LNG in all countries of the United Nations. The rules for design such tanks are enclosed in the IMDG (International Maritime Dangerous Goods), US DOT - CFR49 (Codes Federal Regulations book 49) from the United States Department of Transport. And ADR chapter 4.2 and 6.7 (Un Portable tanks), and Chapter 4.3 and 6.8 (Tank containers).

By complying to those rules already approx. 95% of the transport and use of LNG as fuel was covered. Including materials, Fatigue, etc. etc.

But by the implementation of Annex 8 in the ESTRIN (IGF) the possibility to standardize was blocked.

1.3.1 of this Annex 8 says that risk assessments shall be conducted on all concepts and configurations which are new or significantly modified.

When only looking at the tank itself it would not be an big issue, but unfortunately the classes look at it in combination with the ship itself, which comes in many variations and designs, meaning that depending on the type of vessel, the outcome of such a risk analysis can differ and therewith the design of the tank. Even when the standard design will comply with each different type of vessel, the risk assessments which need cannot be seen as a standard.

2.1.4 The LNG fuel tank shall be an independent tank designed in accordance with the European Standards EN 13530 : 2002, EN 13458-2 : 2002 in combination with dynamic loads, or the IGC-Code (type C tank). The inspection body can accept other equivalent standards of one of the Rhine riparian States and Belgium.

The issue with above rule is that every class determine their own rules about dynamic forces which need to be taken into account. This can differ for each vessel and therefore are needed for for each vessel.

Since no vessel is the same, the requirements for such FEM calculation will be different for each vessel and for each class. Standardization is hardly possible, even when the design will meet all requirements, the fact that for each ship the calculations (engineering) needs to be done make it nonstandard.

Also this rule requires a type C tank. Type C tanks in general come with a top discharge (opening above liquid level). I case a bottom discharge is used all kinds of special requirements will be introduced (like double wall piping) which makes the standard design nonstandard again and much more expensive.

2.1.5 Tank connections shall be mounted above the highest liquid level in the tanks. The inspection body can accept connections below the highest liquid level.

This rule practically says that every inspection body can choose different which likely will lead to different ideas of the level of safety and therefore different standards depending on the class or inspection body.

Conclusion based on regulations:

- 1: A standard cannot be made as long the rules give room for discussions and different opinions between the different inspection bodies/class societies.
- 2: A standard like there is for the multi modal international transport of LNG is not possible looking at the several additional rules for fuel tanks on board inland waterway vessels.

3.3 Technical

Technically the first step was to define a the standard which could work for the transport, the storage as well as a fuel tank for inland waterways.

See Annex 1 to this report for a standard specification.

See Annex 2¹ for a P&ID from 1 manufacturer showing a standard transport tank. This standard would be the best and economically the most interesting option for Trifleet to use where we are able to reach the goal to supply tanks with at least 10% cost saving compared with the tanks used on the current vessels.

For technical issues we needed to find a manufacturer who was not only able to do the engineering, but also was able to perform the whole approval process. Many manufacturers did offer us a solution, but in the end none of them could provide us the approval documents.

See attached annexes 3, 4 and 5² from Gascon South Africa, who worked with Bureau Veritas Marine and Offshore towards a solution where those tank containers could receive an approval for the use as fuel tanks on board inland waterway vessels.

This design differs from the standard we had in mind since a bottom discharge was not possible without introducing the issue with the double walled piping. For this reason a top discharge was introduced.

This top discharge is not that interesting because it introduces an additional pumping/pressure system to empty the tank. With this extra system also the controls will be much more and commercially less interesting.

Also the requirements regarding for example the materials are not that interesting. Where standard transport tanks require to have 3.1B certificates, those type C approved tanks would require 3.2 certificates. Difference is that with 3.2. certificates each material, each part need to be tested and investigated and inspected by an in depended authority.

¹ Annex 2 contains confidential information and cannot be published without consent.

² Annexes 3, 4 and 5 contains confidential information and cannot be published without consent.

This will introduce many extra cost to the material making it less interesting than the regular transport tank.

The requirements regarding the calculations of the dynamic loads on the tank are different as those from a standard transport tank. With a standard transport tank it is enough to take, for example Fatigue calculations into account based on the loads acting on the tank during transport by Rail road and sea. In general the rail traffic is the worst case regarding the fatigue loads. According to the ISO rules and the CSC rules transport tanks need to be impact approved.

Similar calculations are asked with the type C tanks but then the manufacturer need to show those calculations for each different ship, and even locations on the ship making a standard more or less impossible.

In practice it means that for each ship the fuel tank needs to be approved separately making a standard impossible. And again, even when a standard UN Portable tank will pass those calculations, the fact that it needs to be done with each new ship makes it less interesting. Engineering cost on a ship are proved to be the highest cost.

3.4 Conclusion

Based on the previous conclusions Trifleet decided to stop the research towards an approved certified standard fuel tank . Our conclusion is that under the current circumstances a standard like described is not feasible and type approval is not possible.



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

Annex 1 Standard specification



1 Technical Characteristics

1.1 Design and Testing

Tank	in accordance with:	RID/ADR, IMDG & ASME VIII Div 1
	Type:	T75 UN Portable Tank / R14.3BN
Frame	in accordance with:	ISO 1496/3
	Type:	TBD (Gooseneck design optional)
Piping	in accordance with:	ASME B31.3
Corner Castings		ISO 1161
Size and type code		42K8

1.2 Capacity

Nominal Capacity ($\pm 1\%$ Tolerance)	≥ 46000 Liter
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1.3 Frame dimensions and Mass

MPGM	36	tons
Tare Mass ($\pm 3\%$ Tolerance)	TBD	kg
Length	12 192 mm	40 ft
Width	2 438 mm	8 ft
Height	2 591 mm	8 ft 6 in

1.4 Tank Dimensions

Inner Vessel

Inside Nominal Diameter	(TBC by manufacturer)
Tan to Tan	(TBC by manufacturer)
Corrosion Allowance	0 mm

Outer Vessel

Inside Diameter	(TBC by manufacturer)
Tan to Tan	(TBC by manufacturer)

1.5 Baffles

Six (6) sets of stainless steel baffles plates should be fitted (according ADR)

1.6 Pressure and temperature Rating

Inner Vessel

Design Pressure ASME VIII	7 Barg (101,5 PSIG)
Design Pressure EN13530	10 Barg (145 PSIG)
Design Temperature Range	-196 to +20 °C

Outer Vessel

Internal Design Pressure	-1,0 barg
External Design Pressure	1,0 barg
Design Temperature Range	-196 to +50 °C



1.7 Performance

Under standard conditions as defined in clause 3.3 of BS EN 12213-1999: Methods of Performance Evaluation of Thermal Insulation:

Product	Holding Time(days)	Payload at max. Holding time Kg	Initial/ Filling Pressure (Barg)
UN1977 -LIN	TBD	TBD	0
UN1073-LOX	TBD	TBD	0
UN1951-LAR	TBD	TBD	0
UN1972-LNG (CH ₄)	TBD	TBD	0
UN1961-Ethane (C ₂ H ₆)	TBD	TBD	0
UN1038-Ethylene (C ₂ H ₄)	TBD	TBD	0

1.8 Insulation

Insulation type	Super insulation
Vacuum level warm	<10 microns
Vacuum level cold	<1 microns
Theoretical k-Value	TBC by manufacturer

1.9 Material of construction

Framework:	Hollow section	EN 10210 S355 J2H or equivalent
	Plates	EN 10025 S355 K2G3 or equivalent
	Rolled section	EN 10025 S355 K2G3 or equivalent
Valve cabinet doors and frame		SA240/EN10028-7 – 1.4301 304L Stainless Steel
Inner tank		SA 240/EN10028-7 1.4301 304L Stainless Steel (preferably NON COLD STRETCHED)
Baffles		A 240/EN 10028-7 1.4301 304L Stainless Steel
Outer tank		SA 240/EN 10028-7 1.4301 304L Stainless Steel

1.10 NDE (Non destructive Examination)

Visual	100% All welds	Before and After Hydro test
Radiography	100% All long. and Circ. Welds	Before Hydro



2 Tank fittings And Accessories

Valve types Fire safe Design Stainless Steel Cryogenic with extended spindle
Thermal relief valves fitted at all possible liquid traps.

Valve supports Valve and pipe supports connected to vacuum rings.

2.1 Bottom fill / Liquid line

Valve Supplier	Herose
Quantity	1 x DN50 (2") Firesafe Globe Valve Pneumatically Actuated
Valve Supplier	Herose
Quantity	1 x DN50 (2") Globe
Valve Supplier	Herose
Quantity	1 x DN15 (½") Globe
Line Size	DN50 (2") – Optional 65 NB (2.5")
End Connection	DN50 (2") - PN16 Flange + Blind Flange
Gasket	PTFE Bottom fill / Liquid line 2 (Optional)

2.2 Bottom fill / Liquid line provision (Optional)

Valve Supplier	N/A provision only (pipe ends blinded)
Quantity	1 x DN50
Line Size	DN50 (2")
End Connection	Blinded by welding

2.3 Top Fill / Gas Line (Spray line)

Valve Supplier	Herose
Quantity	1 x DN40 (1 ½") Firesafe Globe Valve Pneumatically Actuated
Valve Supplier	Herose
Quantity	1 x DN40 (1½") Globe
Valve Supplier	Herose
Quantity	1 x DN15 (½") NB Globe
Line Size	DN40 (1½")
End Connection	DN40 (1½") PN16 Flange + Blind Flange
Gasket	PTFE



2.4 Balance Line

Valve Supplier	Herose
Quantity	1 x DN40 (1½")Globe
Line Size	DN40 (1½")

2.5 Vent Line

Valve Supplier	Herose
Quantity	1 x DN40 (1½")Globe
Line Size	DN40 (1 ½")
End Connection	1½" NPT socket

2.6 Safety Relief Valve Assembly

Valve Supplier	Herose
Quantity	4 x ?" x ?" bronze safety relief valves
Specification	Set pressure, 2 x 7 Bar + 2 x 10 Bar
Valve Supplier	Herose
Quantity	1 x ¾" x 4 port 3 way diverter ball valve

2.7 Try-cocks

Valve	Supplier Herose
Quantity	2 x DN15(½") Globe– Optional 3rd trycock on 90%.
Specification	82% and 95% of gross volume
Line Size	DN15 (½")

2.8 Vapor recovery Line

Valve Supplier	Herose
Quantity	1 x DN40 (1½")Globe
Valve Supplier	Herose
Quantity	1 x DN15 (½") Globe
Line Size	DN40 (1½")
End Connection	DN40 (1½") PN16 Flange + Blind Flange
Gasket	PTFE

2.9 Sampling Lines

Valve Supplier	Tech Tube or equivalent.
Quantity	2 x DN6 (¼") Needle valves– Liquid and Gas.
End Connection	¼" NPT + ¼" NPT Plug.



2.10 Level Gauge

Supplier	WIKA
Quantity	One
Specification	Calibrated + 4-20mA ATEX transmitter fitted.
Valve Supplier	Generant or equivalent
Quantity	2 x 6 NB Needle valves– Liquid and Gas Isolation

2.11 Pressure Gauge

Supplier	WIKA
Quantity	One
Specification	Scale in BAR and PSI + 4-20mA ATEX transmitter fitted.

2.12 DELETED.

2.13 Pressure build up unit (PBU)

Valve Supplier	Herose
Quantity	1 x DN25 (1") Globe + 1 x DN40 (1½") Globe
Line Size	Tank-out to PBU-in (Liquid) DN25 (1")
Line Size	PBU-out to Tank-in (Vapor) DN40 (1½")

Aluminum fins with stainless steel pipe reinforcement or similar design TBD by manufacturer.

Capacity should be shown as well the length and amount of the different units.

2.14 Vent Stack

All blow down and relief valves exhaust into one single vent stack to the top of the tank.

2.15 Pneumatic Controls panels

- "Alfons Haar" or equivalent Pneumatic valves
- Indicators when "on"
 - Emergency Shut Down (ESD) valve closure when button is pushed "in"
 - Manual reset required to operate valve after air pressure is lost.

2.16 Thermocouple

A Hastings DV6R thermocouple for vacuum measurement is fitted.

2.17 Pump provision (optional)

Valve circuit built to allow pump fitment through flanged connections. Extra cabinet fitted.

2.18 Earthing connection

2-off stainless steel lug LxBxT with a 20mm hole, is located at the rear of the tank frame.



2.19 Document Holder

1-off clear water-resistant PVC document holder is fitted to the frame.

2.20 Decals

One set per tank as per code requirements. Owner logos supplied and applied by Manufacturer.

2.21 Data Plates

One set of stainless steel data plates per tank as per code requirements.

2.22 Valve Cabinet

Stainless steel valve protection cabinets, complete with stainless steel doors and fixation provisions to keep the doors open.

3 Finish

3.1 Internal

Internal Shell Surface No 1 finish
Weld Seams As welded

3.2 External

External Surface No 1 finish
Weld Seams As welded

3.3 Fittings

All fittings, including valves and pipe sections shall be degreased and then stored in clean sealed plastic bags until fitted to the tank. Cleaned for oxygen service, CGA4.1.

3.4 Cleaning

On completion of fabrication, the inner vessels internal surface shall be degreased, pickle and passivated. A cleaning certificate is to be provided in the document folder.

3.5 Leak Test and Nitrogen Purge

A helium mass-spectrometer leak test will be performed on inner and outer vessels. The vessel need to be delivered in a Nitrogen purged condition. Dry nitrogen need to be used ($O_2 < 1\%$ residual oxygen, 1,0 bar pressure, Nitrogen dew point - 40°C).

3.6 Painting

The carbon steel frame components are shotblasted to SA 2½ and painted as follows:



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Primer coat	Hempadur Zinc	30 micron min DFT
Intermediate coat	Hempadur Primer	30 micron min DFT
Final coat	Hempathex/Hempathane	60 micron min DFT

TOTAL 120 micron min DFT

Colour: RAL 3009

The stainless steel outer barrel is cleaned and painted as follows:

Intermediate coat	Hempadur Primer	40 micron min DFT
Final coat	Hempathane	50 micron min DFT

TOTAL 90 micron min DFT

Colour: RAL 9010

4 Test and Homologations

These tank containers are constructed according to an approved design.

Each production unit is subject to testing and non-destructive examination as required by ASME VIII Div 1 and/or EN13530 UIC and manufacturers own quality requirements. Each unit is inspected by the independent inspection authority Bureau Veritas or Lloyd's.

The container has to be subjected to a stacking test load of 86400kg per corner post and is approved for 9-high stacking (8 x 24000kg).

The UN Portable Tank complies with the performance specification of the following International Organization's regulations and recommendations and is supplied with their Approvals.

IMDG - T75

RID/ADR – T75 + R14.3BN

Additional Approvals:

CE approval (PED)

TIR/Customs

CSC

UIC (36000Kg, in case of MPGM 39 tons a super heavy decal is needed as well as a decal mentioning UIC 36000Kg)

TC Impact Approved

US DOT (CFR49) – T75



5 Documentation

The following documentation need to be provided:

- Operation manual
- Certificate of cleaning (placed in the document holder).
- Initial Inspection Certificate for each tank.
- Approval documentation such as type approval certificates.
- As build documentation (Specification, full set of drawings etc.)
- Name plate details.
- List of transportable products.

6 Products

- UN1972 Natural Gas, refrigerated liquid. (CH₄)
- UN1038 Ethylene, refrigerated liquid. (C₂H₄)
- UN1961 Ethane, refrigerated liquid. (C₂H₆)
- UN1977, Nitrogen, refrigerated liquid. (optional)
- UN1073, Oxygen, refrigerated liquid. (Optional)
- UN1951, Argon, refrigerated liquid. (Optional)

7 General

- Internal piping stainless steel 304 / 304L
- External piping stainless steel 316 / 316L