Economic Commission for Europe

Inland Transport Committee

Working Party on the Transport of Dangerous Goods

Joint Meeting of Experts on the Regulations annexed to the European Agreement concerning the International Carriage of Dangerous Goods by Inland Waterways (ADN)
(ADN Safety Committee)

Twentieth session
Geneva, 23–27 January 2012
Item 7 of the provisional agenda
Special authorizations, derogations and equivalents

30 October 2011

Proposal for a derogation regarding the use of LNG for propulsion – Tanker 1402

Transmitted by the Government of the Netherlands

Version 11-10-2011

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE (UN-ECE)

RECOMMENDATION OF THE ADMINISTRATIVE COMMITTEE RELATING TO THE ADN REGULATIONS

RECOMMENDATION No. xx/2012
of xx xx 2012

The competent Authority of The Netherlands is authorised to issue a trial certificate of approval to the motortankvessel “Type I-Tanker” (yard no. 1402 of Peters Shipyard Kampen, European vessel identification number to be obtained), type C tanker, for use of Liquefied Natural Gas (LNG) as fuel for the propulsion installation.

Pursuant to regulation 1.5.3.2 the vessel may deviate from the regulations 7.2.3.31.1 and 9.3.2.31.1 until 30-06-2017. The Administrative committee decided that the use of LNG is sufficiently safe under the following conditions which shall be complied with at all times:

1. The vessel has a valid certificate of approval according to RVIR, based on recommendation XXX by the CCNR.
2. [The vessel shall be constructed and classified under the supervision and in accordance with the applicable rules of an recognized classification society, which has special rules for LNG installations. The class shall be maintained];
3. [The LNG propulsion system shall be annually surveyed by a recognized classification society;]
4. A HAZID study by a recognized classification society (see annex 1) shows that the safety level of the LNG propulsion system is sufficiently safe. This study to cover, but not limited to, the following issues:
   - Interaction between cargo and LNG
   - Effect of LNG spillage on the construction
   - Effect of cargo fire on LNG installation
   - Different types of hazard posed by using LNG instead of diesel as fuel
   - An adequate safety distance during bunkering operation;
5. [The LNG propulsion system is in conformity with the IGF Code (IMO Resolution MSC 285(86), June 1st 2009), except for the items listed in annex 2;]
6. [The LNG storage tanks shall comply with the requirements of EN 13458-2 (2002). The tank shall be connected to the vessel in a way that ensures that the tank shall remain attached to the vessel under all circumstances.]
7. The bunkering and maintenance of the LNG propulsion system shall be done according to the procedures laid down in annex 3 and 4;
8. All crewmembers shall be trained on the dangers, the use, the maintenance and the inspection of the LNG propulsion system according to the procedures laid down in annex 5;
9. A safety rota shall be provided on board the vessel. The safety rota describes the duties of the crew. The safety rota includes a safety plan;

10. The use of LNG as fuel is included in the dangerous goods report to Trafic management and in emergency notification;
11. All data related to the use of the LNG propulsion system shall be collected by the carrier. The data shall be sent to the competent authority on request;
12. An annual evaluation report shall be sent to the secretariat of the UN-ECE for information of the administrative committee. The evaluation report shall contain at least the following information:
    a. system failure;
    b. leakage;
    c. bunkering data;
    d. pressure data;
    e. repairs and modifications of the LNG system.

Attachments:
- Annex 1. Report No. ROT/11.M.0090 Issue 2, dated May 23rd 2011
- Annex 2. Overview deviations from the IGF Code
- Annex 3. Bunkering procedure
- Annex 4. Maintenance procedure
- Annex 5. Training procedure

Peters Shipyards I-tanker

HAZARD IDENTIFICATION STUDY

Liquefied Natural Gas powered inland waterways chemical tanker

Document No. ROT/11.M.0090
Issue: 2
Date: 23 May 2011

Technical Report Document Page

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8. Author(s)

P A Stanney
Machinery Specialist
London Design Support
LR EMEA

9. Authorisation

W Verdonk
Surveyor
Rotterdam Design Support
LR EMEA

10. Reporting organisation name and address

Lloyd's Register EMEA
Weena-Zuid 170
3012 NC Rotterdam

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Peters Shipyards
PO Box 291
8260 AG Kampen
Netherlands

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16. Summary

This report details the results of the Hazard Identification Study (HAZID) on a Liquefied Natural Gas (LNG) powered inland waterways chemical tanker. The HAZID was undertaken as part of a safety case examining the safety of LNG as a fuel for inland waterways ships.

The objectives of the HAZID were to :-
1. Identify potential hazards associated with the use of LNG as fuel.
2. Comply with Part 7, Chapter16 of Lloyd's Register's Rules for Systems of Unconventional Design with a view to Classification of the vessel.
3. Comply with RVIR (Rhine Vessels Inspection Regulations).

The level of safety of the LNG fuel system was compared to that of existing inland waterways vessels using fuel oil and the prescriptive requirements of Lloyd's Register's Rules for Inland Waterways Ships and the Provisional Rules for Methane Gas Fuelled ships .

The study concentrated on the following main areas :-
(a) The design and installation of the LNG storage tank.
(b) Bunkering and gas delivery arrangements.
(c) The design and operation of the gas burning machinery.

The results of the study indicate that, provided the actions and recommendations listed in Appendix 3 of this report are successfully resolved and implemented then, subject to the normal general design and construction requirements, the proposed design is acceptable for classification by Lloyd's Register and could provide an equivalent level of safety to that of a conventional inland waterways vessel.

EXECUTIVE SUMMARY

Inland waterways vessels are currently required by RVIR to burn fuel with a flash point exceeding 55°C. This requirement is in place in order to achieve an acceptable level of fire safety by ensuring that the fuel is normally stored and processed at a temperature well below its flash point.
Natural Gas has a very low flashpoint in the region of -50 °C. The fuel is stored on the ship as Liquefied Natural Gas at around -165 °C, and then warmed up and vaporised before being supplied to the engine room at around ambient temperature. In this condition the gas is well above its flash point and any leakage may, under the right conditions and with a source of ignition, potentially result in an explosion.

It is very difficult to compare 'like with like' when considering gas burning vessels compared to oil burning vessels as gas burning only occurs when certain conditions are met and then only with a large energy ignition source. In addition a gas fuel explosion has very different characteristics to an oil fuel fire or explosion and the results will be very different.

The three main areas where a gas fuel ship varies from a conventional oil fuel ship are:-

1. Fuel storage arrangements and bunkering. In a gas fuelled ship the gas fuel is stored at very low temperature in a pressurised storage tank. Any leakage of LNG may damage the hull of the ship by freezing as well as being a fire hazard. In service the tank pressure slowly increases and pushes the vaporised and warmed gas towards the machinery space with no pumps. The bunkering, storage and pressurising process must be carefully designed and controlled to ensure safe operation.
2. As the gas in the machinery space is well above its flash point it is important as far as possible to prevent leaks. Leaks will always occur, and it is important that the machinery compartment is well ventilated to ensure that any gas leak is diluted with air to well below its explosive limit and there is no possibility of an accumulation of gas within the space. This is proved by applying CFD (computational fluid dynamics) techniques to the space.
3. In case of gas leaks the machinery must be stopped. Arrangements must be provided to ensure that propulsion and essential services are maintained. In the design being considered this is achieved by having two separate LNG tanks and gas supply lines together with two separate machinery spaces arranged such that a failure in one supply line or machinery space will not affect the other tank or operation of the machinery in the other space and that 50% propulsion will be retained.

The procedure for assessing the safety of the machinery has been carried out in accordance with LR's requirements for Classification for Machinery and Engineering Systems of Unconventional Design and The Provisional Rules for Methane Gas Fuelled Ships using the technique defined in I.M.O. MSC.392 Appendix 3 section 5 (What if Technique) addressing the hazards defined in section3.2. of this report.

The following are the principal findings of the HAZID study :-

1 The proposed arrangement is not considered to present any risk significantly greater than that present on a conventional oil fuel powered IWW vessel providing clearly defined operating procedures are in place and adhered to and that the crew is trained in the storage and operating techniques required for the safe use of gas fuel.

2 Aspects of the design which could cause a reduction in safety from that of a conventional oil fuel powered vessel are principally concerned with the storage tank location on deck, bunkering procedure and engine room ventilation system. These issues may be managed by effective operational procedures for bunkering and ensuring adequate protection for the tank against heavy collision with fixed objects when the vessel passes under bridges etc.

The various issues raised at the HAZID are detailed on the HAZID worksheets (Appendix 5)

CONTENTS

APPENDICES

1. INTRODUCTION

1.1 General

The Inland Waterways Legislation is laid down in RVIR (Rhine Vessels Inspection Regulations, i.e. technical requirements for inland waterway vessels).
The RVIR gives ship owners and ship builders the opportunity to develop alternative arrangements to meet the regulations. These alternative arrangements are to be discussed within the CCNR (Central Committee for Navigation on the Rhine), and when an arrangement is agreed upon this will be noted in the vessels' certificate. To start such a discussion a member state should present a proposal for a recommendation in which the alternative arrangement is described. The proposal must demonstrate that the alternative arrangement is at least as safe as the original requirement in the RVIR.

Lloyd's Register (LR) has been engaged by Peters Shipyard to carry out a Hazard Identification Study for the proposed LNG propulsion package to demonstrate an equivalent level of safety as required by the RVIR. This HAZID was carried out as part of the initial phase which, together with approval of preliminary plans and FMEA (Failure Modes and Effect Analysis) will form the basis for an 'acceptance in principle' of the system by Lloyd's Register.

Various action points and clarification was requested during the course of the 3 day HAZID. Some of these issues were closed out after discussion around the table, but other action points could not be resolved at the time or were subject to detail system design. Plans of detailed design incorporating the recommendations as indicated in Appendix 5 remain to be submitted to LR and are subject to plan approval. It is considered that none of these actions would prevent an 'acceptance in principle' being granted.

1.2 System description

1.2.1 LNG storage tanks

The LNG storage tanks and gas processing equipment are installed on the main deck above the cargo tanks in a designated gas dangerous zone.
The storage tanks proposed are two double walled, vacuum insulated tanks located in a lowered section of the main deck just forward of the two containers on the aft end of the vessel containing the four gas fuelled engines. The tanks will be designed and constructed in accordance with the EU Pressure Equipment Directive (PED) for static tanks with modifications for on board loadings and ship motions. The actual design standard and forces/movements to be considered for the design is discussed in Section 4.

All pipework connections to the inner tank are within the outer tank boundary. The outer tank serves as a secondary barrier if the inner tank or pipe work inside the outer tank fails.
All pipes are led out of the outer tank boundary within a cold box welded to the outer tank boundary at the aft end of the tank. Tank shut off valves (root valves) are fitted where the pipes exit the outer tank barrier.

The cold box also contains the Pressure Build Up unit (PBU) and Gas Processing Equipment.
The two tanks, PBU and gas conditioning systems are completely separate and designed such that a fault in one system will not affect the other system. In case of failure of one tank then there is a cross over connection to allow all engines to run on gas from one tank. Before leaving the tank system the gas passes through an SSV (slam shut valve). This valve serves to isolate the tank from the consumers in case of a failure in the downstream system and operates as the gas master valve as required by the MSC interim guidelines.

1.2.2 Machinery room arrangement

Four pure gas, zero pressure type engines (Scania type SGI 16) installed in two separate compartments (containers) supply power for the propulsion system. Each engine has its own gas inlet piping, control system and starting batteries.

The engine room ventilation system is arranged such that any foreseeable gas leakage in the engine room will not result in a hazardous situation. The gas entering the engine compartment has a maximum pressure of 50mb which is reduced to zero pressure before being mixed with air and fed to the engine. The gas pressures within the compartment are thus very low and the gas inventory within the compartment is small. A CFD analysis has been carried out to demonstrate that any gas leaking from gas filled equipment in the compartment will be diluted below the LEL and evacuated directly through the exhaust fan. The required ventilation rate in the compartment is in fact dependent on the cooling requirements for the engines and this far exceeds the ventilation required for gas leak dilution. The CFD analysis also demonstrates that there are no stagnant areas where gas could accumulate within the engine room. The pressure within the engine compartment will be maintained positive in order to ensure a gas safe environment.

Power from the engines will be delivered via a switchboard designed such that a single failure will not cause more than 50% loss of power, to two separate thruster units.

2. SAFETY CASE

2.1 General

The basic intention of the safety case approach is to ensure that the consequences of all possible hazards are considered at an early stage in the design. A set of design criteria can then be produced based on these hazards, which can be followed up during the later design stages of project development. It is the Owner's responsibility to define acceptable safety criteria which will form the basis of any risk assessment work.

Specifically for the proposed LNG propulsion system these criteria are :-

- Provide an equivalent level of safety as a conventional oil fuel propulsion systems for an IWW vessel.
- Satisfy Classification and National Administration requirements.

LR were requested to assist in the development of the safety case requirements and provide independent third party assurance for the decision making process.

The objectives of LR's scope of work are as follows:

- To establish the documentation content of the Safety Case in line with internationally accepted practices
- To facilitate key formal safety review studies such as HAZID and recommend any resulting additional formal safety studies to be undertaken
- To verify that the proposed concept will result in an acceptable propulsion system and that no major changes and resulting cost penalties will be necessary because of safety and regulatory requirements.

During the evaluation, the overriding factor should be the ability to prevent or minimise hazards occurring. Where there still is the potential for a hazard, the safety function will be to minimise the consequences for that hazard. This can be achieved by the following: -

Application of the single failure criteria

A single failure in any component or system is to be considered.

Application of Inherent Safety in the Design

As a basic principle the design of the LNG system and the machinery space arrangement should adopt where possible aspects of inherent safety in order to prevent hazards occurring.

Avoiding Exposure to Personnel

Direct exposure to personnel can be reduced by minimising their operating and maintenance activities, increasing automation and by separating/segregating potential hazardous areas.

Minimising Escalation

Once a hazard has occurred, it may escalate to other parts of the ship, increasing the size of the hazard, rendering certain equipment inoperable or making certain areas impassable. This should be avoided by:

i) adequate separation/segregation of flammable inventories;

ii) reducing the level of confinement in a hazardous area;

iii) minimising the size of flammable inventories available for escalation;

iv) suitable location or protection of essential systems and equipment;

v) use of active detection and protection systems; i.e., fire and gas detection, fire fighting, emergency shutdown (ESD).

2.2 Safety Case Documentation

It is the intent that the Safety Case will follow a typical internationally accepted content as described below:

i) Management Summary
- Safety Case Objectives
- Safety Case Compilation Process
- Endorsement by owner
- Endorsement by Class Society

ii) Project Execution
- Safety Execution Plan
- Safety Action Register (Design change actions and close-outs)

iii) System Description
- Tank design and arrangement
- Bunkering system
- Pressure builup/gas processing
- Machinery room arrangement
- Gas burning machinery

iv) Safety Assessment
- Design Compliance Standards
- Hazard Identification (HAZID) Study
- FMEA study as required by HAZID
- Hazard operability study (HAZOP) as required

3. HAZARD IDENTIFICATION

3.1 General

The HAZID study took place at LR offices in Rotterdam over two sessions on the 6/7 December 2010 and 29th January 2011. The team review was led by a Facilitator. Minutes of the meeting were recorded on the HAZID work sheets.

The remainder of the HAZID team comprised The shipbuilder, LNG tank designer, engine design specialists and LR Specialists. (see Appendix 1 for attendees)

The objectives of the HAZID study were:

- Identify potential hazards associated with the design and installation of the fuel gas system
- Identify and assess the adequacy of the safeguards to prevent or control the hazards.
- Identify and assess the potential of escalation.
- Assess the adequacy of the layout design and piping systems for ensuring the integrity of the installation.
- Identify remedial measures that will reduce the potential hazards and minimise risks.

3.2 Hazards addressed

The procedure considered the hazards associated with installation, operation, maintenance and disposal, both with the machinery or engineering system functioning correctly and following any reasonably foreseeable failure on the following :-

1. The safety of shipboard machinery and engineering systems
2. The safety of shipboard personnel
3. The reliability of essential and emergency machinery and engineering systems
4. The environment.

3.3 Guidewords

Prior to the HAZID study, the facilitator derived a series of guide words comprising potential failures which could be used for identifying hazards. The guide words were supplemented by discussion of potential hazards and scenarios based on the Operator’s experience on engineering activities. The guide words used were as follows:

Leakage
Rupture
Corrosion/Erosion
Impacts (dropped objects)
Fire/Explosion
Structural integrity (supports)
Mechanical failure
Control/Electrical failure
Manufacturing defects
Material selection
Survey/Maintenance

Each part of the LNG system and the area which it would occupy onboard the ship, was reviewed in turn by the HAZID team, applying the guide words or considering potential scenarios, to identify potential hazards. Causes of the potential hazards and resultant consequences were then identified, together with any safeguards and mitigating measures. The following system/areas were examined:

- Tank design and arrangement
- Bunkering system

- Pressure build up/gas processing
- Machinery room arrangement
- Gas burning machinery

Where necessary, recommendations were made with respect to changes in the design and/or implementation of procedures to minimise risk levels.

The team discussions were recorded on the HAZID work sheets, which are presented in Appendix 4. The work sheets are divided into the following categories:

- Item (of System)
- Cause (of Hazard)
- Hazard
- Potential Effects.(of Hazard)
- Safeguards.
- Recommendations.

3.4 Safety Actions Register

In line with the requirements of the Safety Case submission a Safety Action Register (SAR) has been developed and presented in Appendix 3. Actions in the Safety Actions Register must be closed out prior to issuing an Acceptance in Principle for the arrangements. The purpose of the SAR is to:

- To provide project engineering parties with formal requests for actions related to Safety Case studies findings
- To assist understanding and facilitate agreement among parties on the scope of actions required and enable the reporting of these actions
- To establish a formal audit tool from starting with action initiation, to finishing with confirmation of close-out.

3.5 Follow up actions arising

Actions raised during the HAZID session not considered to require resolution prior to completion of the HAZID report but which are necessary to complete the safety case are reported in Appendix 3.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Tank design/arrangement and bunkering

The IGF Code (IMO Resolution MSC.285 (86)) requires that LNG fuel tanks for ships comply with the requirements for I.M.O. Type C tanks i.e. are designed as pressure vessels with a specified factor of safety and are suitable for specified static and dynamic loadings due to ship motion, thermal loads etc. Such tanks are not required to have a secondary barrier.

The alternative proposal by Peters Shipyards is to design the tank in accordance with the PED, taking into account the additional loadings specified for Type C tanks but modified for inland waterways ships which will generally experience less acceleration and static/dynamic movement. The design standard for the tank will be EN13458-2 Cryogenic vessel - Static vacuum insulated vessels Part 2: Design, fabrication, inspection and testing. In addition the tank will be fitted with baffle plates to prevent sloshing due to ship motion. This approach results in a thinner wall thickness for the inner (pressure) tank but additional security is provided by the outer tank which acts as a secondary barrier to contain any leakage from the inner tank. The agreed loadings due to ship motion were 2g (longitudinal collision load) and 10deg. static heel and 1g horizontal/vertical. The 2g collision load is high and represents the highest load that can be foreseen with the tank located forward on any inland waterways vessel. These figures are also in line with the requirements for liftable deck houses.

The alternative arrangement was considered acceptable by the HAZID team.

One of the main Hazards with LNG is structural damage to the tank causing tank rupture. Structural damage can be caused either by mechanical impact with a solid object e.g. hitting a fixed structure or by overpressure, possibly during filling. In this ship the tank is set down such that the top of the tank is lower than the top of the forward wheelhouse and is considered to be sufficiently protected from impact with a fixed structure. For filling protection see the comments below.

The proposed height of the LNG vent above deck of 2m complies with the IWW regulations for LNG cargo tank venting but this is less than the IMO code which requires the safety valve waste pipe vent to be 6m from a working platform. It was considered that the IWW regulations should apply.

There is no provision on the inner or outer tanks for in service regular survey and inspection. However this should be in accordance with PED requirements. The tank manufacturer advised that no corrosion/erosion was expected in service and that the tank did not have any defined working life. This was expected to be in excess of 20 years under normal working conditions. This was generally accepted by the group but as more service experience with the tanks is gained the requirements for survey and inspection will be reconsidered. Survey of the insulation by temperature measurement is possible, but in any case, degradation of insulation would be evident by frosting on the outer shell.

The possibility of a fire on deck damaging the tank structure was considered rather unlikely because of the double walled construction of the tank and protected location of the gas processing equipment within the cold box. In the event of fire on deck the ships fire main will be used to cool the tank and cold box to prevent structural damage and ensure that the pressure in the tank does not build up to a level where the pressure relief valves will lift and vent gas through the 2m high vent on deck. No other fire suppression measures are required. Fire starting within the cold box is similarly unlikely as the box is naturally ventilated to atmosphere to prevent any accumulation of gas and there is no source of ignition in this location as all equipment is Ex rated.

The main hazard was considered to be the bunkering procedure, in particular the possibility of overfilling and thereby overpressurising the storage tank on deck. The supply pressure from the delivery tanker is likely to exceed the design pressure of the storage tank. The main safeguard is the installation of two independent level gauges with automatic closure of the LNG supply valve on deck on high-high level of either of the level gauges on the tank.

Although the bunkering system is manual, with the vessels operator in attendance at all times during bunkering to adjust the tank pressure and filling valves, the system will shut down on various fault conditions including high-high tank level and pressure as well as ship blackout. Providing the ships operator is adequately trained and understands the hazards then these safeguards were considered to provide an acceptable level of safety.

4.2 Pressure Build Up (PBU) and Gas Processing Equipment

The PBU system is largely automatic. The major hazard is concerned with the pressure regulating control valve. If this fails open then the tank pressure will continue to rise at maximum rate. Either the safety valves should be sized for this maximum rate or a flow limitation device should be fitted to limit the maximum evaporation rate in the heat exchanger.
The heat exchanger is dependent on an adequate supply of warm water at all times and freezing can easily occur quickly on any loss of water supply. Adequate safeguards are required to ensure that the water supply to the vaporizer will be maintained under all conditions. Cryonorm investigated the possibility of freezing up of the heat exchanger under blackout conditions and concluded that this was not possible under the most onerous operating conditions.

The gas processing equipment is automatic and requires no manual intervention. Double block and bleed valves ensure that there is no possibility of gas entering the engine room when the system is shut down. All the gas processing equipment up to the Slam shut valve is located within the cold box and therefore the possibility of mechanical damage is unlikely. There is a possibility of LNG leaks from the pipework due to worn seals, joints e.t.c. so a secondary barrier is required to contain these leaks. The cold box is fitted with a drip tray large enough to contain leaks. A gas detector is installed within the cold box with automatic shutdown of the liquid gas line. In addition the tank root valves can be closed manually from an accessible location within the cold box. The drip tray is therefore to be sized for the maximum inventory that may be released before the automatic valve and the manual root valves are closed. In normal operation condensed water vapour will also drain into the drip tray and on land based systems this is drained from the drip tray through a water seal. This is not an option for ship mounted systems as LNG would also be released onto the deck, although in practise the water seal would freeze when LNG is released. This issue is to be further considered by the tank manufacturer and a solution proposed.

4.3 Machinery room arrangement and ventilation.

Four Scania SGI 16 gas fuelled marine engines generator sets are installed in the two separate machinery compartments. The gas supply pressure to the engines is 50mb before being reduced to 0mb for mixing with the inlet air.

The gas pipework within the machinery compartment and on engine manifold/turbocharger ducting is single walled. Pipe joints, flanges, seals e.t.c. within the compartments may leak but in view of the very low pressure and small pipe size any leakage will be restricted. The charge air ducting after the turbocharger operates at a pressure of around 1.5 bar and failure of this could result in a large volume of gas leaking into the machinery space. However at this location the gas is already diluted with air and any leakage will be further diluted with air to a level that cannot support combustion.

A CFD analysis was carried out in accordance with IEC 60079-10-1:2009 to demonstrate that any gas leakage from the low pressure pipe will be diluted to a level below the LEL and that no stagnant areas exist within the container to allow gas to accumulate. In fact the ventilation flow rate is also sized for cooling the engines and this gives a required flow rate far in excess of that required for gas dilution.

The machinery compartment is kept at an overpressure with respect to the hazardous deck areas at the front of the container and may therefore be considered gas safe. It will be necessary to start the ventilation before starting an engine in any compartment to enable the gas free status of the space. For this reason a 24volt ventilation fan will be required to run for a period before starting an engine, but this need only have the capacity required for gas dilution as determined by the CFD.

4.4 Gas fuelled machinery.

The ship has two LNG tanks on the main deck with a cross connection allowing either tank to feed any one or both machinery compartments. In the normal underway condition, there will be a minimum of one engine running in each engine compartment. The two LNG tanks and supply systems will not normally be interconnected. In this way a single failure in the gas supply or gas burning machinery cannot cause an immediate loss of power of more than 50%.

The 'zero pressure' gas inlet system introduces gas at zero pressure i.e. gas is sucked into the air inlet stream before the turbocharger. This is a novel concept for ship systems although it has been used on shore based installations. The system was studied in detail during the HAZID, in particular the safety issues associated with compressing the air/gas mixture in the turbocharger and possibility of gas entering the inlet or exhaust duct. Essential safety of this system is achieved by the lean mixture strength i.e. around one half stoichiometric, implying a mixture that will not easily ignite without a high energy source and use of low melting point materials in the turbocharger. No objection to this principle was raised by the members of the team but the engine designers will present a safety substantiation document for further consideration of this aspect after the HAZID.

The gas fuelled machinery supplies power to the main switchboard which in turn supplies power to two thruster units. A single failure within the switchboard should not result in total propulsive power loss to the two thruster units but this aspect was considered to be outside the scope of this HAZID. The arrangement should be in accordance with the usual ADN requirements.

5. REFERENCES

5.1 General

- Lloyd's Register Rules and Regulations for the Classification of Inland Waterways Ships, November 2008
- Lloyd's Register Rules and Regulations for the Classification of Ships, July 2010.
- Lloyd's Register Provisional Rules for the Classification of Methane Gas Fuelled Ships, January 2007.
- IEC 60092: Electrical installations in ships – Part 502: Tankers-Special Features
- IEC 60079-1: Electrical apparatus for explosive gas atmospheres – Part 10: Classification of Hazardous areas
- IMO Resolution MSC.285 (86) Interim Guidelines for Natural Gas-Fuelled engine installations in ships. (IGF Code)
- International Code for Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code) and amendments.
- EN13458-2 Cryogenic vessel - Static vacuum insulated vessels Part 2: Design, fabrication, inspection and testing

Appendix 1 HAZID Attendees

6 and 7 December 2010 and 14 January 2011, LR Office, Rotterdam

Company	Name	Role	Day 1	Day 2	Day 3
Peters Shipyard	Johan Wijnsma	Purchase Manager	Y	-	Y
Peters Shipyard	Harry Kikkert	Manager Design & Eng.	-	Y	Y
Peters Shipyard	Roald Wijtzes	Project Engineer I-Tanker	Y	Y	Y
Peters Shipyard	Ivo van der Bijl	Proj. Eng. Engineroom Systems	Y	Y	Y
Peters Shipyard	Eelco Ankersmit	Hull	Y	Y	Y
Cryonorm	Hans Stuker	Expert LNG tank, LNG vaporiser and associated control	<14.30	N	N
Sandfirden	Roland Louwsma	Gas Engine Powerpack	N	Y	Y
Sandfirden	Jack Ooms	Gas Engine Powerpack	>13.00	N	Y
Sandfirden	Willem Visser	Project coordinator	Y	Y	Y
Lloyd’s Register	Paul Stanney	Facilitator	Y	Y	Y
Lloyd’s Register	Willemien Verdonk	LR Machinery Expert/Scribe	Y	Y	Y
Lloyd’s Register	Mark Nijhoff	LR Machinery Expert/Scribe	-	-	Y
Lloyd’s Register	Gerard Vromans	LR Electrical & Control Expert	Y	Y	Y
Lloyd’s Register	Henri Reekers	LR Electrical & Control Expert	Y	Y	Y
Lloyd’s Register	Frits Blankestijn	Attending Surveyor	-	Y	Y
IVW	Mark Berkers	Flag Authority Representative	Y	Y	N
Alewijnse	Rommert Boonstra	Electrical & Control	-	-	Y
Alewijnse	Ad Thijssen	Electrical & Control	-	-	Y

Appendix 2 List of Plans

Session 1:

DWG No.	Rev	Description
02-000-000-BA1-00-432-01	P10	General Arrangement
02-000-000-BA1-00-432-02	B	Dangerous Zone Plan
21-100-000-BA1-00-421-01	0	Propulsion System Block Diagram
23-180-000-BA1-00-421-01	0	LNG Fuel Bunker and Supply System
23-610-700-BA1-00421-01	0	Cooling Water Diagram
23-700-000-BA1-00-421-01	0	Compressed Air Diagram
21-100-000-BA1-00-421-02	0	Description of Propulsion Block Diagram
23-180-000-BA1-00-421-02	0	Description of LNG Fuel System
23-180-000-BA1-00-414-01	0	Description of Maintenance Procedures
23-610-700-BA1-00421-02	0	Description of Cooling Water Diagram
23-700-000-BA1-00-421-02	0	Description of Compressed Air Diagram
23-180-000-BA1-00-421-02	A	Description of LNG Power System

Session 2:

DWG No.	Rev	Description
arrangement plan	B	I-tanker Generator Container
100296	B1	Gas Train P&ID Sandfirden
100296	C1	Start Stop Sequence Scania SGI 16 Marine Engine
100296-501	A1	P&ID ENGINE
100296-502	A1	F/G & Safety Alarms/Shutdowns
100296-503	A1	Flow Diagram Genset
100296	C1	Turbo charger as possible source of ignition
document		Draft MSC resolution compatibility
calculation		Flow out calculation in the engine container
23-180-000-BA1-00-411-01_1400	0	Description of automatic controls
02-220-xxx		Operational procedure required for preventative actions to avoid damaging of LNG-tanks on deck
23-180-791X-BA1-00-414-01_1400		LNG Filling procedure
1002-660-2		Trailer to tank filling procedure

Appendix 3 Follow up actions

1. A safety substantiation document for the gas/air mixture in the charge air duct will be provided.

2. The drip tray of the cold box has to deal with normal water condensation at the same time as providing a secondary barrier for any LNG leakage within the cold box. Normal condensation is dealt with by a U seal draining to deck, but LNG leakage cannot be drained to deck. A formal proposal for this issue is to be provided by the tank manufacturer.

3. A CFD analysis demonstrating compliance with IEC 60079-1 is to be carried out by shipyard and is to be approved by LR.

4. The bunkering arrangements are outside the scope of LR Rules and statutory requirements but they are an essential safety issue. The decision on whether and under what conditions automated bunkering is acceptable is a matter for the flag state.

Appendix 4 Safety actions register

No safety actions were raised

Appendix 5 HAZID Work Sheets

System: LNG Tank design and location			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 1
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
In operation mode					
1.1 Rupture					
1.1.1	Mechanical failure due to impact with fixed structure e.g. bridge/other vessel.	Major release of LNG	Freezing of ship structure/fire/explosion	Protected location in deck recess. Forward deckhouse (airdraft 6850mm) higher than tank. Inboard B/5 for side protection Safety valve in coldbox. Does not extend above top of tank. Discharges to common header, on top of tank.	Operational procedure required for preventative actions and actions after collision. Consider whether deck house provides adequate protection: will length of deck provide sufficient damping in case of collision forward? Dangerous cargo on containerships is allowed (transport tanks (TPED), not static tanks)
1.1.2.	Excessive applied loads due to ship motion	Tank failure leading to release of LNG.	Freezing of ship structure/fire/explosion.	Not IMO Tank Type C design but Type C arrangement with secondary barrier, constructed to other recognized standard. Basic design PED / EN 13458-2 (Static Vacuum Insulated Cryogenic Vessels) (covers inner and outer tank) In addition dynamic loads: 2G horizontal, 1G vertical and roll 10° static (compare with liftable wheelhouses requirements : 0.5	

System: LNG Tank design and location			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 1
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
				G horizontal and 10° static roll) Baffles between inner and outer tank and saddles to outer tank are subject to these loads. Thermal expansion in inner tank. Outer tank fixed to the deck Internal baffles for protection against sloshing as per transport tanks	
1.1.3.	Excess pressure due to overfilling	Tank failure leading to release of LNG.	Freezing of ship structure/fire/explosion.	4 x 50% Safety valves 8 bar, Design pressure 8 bar. Two independent level measurement systems; shut down of tank inlet valve (HV101/201) automatically at 95% Pressure transmitter on gas phase high pressure will shut off HV101/201	
1.1.4	Excess tank pressure due to failure in PBU control system.	Tank failure leading to release of LNG.	Freezing of ship structure/fire/explosion.	Orifice plate in gas line after PBU to limit amount of gas from PBU to match release capacity of safety valves in case PBU regulation fails.	
1.1.5.	High nozzle loadings on inner tank.	Fracture of nozzle & pipes between inner and outer tank.	Release of LNG in interbarrier space.	All connections are within secondary barrier. This is designed to contain a leak.	Pressure regulating valve to be moved downstream of automatic valve. Details of valves/fittings/pipe between

System: LNG Tank design and location			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 1
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
				Inner tank and piping 304L, outer tank 316L for low temperature and flexibility characteristics + expansion provisions in pipe between inner and outer tank to allow movement of inner tank relative to outer tank.. Service experience in similar tanks for static applications Outer tank 316L. Stress analysis where pipes penetrate inner and outer tank All pipes exit outer tank in coldbox Manual root valves in accordance with PED where pipes exit secondary barrier. Leak is confined to secondary barrier. Blow off seal on top of tank relieves the pressure. Automatic valve is downstream of manual root valve. All welded short length of piping in between. Root valves to be easily accessible; i.e. by leaning into cold box or extended spindle.	root valve and remote control valve to be submitted for consideration.

System: LNG Tank design and location			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 1
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
				Drip tray is fitted in cold box to contain all leaks fom piping and components within cold box. Thermo element in driptray will close automatic valve on leak detection. Needle valves in level indicators. Additional manual valve will be fitted on LIT inlet Level gauge/display + pressure located in recess visible from outside Transmitters to be calibrated for lowest density and max trim	
1.1.6.	Mechanical damage to components in cold box	Release of LNG/gas within cold box.	Freezing of ship structure/fire/explosion.	All components are in cold box and are protected from mechanical damage. Major external failure is very unlikely. Drip tray is fitted in cold box to contain all leaks fom piping and components within cold box. Thermo element in driptray will close automatic valve on leak detection.	
1.1.7.	Ship deflection; longitudinal bending moment	Outer tank rupture	Loss of vacuum/tank integrity	One of the two saddle supports free/sliding to take into account bending.	

System: LNG Tank design and location			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 1
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
1.2 Leakage					
1.2.1.	Leaking flanges/pipe connections	LNG dripping onto deck Gas inside coldbox	Freezing/fire/explosion.	All pipe connections in cold box. Drip tray is fitted in cold box to contain all leaks fom piping and components within cold box. Thermo element in driptray will close automatic valves on leak detection. Needle valves in level indicators. Additional manual valve will be fitted on LIT inlet Level gauge/display + pressure located in recess visible from outside Transmitters to be calibrated for lowest density and max trim Coldbox also has water condensation and this is contained in drip tray. Overflows through U seal onto deck. LNG leak will freeze water in siphon this will contain LNG in drip tray which will evaporate. Large leaks will be detected by TE (see 1.1.6.)	Gas detection for methane to be fitted in coldbox Electrical/control/mechanical equipment to IIB T4 rated due to chemical cargo. This is also acceptable for LNG.

System: LNG Tank design and location			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 1
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
				Small leaks evaporate Cold box is semi-enclosed space with natural ventilation. Driptray content minimum 1000 liters	
1.2.2.	Gas in cold box	Fire/explosion	Fire/explosion inside coldbox	Ignition not likely; explosion proof equipment. Gas leak detected; valve closed, fire safe valves (metal to metal) suited for 2 hour gas fire, fail to close also deckspray to be activated	Gas detection should be sufficient considering equipment is explosion proof Alarm on gas detection In case of fire, TE to detect high temp, automatic shut down; automatic valves close.
1.2.3.	Valves leaking in line	Valves fail to shut off flow of LNG/gas.	Uncontrolled flow of liquid.	PCV151 fails, pressure may built up, orifice plate fitted if necessary to match safety valve flow. At least two valves in series are fitted so that failure of two valves is unlikely.	
1.2.4	Tank level gauge leaking	Gas/liquid leak.	Fire/explosion	Additional easily accessible valves in top and bottom lines of level indicators will be fitted.	
1.2.5.	Freezing siphon on drip ray	Overflowing driptray due to freezing of waterlock in driptray	Freezing ofdeck		Remedial provisions to be considered; tracing (electrical, heating water)

System: LNG Tank design and location			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 1
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
1.3 Corrosion / erosion					
1.3.1.	Wear in valve spindles/seals	Leakage in valve spindles/discs.	Uncontrolled flow of liquid/fluid	Stainless steel piping, valves. LNG is clean, non corrosive. No corrosion/erosion expcted.	
1.3.2.	Corrosion of tank structure	Leakage of LNG	Fire/explosion/freezing of deck	No corrosion on inner tank. Design life 25 year for carbon steel outer vessel, so not less expected for stainless steel vessel.	
1.4 Impact					
1.4.1.	Hitting fixed structure	Rupture of the tank	Fire/explosion/freezing of deck.	see comments (1.1.1.) above.	
1.4.2.	Hose handling, cargo operation from cranes.	Rupture of the tank	hose flanges hitting tank/coldbox	Bunker hose is small diameter/light. Inner tank space filled with Perlite; Tis also protects inner tank from mechanical damage.	

System: LNG Tank design and location			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 1
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
1.5 Fire / Explosion					
1.5.1.	External cause; fire or explosion on deck not LNG related	Heat build-up/ release of LNG	LNG/gas release feeds the fire.	Water deckspray on cargo deck for cooling cargo tanks (control chemical reaction in tank) also feeds watersprinkler on LNG tanks and under LNG tanks to cool tank and prevent LNG release. Fire safe shutdown valves on tanks Flanges protected against effects of fire using heat resistant wound gaskets	
1.5.2.	External cause; One LNG package fire while other package must remain running	Loss of propulsion if both packages are shut down	One LNG tank is running with a fire in close proximity.	Considered very unlikely event. Cooling by waterspray.	

System: LNG Tank design and location			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 1
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
1.6 Structural integrity					
1.6.1.	Possible impact	Discharge of LNG	Fire/explosion	(See 1.1.1.). Double skin of tank with Pearlite inbetween results in robust structure. Can resist all but the heaviest impacts.	
1.7 Mechanical failure					
1.7.1.	Failure of valves/fittings	Loss of control of process/Leakage of LNG/gas.	Leakage/low pressure/high pressure.	Shut down of one tank unit and use other tank unit while repairs are carried out.	
1.7.2.	Degradation of insulation due to settling and vibration	Loss of thermal insulation, loss of vacuum	High heat transfer.	Can be easily identified by condensation/temperature monitoring. Refill and repair.	
1.8 Control / electrical failure					
1.8.1.	Wire break, short-circuit, software	Safety control loss	Blackout	Electrical system is backed up by DC system. Cooling water supply by one pump is maintained Port and starboard side both	

System: LNG Tank design and location			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 1
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
				running at all times underway. Blackout in DC system will shut down SSV valves (fail to close)	
1.9 Human Error					
1.9.1.	Incorrect operation	Danger to vessel/crew	Danger to vessel/crew	In normal operating mode a single error will not cause hazardous situation or catastrophic event.	On completion of the design an FMEA should be carried out on the whole system.
1.9.2.	Low temperature injuries	Damage to skin/personnel.	Personnel injury.	All cold temperature piping is within cold box . Warning signs on coldbox door. Frostbite would require long contact.	
1.10 Manufacturin g defects					
1.10.1.	Poor manufacturing procedures.	Tank failure.	Fire/freezing of the deck.	Tank is manufactured according to PED requirements	

System: LNG Tank design and location			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 1
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
1.11 Material selection				Valves, piping stainless steel safety valves stainless	
1.11.1.	Material not suitable for service.	Component failure	Release of gas.	All material is suitable for LNG at Cryogenic temperatures.	
1.12 Survey regime	System degradation	Leakage/failure over time.	System failure.	Regular survey of system according to class requirements.	Installation will be surveyed at intervals by LR Surveyor according to manufacturers recommendation and procedures to be established, including at least : - Insulation check Visual inspection through tricock Vacuum checking .

System: LNG bunkering system			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 2
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
2. Bunkering system					
Alongside					Road truck with 2" hose, manual handling one person at truck, one on ship
2.1. Rupture					
2.1.1.	Overpressure bunkering lines, from truck 22/25 bar	Burst hose/tank,pipes	Release of LNG	Lines up to tank designed for 25 bar.	Support of hoses to limit forces on bunker manifold to be considered Bunkering procedures to be drawn up. Bunker one tank at the time. Inertng of bunkering lines may not be necessary: bunker lines are short and in a gas dangerous area of the vessel.
2.1.2.	Ship movement	Broken hose, damaged pipework	Release of LNG	Sufficient slack in hose during bunkering.	Breakaway couplings (including selfclosing valves on either side and strong anchoring point) to be installed
2.1.3.	Excess pressure in bunkering tank caused by overfilling of	Damage/rupture of tank.	Release of LNG	Two independent level indicators with H and HHLA will shutdown bunker valve and isolating valve in PBU line and three way valve	

System: LNG bunkering system			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 2
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
	tank.			HV101	
2..1..4.	Excess pressure caused by incorrect bunker procedure - Bottom filling line opened, top filling line shut	Release of gas	Uncontrolled venting	Safety valves to be sized for maximum gas release during bunkering if bunker procedures are not followed.	
2.2 Leakage					
2.2.1.	Leaking flanges/pipe connections / break away coupling	Faulty pipe connections	Release of LNG	All connections are within separate compartment in coldbox. Separate entrance. Door is open when bunkering is taking place. Leaks will be contained in driptray.	Separated from rest of coldbox as gas leak is likely and gas alarm undesirable
2.2.2.	Valves leaking in line	Faulty valves	Uncontrolled flow of LNG	More than one valve in series in all lines.	
2.2.3.	Air enters tank because the port and starboard bunker lines are	Air enters LNG system	Faulty operation of system	Bunkering procedures to be followed.	Bunkering procedure must demonstrate that lines can be purged to tank and to truck. Specific attention to dead ends.

System: LNG bunkering system			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 2
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
	not effectively purged prior to loading.				
2.2.4.	Liquid in purge line due to error in bunkering procedure	Liquid blocks vent line.	liquid floods vent lines. Prevents proper operation of safety valves. Overpressure of tank.	TE in purge line will close bunkering valves	location of gas vent about 3 m above deck above LNG tank (one each tank)
2.3 Corrosion / erosion					
2.3.1.	Wear in valves/seals.	Leakage of LNG.	Fire/freezing of deck.	No corrosion.erosion issues expected. LNG is clean and all materials are suitable for temperatures.	
2.4 Impact					
2.4.1.	Hose damage to tank (see 1.1.1./1.6.1.)	Gas release			

System: LNG bunkering system			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 2
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
2.5 Fire / Explosion					
2.5.1.	External cause	Fire on deck ignites released vapour.	Vent fire.	Stop bunkering use deck water spray.	
2.6 Structural integrity					
2.6.1.	Temperature and pressure variation in bunker lines.	Fracture of bunker lines See (2.1.1.)			
2.7 Control / electrical failure					
2.7.1.	Blackout	Loss of control	Overfilling/Overpressure	Inlet valve will close on loss of AC power . short circuit on DC system will shut valves on one unt.	
2.7.2.	Sensor failure	Incorrect pressure reading	Overfilling/Overpressure	sensors analogue; out of range detection; bunker valves to close	

System: LNG bunkering system			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 2
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
2.7.3.	Sensor failure	Incorrect level	Overfilling/Overpressure	Inlet valve to close on out of range level sensor failure.	
2.8 Human Error					
2.8.1	Incorrect operation at valve V-109/209	Liquid passing at venting system		(see comment 2.2.4.)	
2.8.2.	Low temperature injuries	Damage to skin	Injury		Training of bunker operators to include personal hazards in handling cryogenic liquids. PPE to be supplied.
2.8.3.	Bunkering procedure not followed	Bad communication ship/shore	Overpressure of tank, release of LNG.		means of communication between lorry and ship to be in bunkering procedure

System: LNG bunkering system			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 2
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
2.9 Manufacturing defects					
2.9.1.	Out of spec materials	Material failure	Release of LNG		System to be constructed under survey.
2.10 Material selection					
2.10.1.	Incorrect materials	Material failure	Release of LNG		All materials are specified by tank manufacturer and suitable for cryogenic temperatures.

System: PBU/Gas conditioning system			Drawing:23-180-000-BA1-00-421-01		HAZID sheet 3
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3. Pressure build up					
Underway					
3.1 Rupture					
3.1.1	Mechanical damage to pipework	Leakage of LNG		Design pressure 16 bar Protected location inside coldbox Automatic shut off and manual closing of root valve.	
3.1.2.	Corrosion/erosion	Leakage of LNG		Piping and valves st steel Material of vaporiser unit; st steel fresh water/glycol mixture in heating coils	Rupture disc on fresh water side in vaporiser unit in case of tube failure.
3.1.3.	Failure of PCV diaphragm	Fast built up of pressure inside tank greater than relief valve capacity.	Tank overpressure/rupture	Orifice will be installed in gas line to prevent excessive pressure built up. Protection of tank by pressure alarm	

System: PBU/Gas conditioning system			Drawing:23-180-000-BA1-00-421-01		HAZID sheet 3
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3.2 Leakage					
3.2.1.	Leaking flanges/pipe connections	Dripping onto deck	Fire/explosion	All stainless steel, welded piping and valves gas detection, drip tray Small leaks will vaporise before touching drip tray.	(see 1.2.1.)
3.2.2.	Valves leaking in line	leaking in line		PCV leaking: excessive pressure in tank detected PSH150 and alarm and shutdown of HV151	(see 3.1.3.) At least two valves in each line in series.
3.2.3.	Internal leaking heat exchanger	Gas in cooling water system in machinery space	Loss of cooling water	Bubbles in expansion tank, high level alarm.	Pressure or high level alarm on pressure tank or expansion tank in cooling water system.
3.3 Corrosion / erosion					
3.3.1.	Leakage of pipework/fittings.	Dripping onto deck	Fire/explosion	All pipework is within cold box. All stainless steel pipes/fittings (see above). No corrosion/erosion is foreseen	

System: PBU/Gas conditioning system			Drawing:23-180-000-BA1-00-421-01		HAZID sheet 3
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3.4 Impact					
3.4.1.	Rupture of pipework	LNG/gas leakage	Fire/explosion	Protected location; within cold box no impact damage foreseen. Liquid pipes are automatically shut off.	
3.5 Fire / Explosion					
3.5.1.	External cause of fire/explosion	Heat build-up.	LNG/gas leakage	All pipework is protected by cold box. Cooling of LNG tank and coldbox by water spray	
3.6 Structural integrity	See rupture above.				

System: PBU/Gas conditioning system			Drawing:23-180-000-BA1-00-421-01		HAZID sheet 3
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3.7 Mechanical failure					
3.7.1.	Failure of fresh water system	Loss of gas supply Possible freezing of PBU unit	Shut down of engines on one side until crossover is opened.	Two pumps; each powered by PS/SB power. If heater does not work temperature in gas line drops and on low temp HV150 shuts	Calculations on freezing of vaporizer are being conducted by Cryonorm
3.8 Control / electrical failure					
3.8.1.	Blackout	control system fails	Loss of control of gas supply.	Fail close valves will shut off LNG supply to vaporiser.	

System: PBU/Gas conditioning system			Drawing:23-180-000-BA1-00-421-01		HAZID sheet 3
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3.9 Human Error					
3.9.1.	Incorrect manual operation.	System malfunction			System is automatic with no manual operation possible. No reversionary modes available. Change over to other tank on system failure. Automatic valves close on system failure.
3.9.1.	Closure/opening of valves in error	System malfunction			No manual operation is necessary in normal operation. If system fails then tank root valves should be closed.
3.9.2.	Low temperature injuries				Crew must be trained in low temperature systems.
3.10 Manufacturing defects					
3.10.1.	Poor manufacturing procedures	Pipe failure		System is manufactured under survey.	

System: PBU/Gas conditioning system			Drawing:23-180-000-BA1-00-421-01		HAZID sheet 3
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3.11 Material selection	Materials not suitable for service.	Component failure	Release of gas	All material is suitable for LNG at Cryogenic temperatures.	
3. Gas conditioning system.					
Underway					
3.12 Rupture					
3.12.1	Mechanical damage to pipework	Leakage of LNG		Design pressure 16 bar Protected location inside coldbox Automatic shut off and manual closing of root valve.	Piping is protected inside cold box.
3.12.2.	Corrosion/erosion	Leakage of LNG		Piping and valves st steel Material of vaporiser unit; st steel fresh water/glycol mixture in heating coils	Rupture disc on fresh water side in vaporiser unit in case of tube failure.

System: PBU/Gas conditioning system			Drawing:23-180-000-BA1-00-421-01		HAZID sheet 3
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3.13 Leakage					
3.13.1.	Leaking flanges/pipe connections	Dripping onto deck	Fire/explosion	All stainless steel, welded piping and valves gas detection, drip tray Small leaks will vaporise before touching drip tray.	(see 1.2.1.)
3.13.2.	Valves leaking in line	leaking in line		PCV leaking: excessive pressure in tank detected PSH150 and alarm and shutdown of HV151 At least two valves in each line in series.	(see 3.1.3.)
3.13.3.	Internal leaking heat exchanger	Gas in cooling water system in machinery space	Possible loss of cooling water	Bubbles in expansion tank, high level alarm.	Pressure or high level alarm on pressure tank or expansion tank in cooling water system.
3.14. Corrosion / erosion					
3.14.1.	Leakage of pipework/fittings.	Dripping onto deck	Fire/explosion	All pipework is within cold box. All stainless steel pipes/fittings (see above). No corrosion/erosion is foreseen	

System: PBU/Gas conditioning system			Drawing:23-180-000-BA1-00-421-01		HAZID sheet 3
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3.15 Impact					
3.15.1.	Rupture of pipework	LNG/gas leakage	Fire/explosion	Protected location; within cold box no impact damage foreseen. Liquid pipes are automatically shut off.	
3.16 Fire / Explosion					
3.16.1.	External cause of fire/explosion	Heat build-up.	LNG/gas leakage	All pipework is protected by cold box. Cooling of LNG tank and coldbox by water spray	
3.17 Structural integrity	See rupture above.				
3.18 Mechanical failure					
3.18.1.	Failure of fresh water system	Loss of gas supply Possible freezing of PBU unit	Shut down of engines on one side until crossover is opened.	Two pumps; each powered by PS/SB power. If heater does not work temperature in gas line drops and on low temp HV150 shuts	Calculations on freezing of vaporizer are being conducted by Cryonorm

System: PBU/Gas conditioning system			Drawing:23-180-000-BA1-00-421-01		HAZID sheet 3
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3.19 Control / electrical failure					
3.19.1.	Blackout	control system fails	Loss of control of gas supply.	Fail close valves will shut off LNG supply to vaporiser.	
3.19.2.	Pressure control valve failure	Excessive high/low pressure to engine	Loss of control of engine/damage.	Pressure switch shuts down liquid valve.	
3.20 Human Error					
3.20.1.	Incorrect manual operation.	System malfunction			System is automatic with no manual operation possible. No reversionary modes available. Change over to other tank on system failure. Automatic valves close on system failure.

System: PBU/Gas conditioning system			Drawing:23-180-000-BA1-00-421-01		HAZID sheet 3
Area: Cargo area			Revision: 0		Session 1
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3.20.1.	Closure/opening of valves in error	System malfunction			No manual operation is necessary in normal operation. If system fails then tank root valves should be closed.
3.20.2.	Low temperature injuries				Crew must be trained in low temperature systems.
3.21 Manufacturing defects					
3.21.1.	Poor manufacturing procedures	Pipe failure		System is manufactured under survey.	
3.22 Material selection	Materials not suitable for service.	Component failure	Release of gas	All material is suitable for LNG at Cryogenic temperatures.	

System: Gas fuel engine arrangement			Drawing: Gas Train P&ID 100296, 100296-501		HAZID sheet 4
Area: Machinery space			Revision: B1		Session 2
Equipment : Gas fuel engine					
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
Gas fuel engine and gas supply.					All components downstream of reducing valves (item5) to be inside container. Components on plan are duplicated for each engine.
Underway					
4.1. Rupture					
4.1.1.	Mechanical damage to low pressure supply pipe outside container	Leakage of gas	Fire/explosion due to gas leak	Mechanically protected against falling objects/impact. Design pressure 10 bar, carbon steel, Piping PN10, filter PN16, reducing valve PN16 Gas supply can be shut down by emerg. shut down valve with local/remote operation.	
4.1.2.	Failure of reducing valve (item 5)	High pressure downstream of reducing valve.	Damage to downstream low pressure controls	Two stage reducing valve, so ruptured diaphragm would not introduce 2 bar downstream. Also safety valve (no. 6 about 0.5 bar) and pressure switch high (not shown on plan).	High pressure switch to be added to plan.

System: Gas fuel engine arrangement			Drawing: Gas Train P&ID 100296, 100296-501		HAZID sheet 4
Area: Machinery space			Revision: B1		Session 2
Equipment : Gas fuel engine					
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
4.1.3.	Failure of 50mb piping inside container.	Gas leak in container	Fire in container	Gas train inside container will be mounted high up, protected from mechanical damage in a well ventilated area. Flexible hose at engine to isolate piping. Carbon steel. Natural thermal air circulation by engines. Design pressure 10 bar; working 0 to 50 mbar Rupture will cause low pressure; L alarm and LL stop on one engine (no. PS 7 and 8) Gas detection will give alarm.	
4.1.4	Failure of flexible hose between gas train and engine	Gas leak or air leak into engine	Too much air, no fuel	50 mm, metallic, certified hose. Engine will stop at no fuel double block and bleed will isolate piping from rest of system, Other engine keeps running unless gas detection goes off	Flexible hose to be visible and in a well ventilated area. Design life of hose to be stated by manufacturer.
4.1.5.	Engine inlet ducting, including turbocharger and mixing valve	Gas release in container	Fire/explosion	Aluminium piping, mixing valve and turbocharger. Rubber compensator after turbocharger replaced by steel coupling with V clamp and 'O' ring sealing. Details and diagram will follow. Mixture very lean. After rupture and dilution with ventilation air it would be even leaner and not	Good flow of ventilation air over engine to be verified by CFD

System: Gas fuel engine arrangement	Drawing: Gas Train P&ID 100296, 100296-501	HAZID sheet 4
Area: Machinery space	Revision: B1	Session 2
Equipment : Gas fuel engine		

ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
				hazardous	
4.1.6.	Rupture of coil in intercooler	Gas leak into water/water leak into gas.	Water in engine – engine damage. Gas in water will be released in header tank.	Under normal condition, water pressure is higher than gas and water would leak into engine. This is dangerous for engine but same as oil fuel engine.	level detection in expansion tank; fluctuation to give alarm.
4.1.7.	Rupture of engine inlet manifold	Gas leak in container	Fire/explosion	Mixture very lean. After rupture and dilution with ventilation air it would be even leaner and not hazardous Tried and tested design on industrial/automotive gas engines and marine diesels since 2000 Major leak/rupture measured on pressure differential transmitters	
4.2 Leakage					
4.2.1.	Leaking flanges/pipe connections outside container (2 bar)	Release of gas	Local build up of gas	Small leak may not be identified; considered not dangerous because: - Well ventilated area; outside - Hazardous area, no source of ignition present	Odorising the gas could be considered

System: Gas fuel engine arrangement			Drawing: Gas Train P&ID 100296, 100296-501		HAZID sheet 4
Area: Machinery space			Revision: B1		Session 2
Equipment : Gas fuel engine					
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
4.2.2.	Leaking flanges/pipe connections inside container	Release of gas	Built up of gas within container. Fire/explosion	Design of ventilation system to be adequate to keep area safe CFD to show flow is adequate and no stagnant areas. Reference to IEC 60079-10-1. 2 inlet fans, one from SB, one from PS Ventilation air for engine cooling is far greater than that required for gas dispersion. System capacity will be that required for engine cooling. 24v start-up fan will be lower capacity.	Out flow calculation to be discussed in detail with LR Fan availability to be included in CFD. Sizing and configuration with respect to cooling and gas leaks to be communicated. Submit additional information about purge procedure and/or initial start up after black out. One fan on 24 V for start up from black out or initial start up as recommended during session 1.
4.2.3.	Leaking valves/fugitive emissions	Release of gas	Built up of gas within container. Fire/explosion	See 4.2.2. above.	
4.24.	Valves leaking in line	Gas will enter inlet duct when there is no air low	Explosion	Double block&bleed operated by two separate contr. signals	
4.2.5	Crankcase seals/vents	Gas leakage into engine room	Explosion	Piston blow by mixture will be diluted; mixture will not be explosive.	

System: Gas fuel engine arrangement			Drawing: Gas Train P&ID 100296, 100296-501		HAZID sheet 4
Area: Machinery space			Revision: B1		Session 2
Equipment : Gas fuel engine					
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
4.2.6	Leakage of cylinder charge into exhaust system	Flammable gas mixture in exhaust	Explosion in uptake	One cyl not functioning the mixture will not be explosive as it is diluted with exhaust gas. One cyl not running indicated by low temp indication on this cyl.	
4.3 Corrosion/erosion				LNG/methane is non corrosive. Only corrosion is external but vessel operates in fresh water.	
4.3.1.	Aftercooler corrosion	Leaking tubes	Water in cylinders.	Fresh water only (IWW) no corrosion effect on aluminium.	
4.3.2.	Galvanic effects at s/s to c/s interface.	Corrosion on one side leading to gas leak.	Fire/explosion	Carbon steel will be isolated from st steel pipework in tank.	

System: Gas fuel engine arrangement			Drawing: Gas Train P&ID 100296, 100296-501		HAZID sheet 4
Area: Machinery space			Revision: B1		Session 2
Equipment : Gas fuel engine					
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
4.4 Fire/Explosion					
4.4.1.	Fire in container	Gas release/fire spread to tank	Escalation of fire	Due to the high vent rate inside container, explosion inside the cont. is very unlikely. Jet fire is not possible due to low pressure.	
4.4.2.	Fire in container due to electrical failure	Fire melts components in gas supply system – gas release.	Explosion.	2 flame detectors: manual providing an alam & manual closing of the fire dampers. Fire detection based on ADNR Procedure afterwards: closing the master valve & let the engine run to suck out rest of gas: no automatic shut down of engines.	
4.4.3.	Misfire, damaged turbocharger	Source of ignition in inlet duct.	Explosion in inlet duct.	Weak mixture will not support combustion. Sandfiren will present documentation confirming safety of the arrangements.	
4.4.4.	Misfire/damaged exhaust valve	Gas enters exhaust	Explosion in exhaust.	See also 4.2.6. Engine will shut down on exhaust deviation.	

System: Gas fuel engine arrangement			Drawing: Gas Train P&ID 100296, 100296-501		HAZID sheet 4
Area: Machinery space			Revision: B1		Session 2
Equipment : Gas fuel engine					
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
4.4.5.	Crankcase explosion	Danger to machinery and personnel	Loss of engine/life.	Crancase explosion is similar to conventional engine. No relief valves required by class Rules.	
4.4.6.	Fire outside the container	Fire may spread into container.	Loss of propulsion in one container.	Water sprinklers will cool around the LNG tanks: ADNR req. Space between the containers will provide sufficient isolation containers wall may be A0.	
4.5 Structural integrity					
4.5.1.	Major engine damage	Personel injury/loss of propulsion	Loss of one engine. May affect other engine in same container.	Engine stop(<50rpm) ; crankshaft speed indicator will switch off the gas supply Losing eng performance will request for shut down LL or L alarms will request eng stop. SSV will close. maximum power loss will be 50%.	

System: Gas fuel engine arrangement			Drawing: Gas Train P&ID 100296, 100296-501		HAZID sheet 4
Area: Machinery space			Revision: B1		Session 2
Equipment : Gas fuel engine					
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
4.6 Mechanical failure					
4.6.1.	Failure turbocharger	Personel injury/loss of propulsion. Source of ignition in inlet duct.	Explosion in inlet duct.	See 4.4..3. Asessment of safety will be provided by Sandfirden.	
4.6.2.	Failure of inlet/exhaust valves	Source of ignition in inlet/exhaust. duct.	Explosion in inlet/exhaust	See 4.2.6/4.4.3.	
4.6.3.	Clogged air filter	Increased mixture strength.	Explosion in inlet duct	Clogged air filter will be compensated by decrease of gas supply; power goes down	
4.7. Control/electrical failure					
4.7.1.	Faulty control signal; signal out or range;	Poor gas combustion	Loss of power	Control logic will be approved by LR Programmable system: watch dog must be provided.	

System: Gas fuel engine arrangement			Drawing: Gas Train P&ID 100296, 100296-501		HAZID sheet 4
Area: Machinery space			Revision: B1		Session 2
Equipment : Gas fuel engine					
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
	signal deviation;			Most alarms will be warning only. System to be shutdown manually by one of the block valves. Each engine has its own control system.	
4.7.2.	Loss of power/blackout	loss of control; loss of ventilation	Loss of power.	1 set of batteries per eng. control (2 x 12 =24VDC) control has also a back-up supply for half an hour	
4.7.3.	Emergency shut down	Loss of propulsion Blackout	loss of manoeuvring loss of auxiliary generators	Port and stbd side containers are separate and independent. ESC on one side will not affect the other side.	
4.8 Human Error					
4.8.1.	Incorrect operation	Override of control system.	Damage to machinery.	Multiple engines; so no manual override required; depends onowners preference.	

System: Gas fuel engine arrangement			Drawing: Gas Train P&ID 100296, 100296-501		HAZID sheet 4
Area: Machinery space			Revision: B1		Session 2
Equipment : Gas fuel engine					
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
4.9 Material selection					
4.9.1.	Aluminium in gas system	Failure due to fire	Loss of machinery in one container.	All components up to pressure regulator (item 11) are of steel. SSV closes on fire detection. 50% power is maintained.	
4.10 Environmental conditions					
4.10.1.	Low gas temperature on startup due to exposed pipework	Poor combustion/fail to start	Engine fails to start.	Temperature alarm on Cryonorm pack and engine (TS 14).	

System: LNG machinery room arrangement - ventilation and gas detection/operating modes.			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 5
Area: Machinery space			Revision: 0		Session 1
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
Machinery arrangement					
Continuous operation underway					
5.1 Rupture					
5.1.1	Failure of single walled cross over pipe	Gas release	Explosion/fire	Cross-over line protected by grid/framework. On open deck – gas will disperse quickly. Pipes are of stainless steel, manual crossover valves normally closed. Used in case of emergency If it is in use and it breaks, manual valves closed to isolate Flexibility loop provided Full pipe rupture very unlikely.	
5.1.2.	Failure of Single walled pipe between coldbox and container	Gas release	Explosion/fire	Pipe protected by grid/framework. On open deck no source of ignition. Gas will disperse quickly. Pipes stainless steel of substantial	

System: LNG machinery room arrangement - ventilation and gas detection/operating modes.			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 5
Area: Machinery space			Revision: 0		Session 1
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
				thickness (PN16 min) On low pressure SSV101 will shut.	
5.1.3.	Single walled pipe at engine	Gas release	Explosion/fire	Nominal working pressure 2 bar (max 3 bar from Cryonorm). (Design pressure of pipe within container well above working pressure. Relief valve set to protect piping within container if required . SSV101 to be considered master shut off valve for machinery space. Pipe is relatively short, small diameter, low pressure	Setting of pressure relief valves TRV109 and TRV702 to be further considered. Master valve to be controlled as per the Rules and controlled from entrance to engine room *LR NOTE: During HAZID Session 2 it was concluded that first pressure reduction of 2 bar to 50 mbar is done outside container on open deck. See sheet 4.*
5.1.4.	Rupture reducing valve diaphragm in fuel train	High pressure in PCV713, which it cannot handle	Damage to downstream reducing valve/zero pressure valve.	Pressure switch on shut down valve (new plan) will shut valve down Block and bleed seems to be fitted between PCV valves to protect engine	HOLD FOR PROPER PLAN Details remain unclear. Block and bleed and shut off valve within Sandfirden package to be reconsidered Bleed line to be led to safe area. Consider open bleed valve; how to detect?

System: LNG machinery room arrangement - ventilation and gas detection/operating modes.			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 5
Area: Machinery space			Revision: 0		Session 1
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
5.2 Leakage					
5.2.1.	Leaking flanges/pipe connections outside MS	Gas release in vicinity of tank and machinery space	Gas build up	Hazardous area plan drawn around possible pipe leaks. On open deck - no source of ignition. Gas will disperse quickly	Adding odour to gas would help detect any leak.
5.2.2.	Leaking flanges/pipe connections inside MS	Gas release in confined space	Fire/explosion	Intention to apply IEC 60079-10-1: Ventilation sufficient to deal with specified maximum leakage inside container from pipe, flange and valves No stagnant areas Gas detection in container	CFD analysis to be prepared to demonstrate adequate ventilation Ventilation is an essential system for hazardous areas classification.
5.2.3.	Valves leaking in line inside MS	Gas leaking into engine air intake.	Fire/explosion.	Double block and bleed before engines.	
5.2.4.	Leakage of water inside container	Flooding of container/loss of coolant	Overheating engine/electrical problems	Driptrays under generator set. High temperature alarms.	Drainage arrangements for leaking oil/water to be provided. Closed circuit surveillance of MS could be considered.

System: LNG machinery room arrangement - ventilation and gas detection/operating modes.			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 5
Area: Machinery space			Revision: 0		Session 1
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
5.2.5.	Gas leaking into MS from hazardous area	Gas build up in machinery space.	Fire/explosion.	Air intake located outside hazardous area. Pressure differential inside MS.	
5.3 Corrosion / erosion	Corrosion of pipework	Gas leak.	Fire/explosion	No particular issues are expected for gas & freshwater	
5.4 Fire / Explosion					
5.4.1.	Engine room fire	Electrical/lub oil leak Gas leak.	Fire/explosion.	IP55 containers for electrical equipment (ADNR) Normal machinery space fire fighting measure to be taken: water jet, dry powder extinguishers, CO2 system, Fire detection. Detectors suitable for oil and gas flames. automatic shut down as per MSC doc. (In case of fire master valve (SSV101) to be shut off.) Engine stop in controlled manner, ventilation off, start CO2 if required. Each container is A0; so fire would be contained	

System: LNG machinery room arrangement - ventilation and gas detection/operating modes.			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 5
Area: Machinery space			Revision: 0		Session 1
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
				Fire alarms port and starboard independent; not to affect each other.	
5.4.2.	Engine room explosion	Loss of propulsion Personnel hazard Damage to other MS.	Explosion in one container may affect the other.	MS containers are on deck . Explosion in one is very unlikely to affect the other. Master gas valve will shut. Gas leak and gas build up unlikely due to ventilation arrangement. Electrical equipment spark free; IP55 containment.	
5.5 Structural integrity	Major engine failure	Release of gas in MS. Personnel hazard	Loss of power	Master valve will stay open on engine deviation signal; fuel train for failed engine will shutdown. Same safe guards as 5.6.2. Engine stops.	Engine parameter deviation signals that close the master valve to be defined.
5.6 Mechanical failure					

System: LNG machinery room arrangement - ventilation and gas detection/operating modes.			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 5
Area: Machinery space			Revision: 0		Session 1
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
5.6.1.	Failure of valves/fittings	Release of gas	Fire/explosion	Gas pressure is very low compared to design pressure of system so no major mechanical failure of components is expected.	
5.6.2.	Major mechanical failure of engine	Release of gas.	Fire/explosion Loss of propulsion.	Two engines running. One of these fails, comes off the board Power will be shared by engine that is still running by control system Reduced power for propulsion. Slow down but keep running. Master valve stays open, fuel train for failed engine will shut down on signal from control system (on throttle valve (discrepancy), misfire) Manual controlled shutdown of running engine in same container is required.	Determine required number of gensets to meet minimum speed requirements for ADNR
5.6.3.	Failure of ventilation	Gas accumulation	Fire/explosion	If ventilation is not adequate master shut of valve to that container to be shut.	Ventilation configuration to be determined 1) Power supply from port and sb switchboards for maintenance reasons; 2) Fans on 24V for initial start up or gas detection

System: LNG machinery room arrangement - ventilation and gas detection/operating modes.			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 5
Area: Machinery space			Revision: 0		Session 1
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
					Monitor fans by flow detection. Starting procedure to be determined
5.7 Control / electrical failure					
5.7.1	Short-circuit on bus bar at main switchboard	Blackout	Complete black out longer than 1 minute not acceptable to RosRijn		Rethink power concept 1) Special frequency converter/discrimination; OR 2) Split SB and PS systems; no connections; OR 3) Dedicated bowthruster supply from one generator that keeps ship at 6 km/h for 30 min
5.7.2.	generator failure	Loss of power	blackout after single failure	One engines at each side must be running while navigating. See also 5.14.1	see above
5.8 Human Error					
5.8.1	Open door of container	Affect ventilation	Gas built up	Self closing door, warning sign	CFD to take account of open door operation.

System: LNG machinery room arrangement - ventilation and gas detection/operating modes.			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 5
Area: Machinery space			Revision: 0		Session 1
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
5.9 Manufacturing defects	Poor manufacturing procedures.	Failure of machinery	Loss of power/gas release	Built under survey This should ensure quality of manufacture.	
5.10 Material selection					
5.10.1	Zero regulator aluminium inside	Component unserviceable after fire.	Loss of one engine.	Outside casing steel Piping is steel	Details required
5.10.2.	Carburator and throttle valve Al	Component unserviceable after fire.	Loss of one engine.	On engine, downstream of steel shut off valve	
5.11.Escape	Engine room fire	No escape from engine room.	Injury/death	Engine rooms <35m^2 may be fitted with one means of escape	
5.12. Flooding	Fresh water leak	Loss of cooling	Loss of power	Above water line & no water cooling so no source from inside	

System: LNG machinery room arrangement - ventilation and gas detection/operating modes.			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 5
Area: Machinery space			Revision: 0		Session 1
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
	Flooding from outside container in damage condition.	MS flooding	Loss of power.	Damage condition ADN results in flooded aft deck; measures will be taken to keep water out of container	
5.13. Start-up/shut down					
5.13.1.	Normal operational procedure	Failure to start machinery		Shore supply connection. Go through black out when switching over. Safety equipment to run on 24V No issues foreseen	Starting procedure remains to be drawn up
5.14. Blackout					
5.14.1.	Short circuit on bus.			See also above; short circuit Can only occur with one engine running under command two engines will always be running (one PS, one SB) Start up can be achieved by using 24V battery system	

System: LNG machinery room arrangement - ventilation and gas detection/operating modes.			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 5
Area: Machinery space			Revision: 0		Session 1
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
5.15. Deadship					
5.15.1.	Normal operational procedure			Each engine has own starting battery; 4 battery sets being empty unlikely Batteries cannot be paralleled.	Battery numbers and locations and function to be defined.
5.16. Docking maintenance					
5.16.1.	Drydock	Build up of pressure in the tank	Release of gas	LNG tank will not vent for 2 to 3 weeks depending on tank filling	Cryonorm to specify maximum times for layup with reference to filling level and air temp/radiation level.
5.16.2.	Drydock			LNG can be pumped from tank back to truck, Nitrogen must be used to gas free lines.	Procedure to be submitted

System: LNG machinery room arrangement - ventilation and gas detection/operating modes.			Drawing: 23-180-000-BA1-00-421-01		HAZID sheet 5
Area: Machinery space			Revision: 0		Session 1
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
5.16.3.	Engine overhaul required.	Engine failure		Replace container with engines every 5 years at major overhaul	Connections for cables, cooling water pipe, exhaust: locations to be determined. Must be watertight, gastight
5.17. Commissioning trials					
5.17.1.	Normal commissioning procedure.			Cryonorm will cool, gas free and fill tank. Testing of engine package at Sandfirden On ship just check connections, safety, control functions.	

Overview of deviations from the IGF code (IMO Resolution MSC 285(86)).

This document is applicable to the IWW tankers ‘Argonon’, ‘I-Tanker 1401’, and ‘I-Tanker 1402’.

IGF code	**Argonon Hazid ROT/11.M.0080** **I-tanker Hazid ROT/11.M.0090**
1.1.2. Reference to Solas	An Inland waterway vessel does not apply to Solas.
2.6.2.Gas save	The vessel is designed to be gas save by means of ventilation instead of gas save by means of double walled piping. Ventilation is simulated by Computational Fluid Dynamics Analysis and tested by Lloyd’s Register in real life with a smoke source.
2.6.3. Emergency Shut Down	The vessels’ engine rooms are not designed as being ESD. ESD is not applicable according the Lloyd’s Register Rules due to zone changes (art. 4.3.2) and due to the disapproval of gas detection systems. Notwithstanding the engine rooms are provided with a emergency shutdown in case of gas leakage.
2.6.2 / 3	The system is gas save by means of ventilation and equipped with an emergency shut down valve.
2.8.1.2 Pipe connections to the tank above highest liquid level	Pipe connections are not above highest liquid level.
2.LNG Tank design: Tank type C	The LNG tank design is according PED/EN 13458-2 Static vacuum insulated cryogenic vessel. The tank can absorb dynamic loads of at least: 2G longitudinal 1G vertical 10 degrees heel. These criteria are being met apart from the IGF Code.
2.8.1.4 Outlet pressure relieve (B/3 or 6m whichever is greater)	Outlet pressure relieve > 2 m according to the ADN. This standard is used to be in line with the equipment on the cargo tanks.

2.8.3.4 Drip trays below LNG tank in case of pipe connections below highest liquid level to have sufficient capacity to contain the volume which could escape in the event of a pipe connection failure.	Drip tray with a volume of 1000 liter and a water spray system to warm up and evaporate liquid LNG in the event of a pipe connection failure. The drip tray has also a drain overboard.
4.3 Definition of hazardous zones	The definition of hazardous zones according to Lloyd's Register rules for methane gas fuelled ships is used. The mayor difference is: changes in zones are not accepted by the Lloyd's Register rules where they are accepted by the IGF code. See IGF code art. 4.3.2 point 7.
5.5 gas detection	A different approach is chosen because the gas safe design is based on ventilation. There is gas detection available but the system is not based on the reliance on gas detection. The system is based on venting gas out which could escape in the event of a pipe connection failure.

LNG Bunkering Procedure

1. PURPOSE

To fill the LNG holding tanks in a safe way, the following procedures should be followed closely:

2. GENERAL

Before the vessel's LNG storage tanks can be filled on a certain place, (local) authorities should be informed. These authorities could demand for extra safety precautions. The authority's approval for the bunker transfer must be available before bunkering is started.

As long as there are no regulations for LNG bunker transfer the following can be used as guidance:

- General bunker transfer procedures for oil fuel
- Precautions and procedures for cargo filling and –discharge by inland waterway tank vessels

3. PRE-FILLING

Before LNG transfer is commenced the bunker checklist has to be filled in and signed both by a ship's representative and the delivery truck driver.

After all questions on the bunker checklist are answered positive and the delivery truck driver has received all necessary documentation, transfer is commenced.

4. FILLING:

The LNG transfer diagram is presented in appendix B of this document.

During transfer the following items should continuously be checked:

- The gas pipes, -hose and connectors for leakage
- The mooring lines
- Forces on the transfer hose
- Tank pressure, which can be controlled by use of the top filling spray facility (with this procedure a vapour return is not required)

5. POST-FILLING:

After LNG transfer, and after the transferhose is disconnected, warning signs on the shore can be removed. At this time the crew and the (local) authorities have to be informed that the transfer is finished.

6. PROCEDURES

LNG transfer checklist	
Precautions and appointments made for transfer of LNG	
- Ship’s particulars ………………………………….. (ship’s name)	………………………………………. (Ship’s European Identification number)
- Truck’s particulars …………………………………… (Companyname)	………………………………………. (plate number)
- Transfer location …………………………………… (adress) …………………………………… (date)	………………………………………. (place) ………………………………………. (time)
LNG related particulars	
Quantity in m^3: …………………….	
Maximum pumprate in m^3/uur: 36	
Emergency procedure	
Filling must be stopped immediately in case leakage occurs on the connection hose or the LNG pipes between the bunker station and the storage tank. All valves have to be set in their safe position. A red flashlight will indicate the abnormal situation described. The truck driver should stop the LNG pump immediately. All personnel should evacuate the bunker station area immediately.	

The start of LNG transfer is only allowed if all questions raised on the checklist of appendix A are answered ‘yes’ and both responsible persons have signed the list.

If one of the items cannot be answered ‘yes’ LNG transfer is **NOT** allowed.

APPENDIX A.

LNG Transfer Checklist		
	Ship	**Truck**
1. Are vessels present in the direct vicinity of the transfer area informed about the LNG transfer?	○	--
2. Is the (local) authority's admittance for the LNG transfer in the designated area available?	○	--
3. Is the (local) authority informed that LNG transfer will be commenced?	○	--
4. Is the vessel well moored?	○	--
5. Is the lightning, both on the truck and on the vessel (bunker station), sufficient and in good working order	○	○
6. Are the signs, that designate the safe area around the tanktruck on the shore, placed?	--	○
7. Are all, for any possible leakage necessary, drip-trays placed and is the waterspray installation for immediate use available?	○	--
8. Is the LNG transfer hose properly supported and are there no extreme forces or stress on the hose?	○	○
9. Are the LNG transfer hose and break away coupling in good condition?	○	○
10. Is the ground cable connected in the right way?	--	○
11. Is the necessary driptray under the hoseconnection placed?	○	--
12. Are all means of communication between truck, bunkerstation and wheelhouse checked and in working condition?	○	○
13. Are all safety and control devices on the LNG installation checked and in good working order?	○	--
14. Is the amount of LNG that will be transferred agreed?	○	○
15. Do the ordered LNG specifications apply on the delivered LNG specifications?	○	○
16. Is the emergency stop procedure discussed with, and understood by, the truck driver?	○	○
17. Is there a LNG certificate available?	○	○
18. Is the crew informed that LNG transfer is commenced?	○	--

Checked and signed:	
Ship's representative: …………………………………….. (Name in capitals)	Tank truck representative: …………………………………….. (Name in capitals)

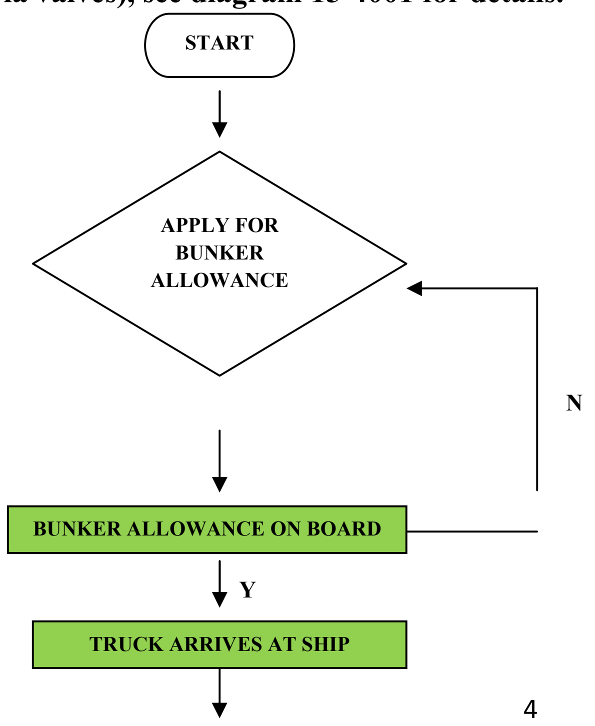
LNG Transfer Checklist			
		Ship	Truck
………………………………………. (Signature)	………………………………………. (Signature)		

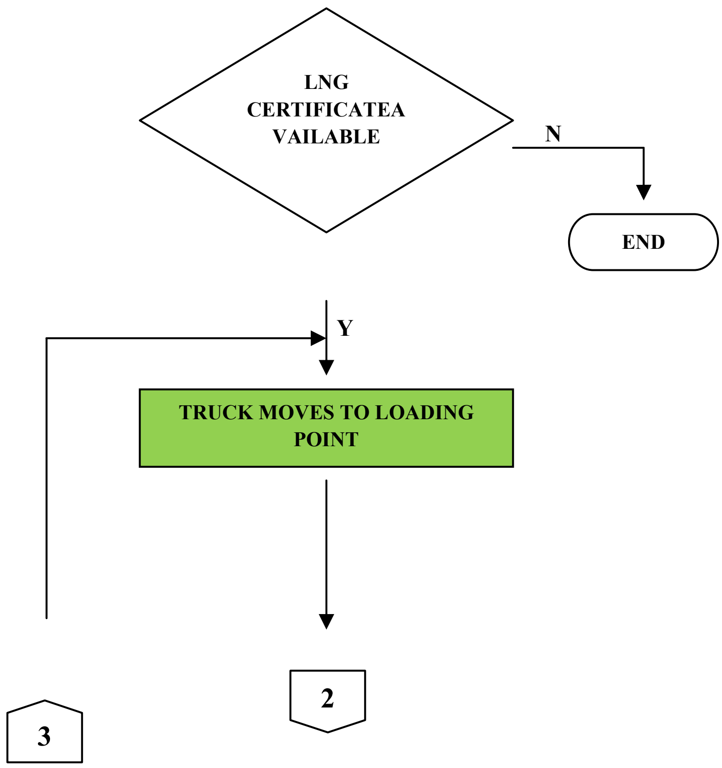
APPENDIX A.

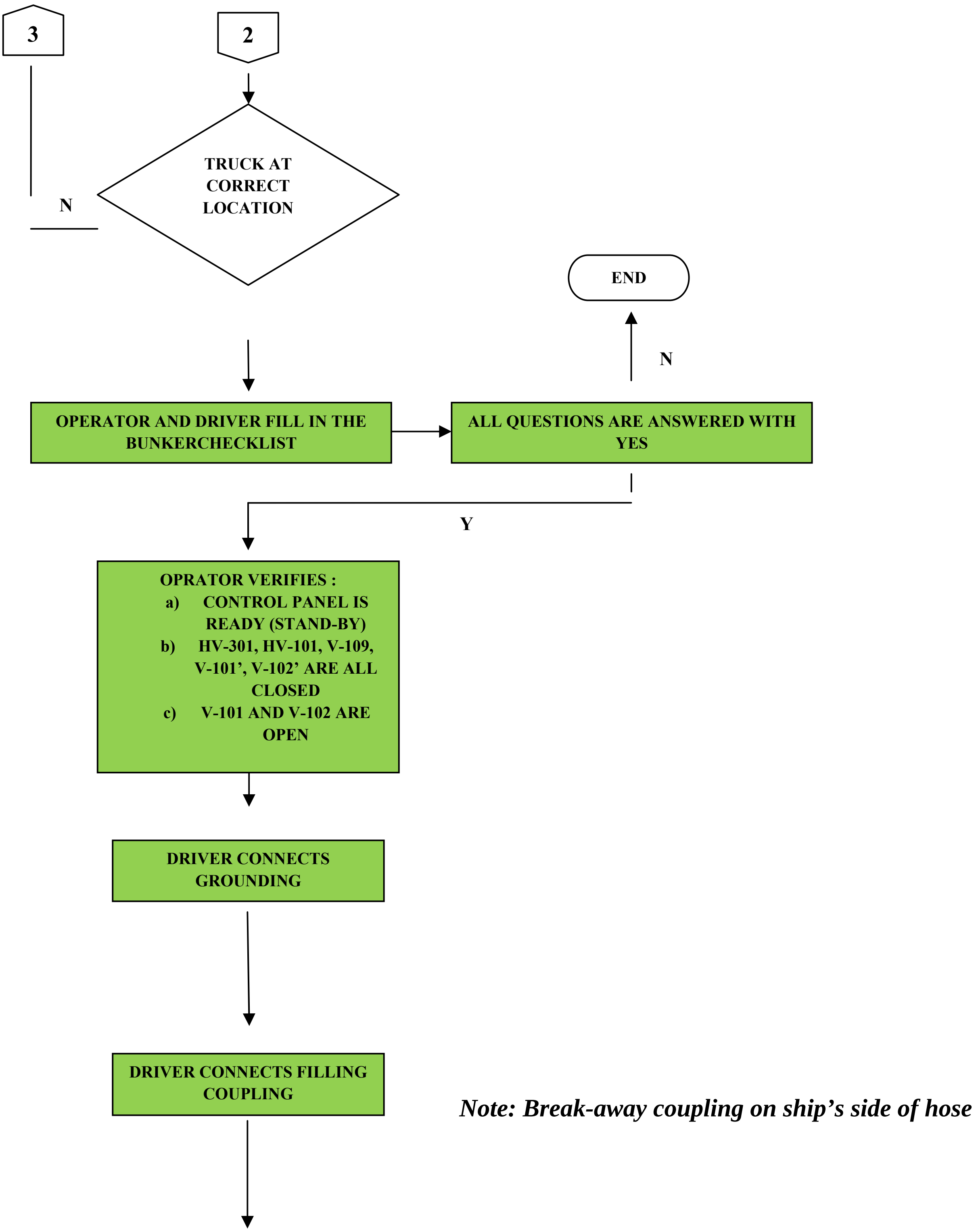
<u>DEFINITIONS</u> :

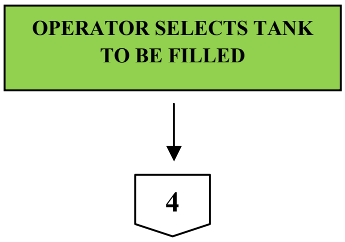
“Operator” = The master or the person mandated by him
“ Driver” = The driver of the truck

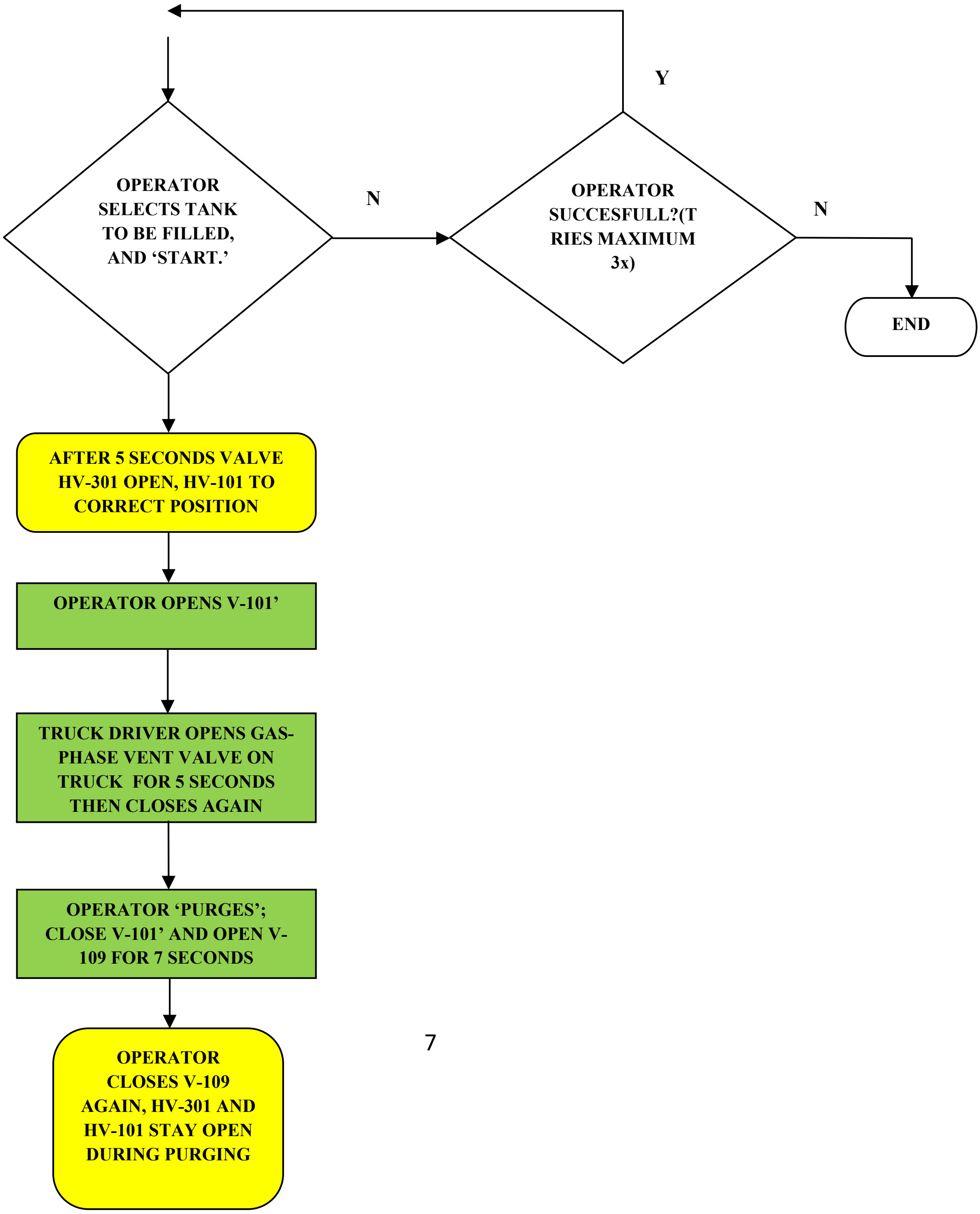
The following procedure describes the filling sequence and actions for filling the on-board Starboard storage tank with LNG coming from a road trailer, through the starboard bunker connection of the ship (through valve HV-301 and valve HV-101).
It is possible to fill both tanks from either side of the vessel (each bunker station is connected to both tanks via valves), see diagram 15-4001 for details.

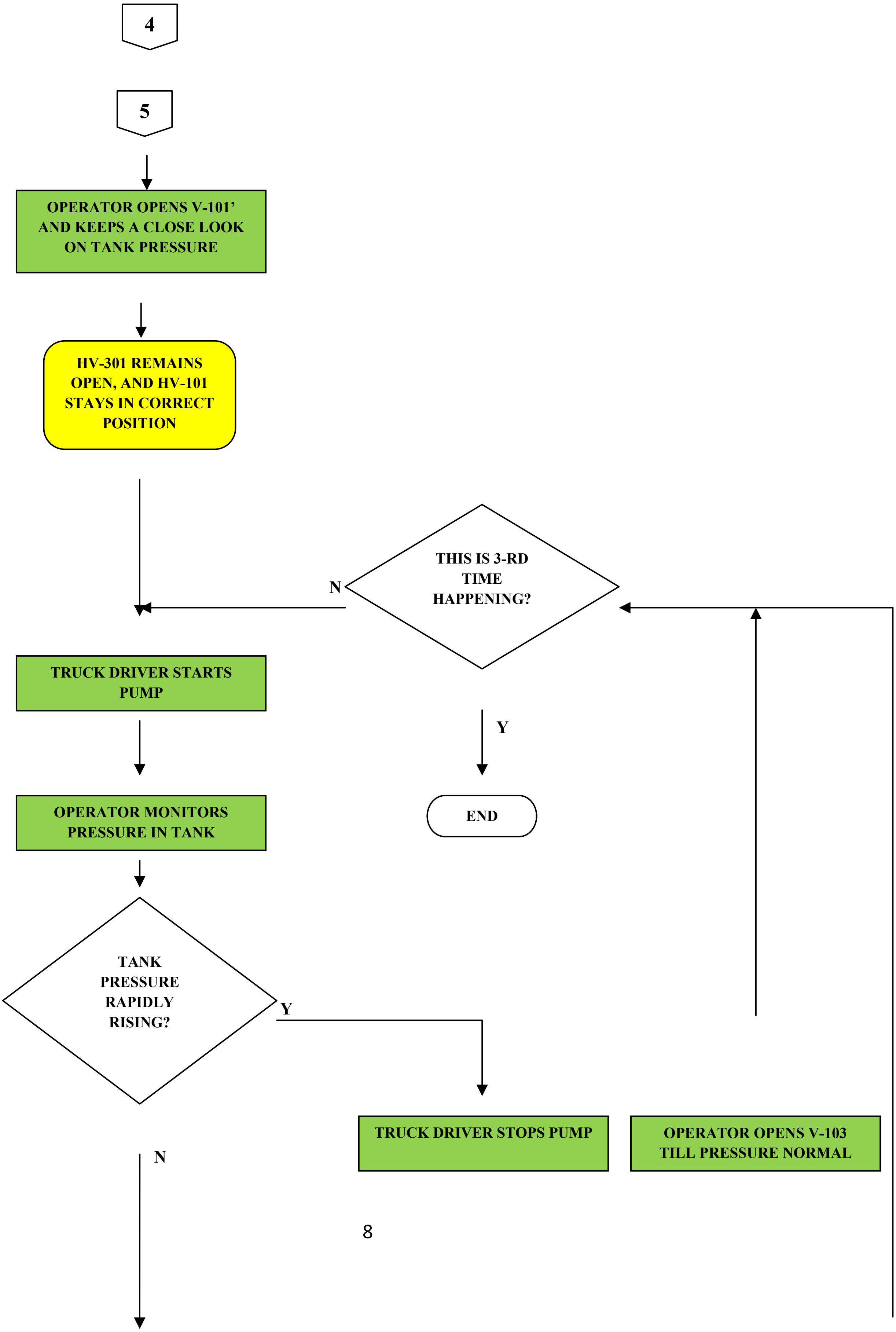


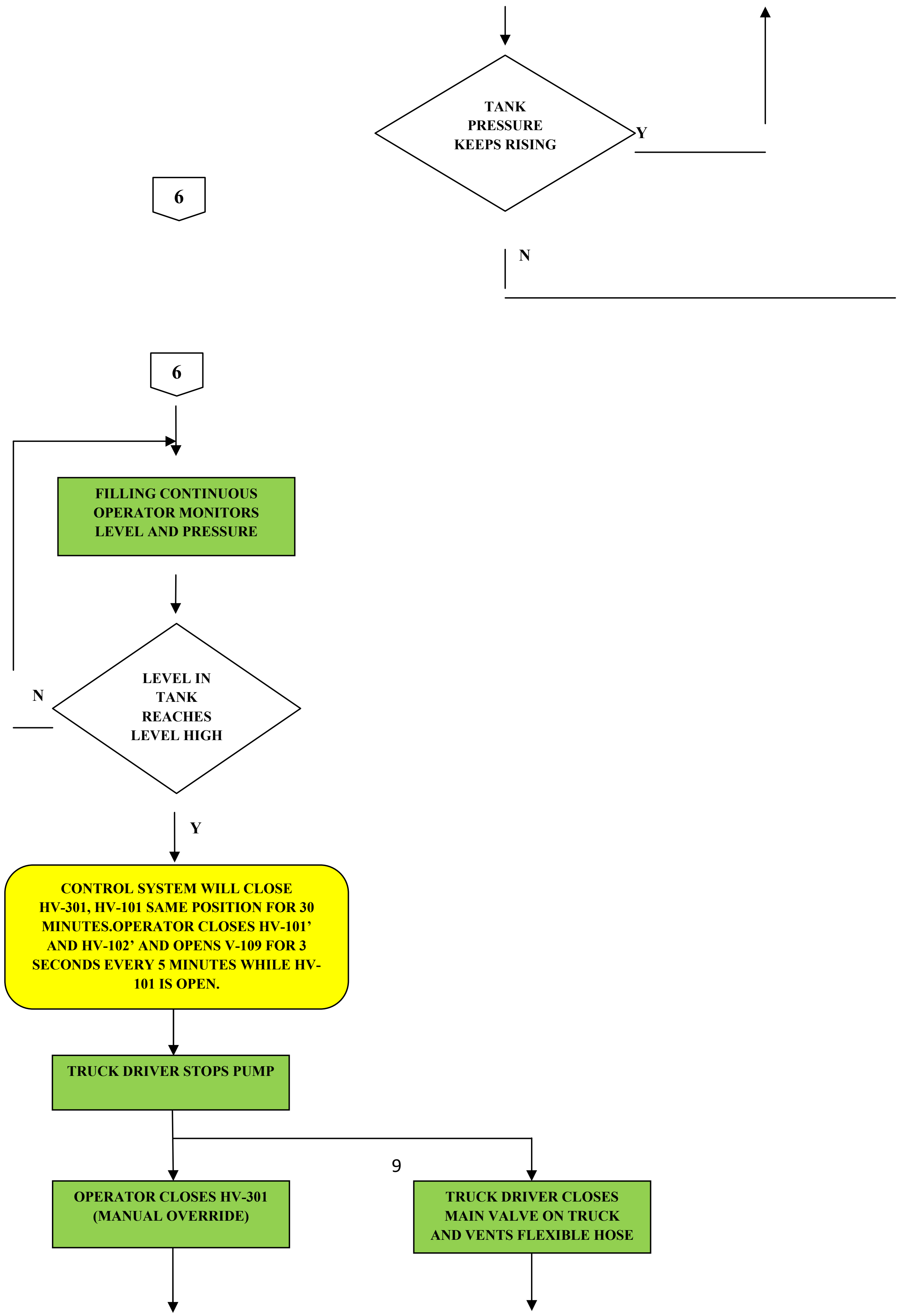

LNG
CERTIFICATEA
VAILABLE
N
END
Y
TRUCK MOVES TO LOADING
POINT
3
2


3
2
TRUCK AT CORRECT LOCATION
N
END
N
OPERATOR AND DRIVER FILL IN THE BUNKERCHECKLIST
ALL QUESTIONS ARE ANSWERED WITH YES
Y
OPRATOR VERIFIES :
a) CONTROL PANEL IS READY (STAND-BY)
b) HV-301, HV-101, V-109, V-101', V-102' ARE ALL CLOSED
c) V-101 AND V-102 ARE OPEN
DRIVER CONNECTS GROUNDING
DRIVER CONNECTS FILLING COUPLING
Note: Break-away coupling on ship's side of hose


OPERATOR SELECTS TANK TO BE FILLED
4


OPERATOR SELECTS TANK TO BE FILLED, AND 'START.'
N
OPERATOR SUCCESFULL?(TRIES MAXIMUM 3x)
Y
N
END
AFTER 5 SECONDS VALVE HV-301 OPEN, HV-101 TO CORRECT POSITION
OPERATOR OPENS V-101'
TRUCK DRIVER OPENS GAS-PHASE VENT VALVE ON TRUCK FOR 5 SECONDS THEN CLOSES AGAIN
OPERATOR 'PURGES'; CLOSE V-101' AND OPEN V-109 FOR 7 SECONDS
OPERATOR CLOSES V-109 AGAIN, HV-301 AND HV-101 STAY OPEN DURING PURGING


4
5
OPERATOR OPENS V-101' AND KEEPS A CLOSE LOOK ON TANK PRESSURE
HV-301 REMAINS OPEN, AND HV-101 STAYS IN CORRECT POSITION
THIS IS 3-RD TIME HAPPENING?
N
TRUCK DRIVER STARTS PUMP
Y
OPERATOR MONITORS PRESSURE IN TANK
END
TANK PRESSURE RAPIDLY RISING?
Y
TRUCK DRIVER STOPS PUMP
OPERATOR OPENS V-103 TILL PRESSURE NORMAL
N


TANK PRESSURE KEEPS RISING
Y
N
6
6
FILLING CONTINUOUS OPERATOR MONITORS LEVEL AND PRESSURE
LEVEL IN TANK REACHES LEVEL HIGH
N
Y
CONTROL SYSTEM WILL CLOSE HV-301, HV-101 SAME POSITION FOR 30 MINUTES.OPERATOR CLOSES HV-101' AND HV-102' AND OPENS V-109 FOR 3 SECONDS EVERY 5 MINUTES WHILE HV-101 IS OPEN.
TRUCK DRIVER STOPS PUMP
OPERATOR CLOSES HV-301 (MANUAL OVERRIDE)
TRUCK DRIVER CLOSES MAIN VALVE ON TRUCK AND VENTS FLEXIBLE HOSE

Description of Maintenance Procedures

(Concerning gas fuel equipment)

1. GENERAL

Depending on the type of maintenance, duration of maintenance, ships location and the condition (pressure) of the LNG storage tanks, which might give an additional hazardous situation, correct precaution should be taken. It is the responsibility of the crew to allocate the type of maintenance in the right category, however 4 levels are defined hereunder, including precautions and limitations.

These types of procedures are not only limited to the planned maintenance, but also apply in case of calamities, such as grounding, collisions etc. Action taken depends on the nature of the calamity, ships location and external facilities.

2.1 MAINTENANCE PROCEDURE- level 1

Descriptions: Services & checks of the LNG installation.

Conditions: The ships' crew will survey the LNG system visually on a weekly basis. Procedures as required according ADN and instructions given by the owner shall be followed. In principle the limitations as given for a tank vessel being **not** gas free is also valid for the LNG storage tank area (for the area: See the hazard zone diagram).

Required precautions: For the LNG system and Power stations the normal maintenance procedures according ADN can be followed.

Limitations: This procedure is suitable for regular maintenance.

(see also chapter 5 of training procedure).

2.2 MAINTENANCE PROCEDURE – level 2

Descriptions: Maintenance, which needs a special permit (for example hot work).

Conditions: Procedures as required according ADN and instructions given by the owner should be followed. Due to the construction of the LNG storage tank, which ensures safe storage, no other requirement are needed as long as the job is outside the hazard zone of the LNG storage tank (for the area: See the hazard zone diagram).

Were specific maintenance is done in the power stations, gas supply must be blocked by the emergency shut down valve as well as the manual supply valve.

Required precautions: Maintenance should be done outside the Hazard zone of the LNG storage tank with cold box. Gas supply should be blocked to the relevant power station if maintenance is done in that area.

Limitations: This procedure is suitable for maintenance outside the LNG storage tanks with cold box and with blocked gas supply to the power stations.

2.3 MAINTENANCE PROCEDURE - level 3

Descriptions: Major maintenance (for example during dry-docking) within the hazard zone area of the LNG storage tanks.

Conditions: Procedures depend on the location (local regulations), the type of work and duration of the work. If dry docking is only done for hull inspection and will take only a few days, LNG storage tanks might stay in normal condition. (level 2)

Required precautions: In case major maintenance is planned, the LNG storage tank should be emptied. For this purpose an empty receiving facility (truck) can be connected to the bunker station. The safety procedures identical for bunkering should be applied. With the pressure build up unit heat can be added to the tank. The pressure in the tank will push the liquefied LNG toward the truck. After emptying the LNG storage tank the tank must be purged by nitrogen (N2) to make the LNG storage tank gas safe.

Limitations: All maintenance can be done which will not effect the construction of the storage tank. Also maintenance of the LNG piping can be done, but only by qualified personal. Before putting the LNG storage tank into operations again, the “First filling procedure” must be followed.

2.4 MAINTENANCE – level 4

Descriptions: Major maintenance which might effect the construction of the LNG holding tank. (for example: steel repair in close vicinity of the LNG storage tank)

Conditions: If the gas free condition of the LNG holding tank is insufficient, alternatively the LNG storage tanks can be removed from the vessel. Following steps should be taken:

Required precautions:

- De-bunkering of the LNG storage tank.
- Purging of the LNG storage tank with inert gas.
- Disconnecting of the control system (control air & automation).
- Disconnection of (1) LNG bunker cross-over’s, (2) GAS cross-over, (3) GAS consumption line.
- Disconnect the heating water supply and return line.
- Lose the tank from the deck foundation and prepare for transport.

Limitations: There are no limitations since the LNG storage tank(s) is (are) removed. Before putting the LNG storage tank into operations again, the first filling procedure must be followed.

3.1 FIRST FILLING PROCEDURE

Before the tank is filled with LNG for the first time (at new build and each time after the tank is completely emptied), the following procedure has to be followed.

The storage tank should first be filled with liquid nitrogen. This is done for:

- Cool the storage tank down, so that it can be filled with LNG.
- Tests of all alarm and control functions

This procedure must be done under supervision of an expert (for instance the tank manufacturer). Special attentions should be given to adjustment of alarms and controls.

Afterwards the tank(s) can safely be filled with LNG.

Version 11-10-2011

Description of the training of the crew on board of LNG driven inland waterway vessels

A. Purpose of the course

The main purpose of the course is to familiarise the crew of inland waterway vessels with the properties and hazards of LNG and to get knowledge how to work with LNG as fuel onboard the vessel. For instance in case of bunkering and maintenance.

The course will include a theoretical part, consisting of the topics mentioned under B and a practical training on board the vessel in which the theoretical items will be dealt with in practice.

B. The LNG course will cover the following topics:

1. Legislation

1.1 General legislation / best practice for ADN, ROSR, European Directive EU 2006/87 and new developments
1.2 Available international legislation concerning LNG (for seagoing / best practices) IMO, IMDG and new developments
1.3 Provisional rules of Lloyds Register
1.4 Legislation concerning health and safety
1.5 Local regulations and permits

2. Introduction to LNG

2.1 The definition of LNG, critical temperatures, LNG hazards, atmospheric conditions
2.2 Compositions and qualities of LNG, LNG- quality certificates
2.3 MSDS (safety sheet): physical / product characteristics

3. Safety

3.1 Hazards and risks
3.2 Risk management
3.3 The use of personal protection

4. The techniques of the installation

4.1 Explanation of the effects of liquefied natural gas
4.2. Temperatures and pressures
4.3 Valves and automatic controls, ATEX
4.4. Alarms
4.5 Materials (hoses, pressure relief valves)
4.6 Ventilation

5. Service & checks of the LNG installation

5.1 Daily maintenance
5.2 Weekly maintenance

5.3 Periodical maintenance
5.4 Failures

6. Bunkering of LNG (see attached procedure)

6.1 Bunkering procedure LNG
6.4 Gas freeing / flushing of the LNG system
6.5 Check lists and delivery certificate

7. Maintenance (see attached procedure)

7.1 Gas free certificate
7.2 Gas freeing / flushing of the LNG system before docking
7.2 Inerting of the LNG system
7.3 Procedure de-bunkering of the bunker tank
7.4 First filling of the LNG bunker tank (cool down)
7.5 Start up after dock period

8. Emergency Scenario's

8.1 Emergency plan
8.2 LNG Spill on deck
8.3 LNG skin contact
8.4 Release of natural gas on deck
8.5 Release of natural gas in enclosed spaces (power stations)
8.6 Fire on deck in the vicinity of the LNG storage tank.
8.7 Fire in engine rooms
8.8 Specific hazard in case of transport of dangerous goods
8.9 Grounding/collision of the vessel

C. The LNG training on board will cover the following topics

9. Description of practical training on board:

9.1 Get familiarised with the content of the ships management system, in particular the chapters concerning the LNG installation.
9.2 Check safety awareness and the use of safety equipment for LNG
9.3 Awareness of monitoring, controls and alarms of the LNG installation on board.
9.4 Awareness of maintenance and control procedures of the LNG installation.
9.5 Awareness and familiarisation with the bunker procedure (preferable in practice)
9.6 Awareness of the maintenance procedures for docking
9.7 Awareness of the emergency scenarios