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)**

30 October 2011

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

Proposal for a derogation regarding the use of LNG for propulsion - Argonon

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 “Argonon” (yard no. 07 KHO 169 of Trico Shipyard Rotterdam, European vessel identification number 02334277), 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

MTS Argonon

HAZARD IDENTIFICATION STUDY

Liquefied Natural Gas powered inland waterways chemical tanker

Report No. ROT/11.M.0080
Issue: 2
Date: 23 May 2011

Lloyd's Register	Technical Report Document Page		
1. Report No. **ROT/11.M.0080/WVE**	2. Report date **1 February 2011**	3. Revision date **23 May 2011**	4. Type of report **HAZID Report**
5. Title & Subtitle **MTS Argonon** **HAZARD IDENTIFICATION STUDY** **Liquefied Natural Gas powered inland waterways chemical tanker**			6. Security classification of this report **Commercial in Confidence** 7. Security classification of this page **Commercial in Confidence**
8. Author(s) **P A Stanney** **Machinery Specialist** **London Design Support** **LR EMEA**			9. Authorisation W. Verdonk **W Verdonk** **Surveyor** **Rotterdam Design Support** **LR EMEA**
10. Reporting organisation name and address **Lloyd's Register EMEA** **Weena-Zuid 170** **3012 NC Rotterdam**			11. Reporting organisation reference(s) **Reissued for errata** 12. This report supersedes **ROT/11.M.0080 Issue 1 (1 February 2011)**
13. Sponsoring organisation name and address **Deen Shipping BV** **Veerplein 22** **3331 LE ZWIJNDRECHT**			14. Sponsoring organisation reference(s) 15. No. of pages 55

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 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. The tank pressure slowly increases and pushes the vaporised and warmed gas towards the machinery space.
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 space is well ventilated to ensure that the gas is diluted with air to well below its explosive limit.
3. In case of gas leaks the machinery must be stopped. Arrangements must be provided to ensure that propulsion and essential services are maintained.

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 Appendix3 section5 (What if Technique) addressing the hazards defined in section 3.2 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.

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 clearance for the deck mounted tank when the vessel passes under bridges. (see Appendix 3)

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 Deen Shipping 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 tank

The storage tank and gas processing equipment is installed on the centre line of the ship on the main deck above the cargo tanks in a designated gas dangerous zone just aft of the cargo manifold.
The storage tank proposed is a double walled, vacuum insulated design which will be designed and constructed in accordance with the EU Pressure Equipment Directive (PED). 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. Two LNG supply lines run from the coldbox on main deck to the engine room.

1.2.2 Machinery room arrangement

In the engine room, two dual fuelled engines (Caterpillar DF3512) will supply power for the propulsion system. Two LNG powered gas turbine generator sets (Capstone C30) provide auxiliary power.

The engine room ventilation system is arranged such that any foreseeable gas leakage in the engine room will not result in a hazardous situation. A CFD analysis has been carried out to demonstrate that any gas leaking from gas filled equipment in the engine room will be diluted below the LEL and evacuated directly through the roof mounted exhaust fan, clear of all non Ex rated electrical equipment. The analysis also demonstrates that there are no stagnant areas where gas could accumulate within the engine room.
The ventilation system proposed does not include a hood over the equipment, but consists of inlet and extraction fans and booster fans in the engine room to improve the flow. Engine room pressure is below atmospheric pressure.

1.3 IMO/Marine Regulations

A list of applicable marine Rules and relevant standards is given in Section 5.

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 was 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 Hilton hotel in Rotterdam over two sessions on the 11/12 October and 29th November 2010. 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 ship owner, LNG tank designer, Design specialists and LR Specialists. (see Appendix 1 for attendees). The plans that were examined are listed in Appendix 2.

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 5. 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 4. 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 and thermal loads. Such tanks are not required to have a secondary barrier.
The alternative proposal for MTS Argonon 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.
The alternative arrangement was considered acceptable by the HAZID team.

The tank extends above the level of the bow and the wheelhouse (when the wheelhouse is lowered). This presents a hazard when passing under bridges and the result of collision could be catastrophic. This can be controlled by operating procedures to ensure sufficient clearance but additional security e.g. breakaway should be considered.

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 tank will be fitted with two independent tank level gauges to provide additional security when the tank is being filled.

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 over pressurising 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.
The bunkering system that was proposed at the HAZID was manual, with the vessel's 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.

Port and Stbd. bunkering manifolds are located at least 2m from the ship side. LNG bunkering manifolds are normally at the ship side and any leakage will be close to the ship side rather than directly on deck. This issue was not resolved and was left open.

In the follow up of this HAZID an automated bunkering procedure was proposed, in which operator supervision and intervention is still required, but some tasks are now controlled by the automation system. The most important ones are maintaining stable pressure in the tank and the purging of the bunkering lines. The revised plan and procedure are subject to plan approval and do not affect this approval in principle.

4.2 Pressure Build Up (PBU) and Gas Processing Equipment.

The PBU system is largely automatic but it may be necessary to have a manual override to anticipate any large load changes on the engine. 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.

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 equipment is located within the cold box and therefore the possibility of mechanical damage is unlikely. There is a possibility of 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 spill 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

Two dual fuel Caterpillar engines (DF3512) are installed in the machinery space together with two small gas fuel only gas turbines (C30 Capstone). The supply pressure into the machinery space to the equipment is 2 bar nominal (3 bar maximum pressure). At the engines the pressure is first reduced to 100 mbar and than to 0 bar at the zero pressure regulator valve prior to mixing with the combustion air. At the gas turbine the pressure is reduced to less than 1 bar before the LNG enters the gas Turbine package.
The gas pipework within the machinery space is single walled of all welded construction but pipe joints, flanges, seals e.t.c. may leak. The area around the pipework and machinery is therefore considered gas dangerous and all electrical equipment should be Ex rated.

The ventilation system proposed consists of one exhaust fan above the gas turbine in the centre of the machinery space and supply fans arranged around the edge of the space. The CFD analysis demonstrated that gas released from a failed pipe after the master gas valve closed would be effectively exhausted from the machinery space.

The information provided at the HAZID was considered insufficient and it was requested that the CFD analysis be reworked such that a continuous leak from a failed component would similarly be exhausted from the machinery space without any gas coming into contact with non Ex equipment.

It was agreed that main concept should be that machinery space is maintained gas safe. To accept the machinery arrangement without a hood over the machinery and single walled piping inside engine room, the effect of the ventilation on the definition of the hazardous zones must be taken into account in accordance with IEC 60079-10-1. (BS EN 60079-10-1 is the same). This standard gives a method to determine that even though a hazardous zone would be expected, there is no hazardous area in practice based on the degree and level of availability of the ventilation.

It must be demonstrated that all areas where gas may be released are effectively ventilated and the resulting diluted gas mixture is effectively evacuated from the space with no stagnant areas for gas to accumulate. In this way any leakage of gas cannot come into contact with non Ex rated equipment.

Analysis should take into account a continuous (undetected) gas leak from the single walled pipe and from the flanges and valve at the gas inlet combinations for engines/turbine.

Degree of ventilation may depend on available units. Any one fan or booster could be out of order; either ventilation should remain adequate in accordance with the standard or failure of any unit should close master valve. After the HAZID work is being continued on this issue. And both the configuration of the system as the CFD are left to be reviewed.

4.4 Gas fuelled machinery

The machinery consists of two Caterpillar ‘zero pressure’ type dual fuel engines and two small gas turbine generators running on natural gas. In addition there is a forward engine room with diesel engines which generate electrical power and which can also can propel the ship at navigable speed.

As the ship only has one LNG tank then a single failure could put all gas fuelled machinery out of action. In this case normal propulsion would be maintained with the dual fuel engines running on oil fuel to maintain propulsion and the forward generators supplying essential auxiliary services.

The ‘zero pressure’ gas inlet system introduces gas at zero pressure. Gas is sucked into the air inlet stream before the turbocharger and 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 lambda 2 mixture strength i.e. 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 was raised by the members of the team.

The gas piping in the engine room is single walled. Using the single failure criteria we must assume that this piping/machinery may leak gas into the machinery space with the possibility of explosion. The machinery space ventilation is to be assessed for compliance with IEC60079 to ensure that no stagnant areas exist for gas to accumulate and that the maximum assumed gas leak is diluted to below the LEL and led directly to the exhaust fan and away from any source of ignition. (See also section 4.3 above).

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

HAZID Attendees m.t.s. ARGONON
Day 1 and 2: 11 and 12 October 2010, Hilton Hotel, Rotterdam
Day 3: 29 November 2010, LR Office, Rotterdam

Company	Name	Role	Day 1	Day 2	Day 3
Deen Shipping	G.C.M. Deen	Owner	Y	Y	Y
Deen Shipping	Klaas den Braven	Project Manager	Y	Y	Y
Pon Power B.V.	Ben Timmerman	Dual Fuel Engine & Gas Turbine	N	N	Y
Pon Power B.V.	Gerhard Groot Enzerink	Dual Fuel Engine & Gas Turbine	N	N	Y
Pon Power B.V.	Damy Barendse	Dual Fuel Engine & Gas Turbine			Y
Cryonorm	Hans Stuker	Expert LNG tank, LNG vaporiser and associated control	Y	Y	Y
Windex	Peter de Ruijter	Ventilation system ER	Y	Y	N
INEC	N. Mihailovic	Designer	N	N	N
Trico	Peter Snijders	Yard	Y	Y	Y
Transafe	Marcel Kind	Safety Advisor for owner	Y	N	Y
Electric marine Support	Ronald Hamstra	Electrical Designer	Y	Y	Y
Lloyd’s Register	Paul Stanney	Facilitator	Y	Y	Y
Lloyd’s Register	Willemien Verdonk	LR Machinery Expert	Y	Y	Y
Lloyd’s Register	J. Dubois	LR Machinery Expert	Y	Y	Y
Lloyd’s Register	Gerard Vromans	LR Electrical & Control Expert	Y	Y	Y
Lloyd’s Register	Liviu Porumb	LR Electrical & Control Expert/Scribe	Y	Y	Y
Lloyd’s Register	John Papadantonakis	LR Electrical & Control Expert/Scribe	Y	Y	Y
IVW	Leendert Korvink	Flag Authority Representative	Y	N	N
IVW	Mark Berkers	Flag Authority Representative	N	Y	Y
Lloyd’s Register	Arie Fredrikze	Attending Surveyor	Y	N	N

Appendix 2 List of Plans

Day 1 and 2		**11 and 12 October 2010**	
DWG No.	**Rev.**	**Description**	
		DF3512 Engine - Tekeningen Pakket	PON
		Capstone C65ICHP Micro Gasturbine	PON
400-000	A	LNG Pipeline Diagram	MSN
4000-01 / 06	A	Double Wall System DN25-DN50 Typical Assembly	MSN
S10-014	06.10.2010	Ventilation Argonon (CFD)	Windex/BUNOVA
1002-110	7	P&ID LNG/CNG Fuel System Deen shipping	Cryonorm
1002-XXX-XX	1	LNG/CNG Fuel System Deen shipping - Assembly	Cryonorm
EMS-10.01.43	1	Motortankschip / Machinekamer AS	Cryonorm/EMS
CN2010QT0-04	0	LNG FUEL TANK WITH WWB VAPORISER (PFD)	Cryonorm
5823-111	-	Fuel Oil System (PSI)	PSI
5823-113	-	Cooling Water System (PSI)	PSI
5823-110	-	Bilge fi-fi deckwash layout	PSI
5823-760	c	Deck layout sht1/2/3	PSI
30822-000	E	General arrangement	INEC
Day 3		**29 November 2010**	
DWG No.	**Rev.**	**Description**	
400-000	B	LNG Pipeline Diagram	MSN
1002-110 sheets 1&2	8	P&ID LNG/CNG Fuel System Deen shipping	Cryonorm
5823-113	-	Cooling Water System (PSI)	PSI
none	05.10.2010	P&ID 3512DF Fuelgas Line	PON
none	25.11.2010	Capstone C30 + Heat Recovery	PON
S10-018	29.10.2010	Ventilation Argonon (CFD)	Windex/BUNOVA

Appendix 3 Follow up actions

1. The tank location on the main deck, extending above the level of the wheelhouse in the retracted position should be re-examined with a view to providing protection/alarms or other mitigating measures in case of collision with a bridge. Proposals remain to be discussed with LR.

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. Subsequent to the HAZID a proposal has been made to provide automatic bunkering arrangements. This is outside the scope of LR Rules and statutory requirements but is an essential safety issue. Before LR could consider this arrangement a formal Failure Modes and Effects analysis on the bunkering automation systems will be required. The decision on whether and under what conditions automated bunkering is acceptable is a matter for the flag state.

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

Appendix 4 Safety actions register

No safety actions were raised

Appendix 5 HAZID Work Sheets

System: LNG Tank design and location	Drawing: P&ID LNG Fuel System (CRYONORM)	HAZID sheet 1
Area: Cargo area	Revision: 1002-110 Rev 7	11 and 12 October 2010
Equipment : LNG supply		

ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
In operation mode					
1.1. Rupture					
1.1.1.	Failure of tank in normal service.	Leakage of LNG	Cracking of carbon steel deck due to low temp./fire/explosion.	Tank to be designed in accordance with EN13458-2 2002 Cryogenic vessels – static, vacuum, insulated vessel Part 2: but with additional applied loadings. Additional loading are taken from the requirements for liftable wheelhouses. Tank is fitted with baffle plates to prevent sloshing at partial filling as per transportable tanks. LNG tank is to be designed for maximum longitudinal , horizontal and vertical accelerations expected during operation (see above). Outer tank is designed as a secondary barrier and constructed of 316L s/s material	Additional loadings due to ship motion will be :- 10 deg. Static roll 2g longitudinal acceleration. 1g horiz. 1g vert.

System: LNG Tank design and location			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 1
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
				suitable for the minimum temperature of the cargo. Pressure relief is provided on the outer tank by a blow out disc; all inlet outlet pipes run between the inner and outer tank, no possible leak onto the deck.	
1.1.2.	Excessive applied loads due to ship motion	Leakage of LNG	Cracked deck/fire/explosion.	Vessel is currently designed for 2g longitudinal, 1g horizontal and vertical and static 10° roll; (see 1.1.1.)	Tank support at deck to be further considered with regards to longitudinal forces.
1.1.3.	Excess pressure due to overfilling	Tank failure	Cracked deck/fire/explosion.	See bunkering spreadsheet.	
1.1.4.	High nozzle loadings	Fracture of nozzle	Cracked deck/fire/explosion.	All nozzles are within the secondary barrier and no external pipe work loads are applied to inner tank.	
1.1.5.	Ship deflection	Fracture of tank	Cracked deck/fire/explosion.	Tanks is not rigidly welded to deck, ship deflections are not transferred to tank.	
1.1.6.	Rupture of pipework in cold box	Release of LNG/gas	Cracked deck/fire/explosion	Rupture of pipework within cold box is very unlikely. No applied loads. Controlled environment. Tank root valves can be closed and automatic valves will close on gas detection.	

System: LNG Tank design and location			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 1
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
1.2 Leakage					
1.2.1.	External leaking flanges/pipe connections	LNG dripping onto deck	Cracked deck/fire/explosion,	Leakage from inner tank is contained within outer tank. Leakage in cold box will trigger remote and automatic shutdown of isolation valves by temperature sensor located in drip tray;	Material of drip tray to be suitable for LNG liquid and to be sized such that it can contain all LNG released before and after tank automatic valves close. Arrangements of drip tray to be made such that spilling on deck of LNG is not possible. Manually operated root valves at tank of liquid phase to be operable from an easily accessible position within the cold box.
1.2.2.	Valves leaking in line	Uncontrolled flow of LNG	Loss of control	Temp./pressure sensors will detect error and shut down system.	Root valves to be adjacent to tank.and operable from an easily accessible location.
1.2.3.	Tank level gauge leakage	LNG/gas leak	Fire/explosion	Location inside the cold box but visible from outside, each with valve top and bottom.	Calibrations to be done in accordance with expected ship trim.

System: LNG Tank design and location			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 1
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
1.3 Corrosion / erosion	Wear in valve spindles/seals	Leakage in valve spindles/discs.	LNG leakage	No corrosion expected. No erosion expected.	Inner tank is 304L and outer tank 316L, low temperature properties. Corrosion not expected.
1.4 Impact					
1.4.1.	Tank hits fixed structure e.g. bridge	Rupture of the inner and outer tank walls causes large release of LNG/Gas.	Cracked deck/fire/explosion	Operational responsibility	IVW recommendation: Tank height to be always available at bridge. This is considered a major issue and should be acceptable to the IVW authorities.
1.4.2.	Hose handling, cargo operation from cranes.	Rupture of the tank	Outside tank deformation	It is expected that inner tank survives based on previous recorded truck road accidents cases.	
1.5 Fire / Explosion					
1.5.1.	External cause	Heat build-up	Heat build-up, relief valve opens	4x fifi monitors on deck, , 1 x main fifi line, additional sprinklers on tank mainly used for cooling tanks; Safety relief valves are not rated	Gas supply to be manually emergency shut-downed. Blackout recovery from forward machinery space including fifi pump; Relief valve / pipe outlet 2m above cargo

System: LNG Tank design and location			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 1
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
				for the fire condition as this is not required by EN13458-2 2002 Cryogenic vessels – static, vacuum, insulated vessel. Cargo area of vessel is protected by water spray system and this is also used to cool the LNG tank. No special Fire fighting arrangements for the LNG tank.	area according to ADN Rules. Relief valves calculations to be assessed. Action Cryonorm Projects. Quantity of drencher water to be sufficient to cool LNG tank to prevent relief valves operating.
1.6 Structural integrity					
1.6.1.	Impact with fixed structure	Discharge of LNG	Fire / explosion	Double wall of tank means tank has inherent resistance to impact.	See 1.4 above. As tank extends above the level of the wheelhouse in the lowered position, other possible mitigating measures e.g. tank breakaway to be considered.

System: LNG Tank design and location			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 1
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG supply					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
1.7 Mechanical failure					
1.7.1.	Failure of valves/fittings	System is uncontrolled	various		An FMEA to be carried out in order to establish failure modes and effects for remote operated valves, sensors, control system.
1.7.2.	Degradation of insulation due to settling and vibration	Loss of thermal insulation, loss of vacuum	Icing	Can be seen visually, requires maintenance, overhaul.	
1.8 Control / electrical failure					
1.8.1.	Blackout, wire break, short-circuit, software	Safety control loss	Control over valves lost, pressure and level indicators malfunction;	All tank isolation valves are fail safe close at blackout; spring charged; all electrical items Ex d; additional valve at filling line is foreseen because LNG tank is required to be filled from either side of ship; at blackout, at control panel then general alarm sounds and audible on deck.	See bunkering spreadsheet 2.1.2 Bunkering valve will fail close.

System: LNG Tank design and location	Drawing: P&ID LNG Fuel System (CRYONORM)	HAZID sheet 1
Area: Cargo area	Revision: 1002-110 Rev 7	11 and 12 October 2010
Equipment : LNG supply		

ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
1.9 Human Error					
1.9.1.	Valve V-9 open during bunkering	LNG enters vent system	Liquid spill on vent line, Relief valve not working		Operational procedure for bunkering. Additional temperature sensor in V-9 line will be fitted in order to close V-9 at liquid detection.
1.9.2.	Incorrect operation			No catastrophic failure is foreseen due to operator error. Tank filling valves will close on high-high signal.	Operators will be trained for LNG propelled vessels.
1.9.3.	Low temperature injuries			Valves have extended handle control. Touching low temperature pipework will not result in serious human injury.	Operation issue. Warning notice at cold box.
1.10 Manufacturing defects					LNG tank will be constructed under survey regime at the Surveyor's satisfaction.
1.12 Material selection					LNG tank will be constructed under survey regime at the Surveyor's satisfaction.
1.13 Survey regime				Prescribed in the manufacturer's manual; visual inspection; lifecycle expected for 20+ years; pressure testing possible with nitrogen including safety valves; measurement of outer tank temperature;	Survey requirements are to be established and verified;

System: LNG bunkering system			Drawing: 1002-110_P&ID LNG Fuel System (CRYONORM)		HAZID sheet 2
Area: Cargo area			Revision: Rev 7		11 and 12 October 2010
Equipment : LNG supply			Additional Document: 1002-660-0_LNG Trailer to tank Filling Procedure		
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
Bunkering system					
2. Alongside					
2.1.1 Rupture	Overpressure bunkering lines, Ship movement	LNG liquid spill, movement of bunkering hose	Operator injury, liquid on deck	Bunker hose not responsibility of ship. Bunker hoses belong to delivery truck. Rules require remote control fail safe close valve in bunkering manifold, with manual operation.	Use breaking cables 1m shorter than hose length to activate self sealing break away coupling at the manifold and hose. More details for bunkering are necessary. Manifold connection needs to be strong enough to sustain maximum load imposed by hose. Bunker supply lines are to be rated for full supply pressure (aprox. 18 bar).
2.1.2.	Excess pressure in bunkering tank			At high pressure HV-1 shuts down. At high-high level HV-1 shut downs.	Additional stop valve required to close automatically on independent high level or high pressure alarm Proposal for bunkering system is required.

System: LNG bunkering system			Drawing: 1002-110_P&ID LNG Fuel System (CRYONORM)		HAZID sheet 2
Area: Cargo area			Revision: Rev 7		11 and 12 October 2010
Equipment : LNG supply			Additional Document: 1002-660-0_LNG Trailer to tank Filling Procedure		
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
2.2 Leakage					
2.2.1.	Leaking flanges/pipe connections / break away coupling	Dripping onto deck Bunkering manifold will not be installed at ship side. It will be 2+ meters inboard.	Steel freezing	Drip trays to be fitted under the break away coupling with capacity for volume within coupling.	Break away coupling to be installed on ship side.
2.2.2.	Valves leaking in line	Gas release		Second valve in loading pipe is foreseen at manifold, but two automatic valves may cause problems.	
2.2.3.	Air enters tank because the port and starboard bunker lines are not effectively purged prior to loading.	Hazardous atmosphere. Condensation	Valves freezing	Thorough purging prior to filling.	Effective purging to be carried out on the bunker manifold not in use.
2.3 Corrosion / erosion				Stainless steel material for pipes / valves. No corrosion/erosion foreseen.	Materials suitable for -196°C

System: LNG bunkering system			Drawing: 1002-110_P&ID LNG Fuel System (CRYONORM)		HAZID sheet 2
Area: Cargo area			Revision: Rev 7		11 and 12 October 2010
Equipment : LNG supply			Additional Document: 1002-660-0_LNG Trailer to tank Filling Procedure		
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
2.4 Impact	Collision	Gas release	Fire	Manifold inboard minimum 2m, AND(R)	
2.5 Fire / Explosion	External cause	Fire		Stop bunkering, emergency manual shut down bunkering ESD valves	See also sheet 1. comments
2.6 Structural integrity	Temperature and pressure variation in bunker lines.	fracture	LNG leak		Stress analysis to be carried out on bunkering lines to check there is sufficient flexibility. Pipework at manifold to be suitably strengthened.
2.8 Control / electrical failure	Blackout	Loss of control		HV-1 fail close with mechanical spring.	
	sensor failure	Incorrect pressure reading	Tank overpressure.	Arrangements for testing pressure transmitters to be incorporated. Relief valves relieve pressure.	
	Sensor failure	Incorrect level	Tank overfilling/overpressure. Potentially catastrophic	Two independent level alarms fitted. Both alarms close inlet valve on high-high tank level.	

System: LNG bunkering system			Drawing: 1002-110_P&ID LNG Fuel System (CRYONORM)		HAZID sheet 2
Area: Cargo area			Revision: Rev 7		11 and 12 October 2010
Equipment : LNG supply			Additional Document: 1002-660-0_LNG Trailer to tank Filling Procedure		
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
2.9 Human Error					
2.9.1.	Incorrect operation at valve V-9	Liquid passing at venting system	Liquid falling on deck	Temperature sensor to detect liquid in pipe will be fitted.	
2.9.2.	Low temperature injuries	Damage to skin	Serious injury will not happen if low temperature pipework is touched inadvertently.		Proper PPE equipment required
2.9.3	Bunkering procedure not followeed	Bad communication ship/shore	High pressure or high level in tank. System should fail safe.		Proper communication system ship – shore required
2.10 Manufacturin g defects	Out of spec materials	Material failure		Piping to be manufactured under survey	
2.12 Material selection				All pipe work stainless steel	System manufactured under survey.

System: PBU/Gas conditioning system			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 3/4
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3. Pressure build up (PBU)					
Underway					
3.1. Rupture					
3.1.1.	Mechanical damage to pipework	Leakage of LNG	Fire/explosion, cracking of carbon steel.	PBU pipework is within cold box. It is in a protected environment. No external loads are imposed on the pipework. Short pipe work runs with continuous welded construction. Liquid line can be shut off at tank root valve or automatically. Pipe operates at the design pressure of the tank which is less than design pressure of pipework. Rupture of the pipework is considered very unlikely.	Pipe joints to be full penetration butt welded and subject to suitable NDE to the Surveyors satisfaction.
3.1.2.	Corrosion/erosion	Leakage of LNG	Fire/explosion, cracking of steel.	The pipework is 316L material and no corrosion/erosion is expected	

System: PBU/Gas conditioning system			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 3/4
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3.2 Leakage					
3.2.1.	Leaking flanges/pipe connections	Dripping onto deck		See 1.2.1.	Tank isolating valves are to be visible and readily accessible in case of leakage.
3.2.2.	Valves leaking in line	PCV51 leaking in line	Pressure in tank is not controlled.	V-19 is sized such that it cannot release more gas than the tank safety relief valves can handle so pressure cannot build up more than the tank pressure relief valve settings.	
3.2.3.	Internal leaking heat exchanger V-80 to cooling system	Gas in machinery space	Gas release from header tank and level rise	Gas detection at header tank	
3.3 Corrosion / erosion				Stainless steel construction. No corrosion or erosion expected.	
3.4 Impact				All components are within the cold box so protected from impact	
3.5 Fire / Explosion				At emergency stop HV51 will shut down and stop the system	

System: PBU/Gas conditioning system			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 3/4
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3.6 Structural integrity				Components have a design pressure suitable for the maximum working pressure to which they may be subjected.	
3.7 Mechanical failure					
3.7.1.	Failure of valves/fittings			Mechanical failure will not result in unsafe operation. System will shut down and propulsion will be maintained using oil fuel.	
3.8 Control / electrical failure					
3.8.1.	Blackout, control system fail			Valve HV51 closes, valve PCV51 is self regulating at 3 bar	

System: PBU/Gas conditioning system			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 3/4
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
3.9 Human Error	Incorrect operation			System is automatic and no human error is expected	
3.9.1.	Closure of valve V19	Pressure build up in PBV-51 above design pressure.	Burst tubes/pipes	System is protected by PSV11 but this is only a small thermal relief valve.	PSV11 to be sized for maximum volume of gas that might be generated in PBV-51 when V-19 is closed inadvertently.
3.9.2.	Low temperature injuries			All pipework is within the cold box.	Warning sign to placed at cold box entrance.
3.10 Manufacturing defects					System to be constructed under survey to the Surveyors satisfaction.
3.11 Material selection					System to be designed by the tank supplier. Materials specified will be suitable for the proposed application.

System: PBU/Gas conditioning system			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 3/4
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
4. Gas conditioning system for D.G. and gas turbine					
Underway					
4.1. Rupture					
4.1.1.	Mechanical damage	Leakage of LNG	Fire/explosion, cracking of steel.	All components are within the cold box and working under design conditions. SSV-1 or SSV-2 will protect system against failed pipe work. Lines from to tank can be shut off by manual root valves at tank. These valves are easily accessible inside the cold box.Pipe operates at up to the design pressure of the tank which is less than the design pressure of the pipework.	Pipe joints to be full penetration butt welded and subject to suitable NDE to the Surveyors satisfaction.

System: PBU/Gas conditioning system			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 3/4
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
4.1.2.	Corrosion/erosion	Leakage of LNG	Fire/explosion, cracking of steel.	The pipework is 316L material and no corrosion/erosion is expected	
4.1.3.	Rupture in heat exchanger	Freezing of heat exchanger	Gas in engine room, overpressure of water side.	3 temperature sensors at heat exchanger monitoring. Valve HV-50 closes on low temperature.	
4.2 Leakage					
4.2.1.	Leaking flanges/pipe connections	Dripping onto deck		See 1.2.1.	
4.2.2.	Valves leaking in line	Uncontrolled flow		Tank root valve and multiple valves in series Double block and before gas enters engine.	
4.3 Corrosion / erosion				Stainless steel 316L piping. No corrosion/erosion expected.	

System: PBU/Gas conditioning system			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 3/4
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
4.4 Impact					
4.4.1.	Pipe damage in gas connection pipe on deck	Gas leakage	Fire/explosion	Pipe in gas dangerous zone. Gas supply can be shut off remotely by SSV-1/2.	
4.5 Fire/Explosion				System will be shut down and isolated automatically or manually. Valves SSV-1/2 will close.	
4.6 Structural integrity				Components have a design pressure suitable for the maximum working pressure to which they may be subjected.	
4.7 Mechanical failure					
4.7.1.	Failure of valves/fittings			Mechanical failure will not result in unsafe operation. System will shut down and propulsion will be maintained using oil fuel.	

System: PBU/Gas conditioning system			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 3/4
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
4.8 Control / electrical failure					
4.8.1.	SSV-1 fails	Trapped liquid	Pipe damage/no gas supply	SSV-1 and HV50 closed, liquid trapped will be released through vent valve	Thermal relief valves TRV5&15 to be sized such that they can relieve the gas generated by the heaters when the heaters are inadvertently isolated.
4.8.2.	SSV-1 closes	Trapped liquid/no gas supply	Pipe damage/no gas supply	Valve SSV-1/2 are self closing in event of control system failure	In the event of blackout, the forward diesels must start automatically.
4.9 Human Error					No manual control is required or is possible for the system.
4.9.1.	Incorrect operation			System is automatic and no human intervention is required. If manual valves are closed in error then system is protected by relief valves.	

System: PBU/Gas conditioning system			Drawing: P&ID LNG Fuel System (CRYONORM)		HAZID sheet 3/4
Area: Cargo area			Revision: 1002-110 Rev 7		11 and 12 October 2010
Equipment : LNG system					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
4.9.2.	Low temperature injuries			All cold pipework is within the cold box.	Warning sign to be placed at cold box entrance.
4.10 Manufacturing defects					System to be constructed under survey to the Surveyors satisfaction.
4.11 Material selection					Materials specified will be suitable for the proposed application.

System: Gas turbine			Drawing: Capstone C30 + heat recovery		HAZID sheet 5
Area: Machinery space			Revision: - (25.11.2010)		29 November 2010
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
Gas turbine arrangement					
Continuous operation underway					
5.1 Rupture					
5.1.1	Blade rupture	Flying parts	Personnel injury/loss of power.	Turbine is built inside recuperator; this provided blade containment shield. blades are one piece casting; 40.000h lifetime / replacement	
5.1.2.	Casing rupture	Flying parts	Fire/explosion/Personnel injury/loss of power	See comment above. Recouperator will protect operator from casing rupture.	

System: Gas turbine			Drawing: Capstone C30 + heat recovery		HAZID sheet 5
Area: Machinery space			Revision: - (25.11.2010)		29 November 2010
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
5.2 Leakage					
5.2.1.	Leaking flanges/pipe connections within the ventilated box	gas and ventilation air mixture	Fire/explosion	ventilation box air ducted to engine room exhaust fan fan is to be spark free	Gas detection within ventilated box
	leaking flanges / pipe connections outside the ventilated box	gas escape	Fire/explosion	to be treated in a similar way to gas pipes on main engines CFD analysis in accordance with IEC 60079-1.	
5.2.2.	Valves leaking in line	Gas cannot be shut off	Engine cannot be shut down.		Block and bleed system to be fitted in gas supply pipe
5.2.3.	Gas leaking into intake	Incorrect gas/air ratio	Engine malfunction/cannot be shut down	Turbine monitoring systems will detect and shut down turbine	

System: Gas turbine			Drawing: Capstone C30 + heat recovery		HAZID sheet 5
Area: Machinery space			Revision: - (25.11.2010)		29 November 2010
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
5.3 Corrosion/ erosion					No corrosion issues are expected
5.4 Fire/Explosion					
1.4.1.	Explosion in engine room	Structural damage to high speed rotating equipment	Personnel injury	Ventilation arrangements will ensure that there can be no build up of flammable gas in the engine room	
5.5 Structural integrity					See casing rupture above
5.6 Mechanical failure				Every 40.000h replacement of engine core	
5.6.1.	Flameout	Unburnt air/gas to pass into uptake	Explosion in uptake	Gas will be shut off automatically and mixture vented by air flow through turbine	
5.6.2.	Failure of valves/fittings in fuel inlet reducing valve	high pressure at gas compressor inlet	unknown		effect to be investigated and risk mitigated

System: Gas turbine			Drawing: Capstone C30 + heat recovery		HAZID sheet 5
Area: Machinery space			Revision: - (25.11.2010)		29 November 2010
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
	Major mechanical failure of engine	Loss of power/ High speed parts ejected.	Loss of power/ personnel injury	Recouperator provides protection from ejection of main rotating parts. Second turbine is available.	
	Failure of ventilation	temperature increase	failure of electronics	temperature measured with temperature sensors; shut down system on high temperature;	
5.7 Control/electrical failure					
5.7.1.	Failure of turbine control systems	Loss of control of turbine	Loss of power/damage	Turbine is designed to shut down on loss of control. UPS system will supply power until other generating capacity is on line.	
5.7.2.	Parallel operation			Capstones not parallel with diesel generators	
5.8 Human Error					
5.8.1.	Incorrect operation			Turbines are automatic with no human intervention required.	

System: LNG machinery room arrangement - ventilation and gas detection	Drawing: 400-00_LNG Pipeline Diagram	HAZID sheet 6
Area: Machinery space	Revision: A	29 November 2010
Equipment : Machinery		

ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
Machinery arrangement					
Continuous operation underway					
6.1. Rupture					
6.1.1	Double walled pipe section	Failure of inner pipe	Gas release	Gas inlet pipes are double walled up to the engine. Nitrogen inside double walled pipe with pressure alarm.	IWW application to be further considered with regards to automatic shut-down of gas valve and purging with nitrogen.
6.1.2	Single walled pipe at engine			Proper support and robust design so complete rupture is not being considered. System rated 16 bar with working pressure 2 bar. Partial failure of pipe through cracks, seals e.t.c. is considered below under 11.2	

System: LNG machinery room arrangement - ventilation and gas detection			Drawing: 400-00_LNG Pipeline Diagram		HAZID sheet 6
Area: Machinery space			Revision: A		29 November 2010
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
6.2 Leakage					
6.2.1.	Leaking flanges/pipe connections			No flanges in double walled pipe. This is butt welded. Engine room CFD modelling of airflow shows that foreseeable leaks are taken away and diluted below LEL as per IEC standards and that no stagnant areas exist within machinery space for gas to accumulate.. Gas detectors with alarms will be installed at suitable locations within the engine room and exhaust duct. Trace gas dosing such that gas leakage will be easily identifiable by the operator will be employed.	The requirement for double walled pipe up to the master valve will be further considered. The CFD calaculation will be reworked in accordance with IEC standards.
6.2.2.	Valves leaking in line			Valves in machinery spaces are double block and bleed.	

System: LNG machinery room arrangement - ventilation and gas detection	Drawing: 400-00_LNG Pipeline Diagram	HAZID sheet 6
Area: Machinery space	Revision: A	29 November 2010
Equipment : Machinery		

ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
6.3 Corrosion / erosion				Pipe is 316L stainless steel. No corrosion or erosion is expected.	
6.4 Fire / Explosion	Engine room fire			Fire detection, shut gas off, stop engine, shut ventilation, close air openings and release extinguishing media.	Smoke detection to be such placed that detection is ensured.
6.4.1.				All pipe material is steel. Zero pressure reducing valve is of aluminium material. This is of thick walled construction and downstream of the block and bleed system. Gas supply will be shut down in event of fire.	
6.5 Structural integrity				Working pressure 2/5 bar. All components will have a considerably higher design pressure.	
6.6 Mechanical failure					

System: LNG machinery room arrangement - ventilation and gas detection			Drawing: 400-00_LNG Pipeline Diagram		HAZID sheet 6
Area: Machinery space			Revision: A		29 November 2010
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
6.6.1.	Failure of valves/fittings			External leakage will be detected by gas alarms. Block and bleed system will prevent in line leakage.	
6.6.2.	Major mechanical failure of engine			Engine will shut down. Propulsion on remaining engine or forward machinery.	
6.6.3.	Failure of ventilation	One fan failure		Failure of one supply fan will not seriously affect the effectiveness of the ventilation. Failure of the exhaust fan will not degrade the ventilation to a level where it is unsafe to operate the machinery.	
6.7 Control / electrical failure		Short-circuit at main switchboard	blackout	Gas will be stopped manually/automatically.	
6.8 Human Error					
6.8.1.	Incorrect operation			Proper training for personnel operating dual fuel engines. No dangerous condition is foreseen with incorrect manual operation.	

System: LNG machinery room arrangement - ventilation and gas detection			Drawing: 400-00_LNG Pipeline Diagram		HAZID sheet 6
Area: Machinery space			Revision: A		29 November 2010
Equipment : Machinery					
ITEM	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
6.10 Manufacturing defects				Machinery to be constructed under Survey.	
6.11 Material selection					
6.12.Escape				Covered by flag regulations.	
6.13. Flooding				Bilge detection will be installed	
6.14. Docking maintenance				Gas turbine to remain operational in order to control the tank pressure. Ventilation must remain operational even with gas turbine off unless pipeline is purged.	
6.15. Commissioning trials				System will be tested and commissioned under the supervision of LR to the satisfaction of the Surveyor.	

System: Dual fuel engine arrangement			Drawing: P&ID 3512DF Fuel Gas Line		HAZID sheet 7
Area: Machinery space			Revision: (-) (5-10-2010)		29 November 2010
Equipment : Dual fuel engine			Also: 400-00_LNG Pipeline Diagram (Rev B) and 1002-110_P&ID LNG Fuel System (Rev 8)		
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
Dual fuel engine and gas supply.					
Underway					
7.1. Rupture					
7.1.1.	Failure of low pressure supply pipe	Leakage of gas	Fire/explosion, cracking steel.		dedicated master shut-off valve located before pipe enters cofferdam (on deck). Pipes will be double walled within the cofferdam. The maximum pressure in the pipe will be 2 bar up to the reducing /shutdown valve. Inerting of the inner pipe is not considered necessary due to the volume of gas in the pipe. Single walled pipe section operates at 100mbar and rupture is not considered likely in this area. A leak in the single walled pipe in the engine room will be assessed in accordance with IED standards by way of CFD analysis.

System: Dual fuel engine arrangement			Drawing: P&ID 3512DF Fuel Gas Line		HAZID sheet 7
Area: Machinery space			Revision: (-) (5-10-2010)		29 November 2010
Equipment : Dual fuel engine			Also: 400-00_LNG Pipeline Diagram (Rev B) and 1002-110_P&ID LNG Fuel System (Rev 8)		
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
					low pressure block and bleed vent pipe to be led to vicinity of engine room ventilation fan; minimum design pressure of various components including block and bleed to be 3 bar; high pressure alarm and shutdown required to protect the reducing valve, activated around 120 mbar.
7.1.2.	Failure of inlet duct				flexible hose is designed for a pressure 16 bar, considered sufficient robust. failure will cause no gas release due to shutdown of valves SV003 and SV002. Failure of this component will be addressed by CFD analysis.
7.1.3.	Failure of manifold			gas / air mixture is below explosion range and auto-ignition temperature is higher than expected temperature at failure of compressor (~500-600 degrees) due to aluminium construction. in case of air filter differential pressure then air pressure sensor will adjust the zero regulator valve and may shut-down and use 100% diesel fuel. Steel bearings are outside gas air stream. Compressor side failure is monitored by outlet	

System: Dual fuel engine arrangement			Drawing: P&ID 3512DF Fuel Gas Line		HAZID sheet 7
Area: Machinery space			Revision: (-) (5-10-2010)		29 November 2010
Equipment : Dual fuel engine			Also: 400-00_LNG Pipeline Diagram (Rev B) and 1002-110_P&ID LNG Fuel System (Rev 8)		
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
				pressure/temperature and will shut down the gas supply if outside limits. Standard turbo-charger with good reliability records. Casing failures not anticipated.	
7.1.4.	Failure of aftercooler	leakage of tubes	Mixture air / gas into the low temperature coolant circuit. Leakage of water into cylinder.	not dangerous air/gas mixture vented through pressure valve. Leakage will be obvious by level change. header tank location in engine room casing. Good airflow around tank.	considered fitting gas detector in low temperature cooling water expansion tank
7.1.5	Unburnt gas in exhaust.	Failure of exhaust due to explosion.	Personal injury/machinery failure	Unburnt mixture will be very weak and cannot ignite. Turbocharger ensures very good mixing of air and gas so no gas pockets.	
7.2 Leakage					

System: Dual fuel engine arrangement			Drawing: P&ID 3512DF Fuel Gas Line		HAZID sheet 7
Area: Machinery space			Revision: (-) (5-10-2010)		29 November 2010
Equipment : Dual fuel engine			Also: 400-00_LNG Pipeline Diagram (Rev B) and 1002-110_P&ID LNG Fuel System (Rev 8)		
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
7.2.1.	Leaking flanges/pipe connections	Release of gas	Explosion	CFD analysis to demonstrate adequate air flow over leaking flanges/pipes and compliance with IED standard	
7.2.2.	Leaking valves/fugitive emissions	Release of gas	Valves worn, no particular indication.	CFD analysis to demonstrate adequate air flow over leaking valves.	THT ‘odorising unit’ fitted will give indication of small leaks when gas flows through the pipes. Gas detectors will be fitted
7.2.3.	Valves leaking in line	gas will enter inlet duct when there is no air low	explosion mixture in inlet duct	block and bleed valves fitted; any leakage vented outside;	
7.2.4.	Gas leaking into inlet duct through carburettor	gas entering inlet duct	explosion	gas can only be turned on when engine is operating on diesel, in this condition no gas built up is possible into inlet duct	
7.2.5.	Crankcase seals/vents			gas component in crankcase is similar to the exhaust side; crankcase will vent outside machinery space;	
7.2.6.	Leakage of cylinders into exhaust system	flammable gas mixture into exhaust	explosion	-PASTOR detection of irregular flywheel angular speed; -exhaust gas temperature detection; -any leakage will be burned in oxidation catalyst; -temperature/pressure before and after catalyser; - quality of mixture: gas air mixing is done before the engine and turbocharger so good	

System: Dual fuel engine arrangement			Drawing: P&ID 3512DF Fuel Gas Line		HAZID sheet 7
Area: Machinery space			Revision: (-) (5-10-2010)		29 November 2010
Equipment : Dual fuel engine			Also: 400-00_LNG Pipeline Diagram (Rev B) and 1002-110_P&ID LNG Fuel System (Rev 8)		
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
				mixture quality is ensured even with a faulty cylinder. Charge in cylinder is homogeneous with a lambda value 2 therefore it cannot explosion in exhaust duct.	
7.3 Corrosion/erosion				No particular corrosion issues are expected.	
7.4 Impact				Machinery will be within machinery space and protected from external impact.	
7.5 Fire/Explosion					
7.5.1.	Misfire	Explosion in inlet duct			See previous comments
7.5.2.	Misfire/damaged exhaust valve	Explosion in exhaust			See previous comments
7.6 Structural integrity	Major engine damage	Personal injury/loss of propulsion		Two engines are installed. Personal injury will be similar to a conventional oil fuel engine.	

System: Dual fuel engine arrangement			Drawing: P&ID 3512DF Fuel Gas Line		HAZID sheet 7
Area: Machinery space			Revision: (-) (5-10-2010)		29 November 2010
Equipment : Dual fuel engine			Also: 400-00_LNG Pipeline Diagram (Rev B) and 1002-110_P&ID LNG Fuel System (Rev 8)		
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
7.7 Mechanical failure					
7.7.1.	Failure t/c	Personal injury/loss of propulsion		Two engines are installed. Personal injury will be similar to a conventional oil fuel engine.	
7.7.2	Failure of inlet/exhaust valves				See previous comments
7.8 Control/electrical failure					
7.8.1.	faulty control signal; signal out or range; signal deviation;	poor gas combustion	loss of power	programmable Kronos system will shut down gas supply and change over to diesel fuel.	
7.8.2	blackout	loss of control; loss of ventilation		-UPS 30kW to supply also engine room fans; up to 10-15 minutes of operation; - engine running on 24V battery; - front generators will start and re-supply;	

System: Dual fuel engine arrangement			Drawing: P&ID 3512DF Fuel Gas Line		HAZID sheet 7
Area: Machinery space			Revision: (-) (5-10-2010)		29 November 2010
Equipment : Dual fuel engine			Also: 400-00_LNG Pipeline Diagram (Rev B) and 1002-110_P&ID LNG Fuel System (Rev 8)		
ITEM/guide	CAUSE	HAZARD	POTENTIAL EFFECTS	SAFEGUARDS	RECOMMENDATIONS
7.8.3	emergency shut down	loss propulsion blackout	loss of manoeuvring loss of auxiliary generators	- LNG supply shut off at master valves; - change over to diesel fuel operation automatic on loss of gas supply - UPS provided, front generators will start	
7.9 Human Error					
7.9.1.	Incorrect operation			Gas fuelled operation is automatic and no human intervention is required. In case of failure, gas is shut off and engine runs on oil fuel.	

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.

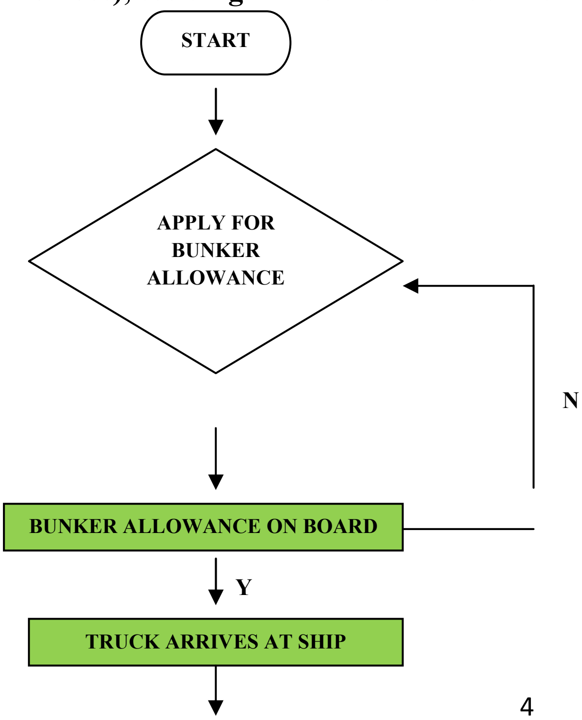
<u>DEFINITIONS</u> :

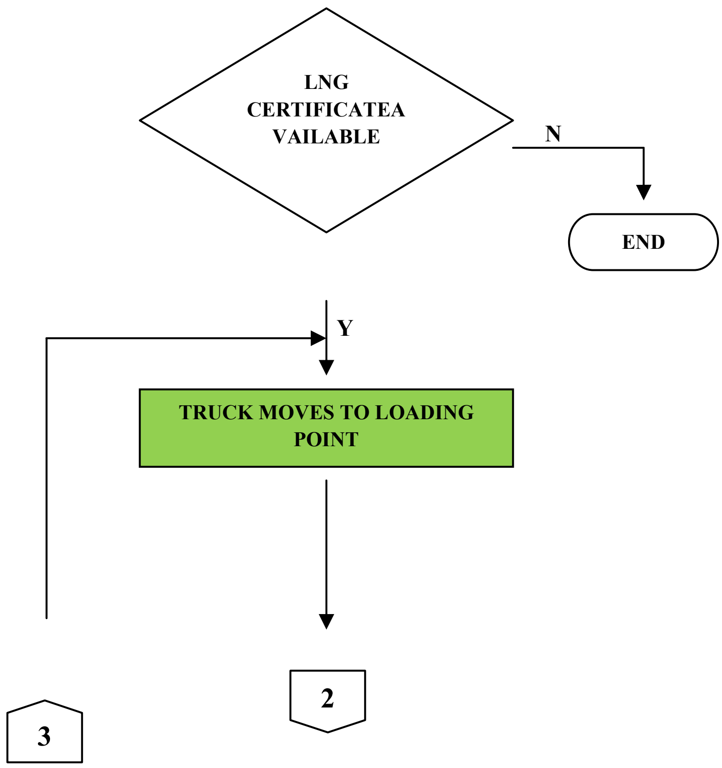
"Operator" = The master or the person mandated by him

" Driver" = The driver of the truck

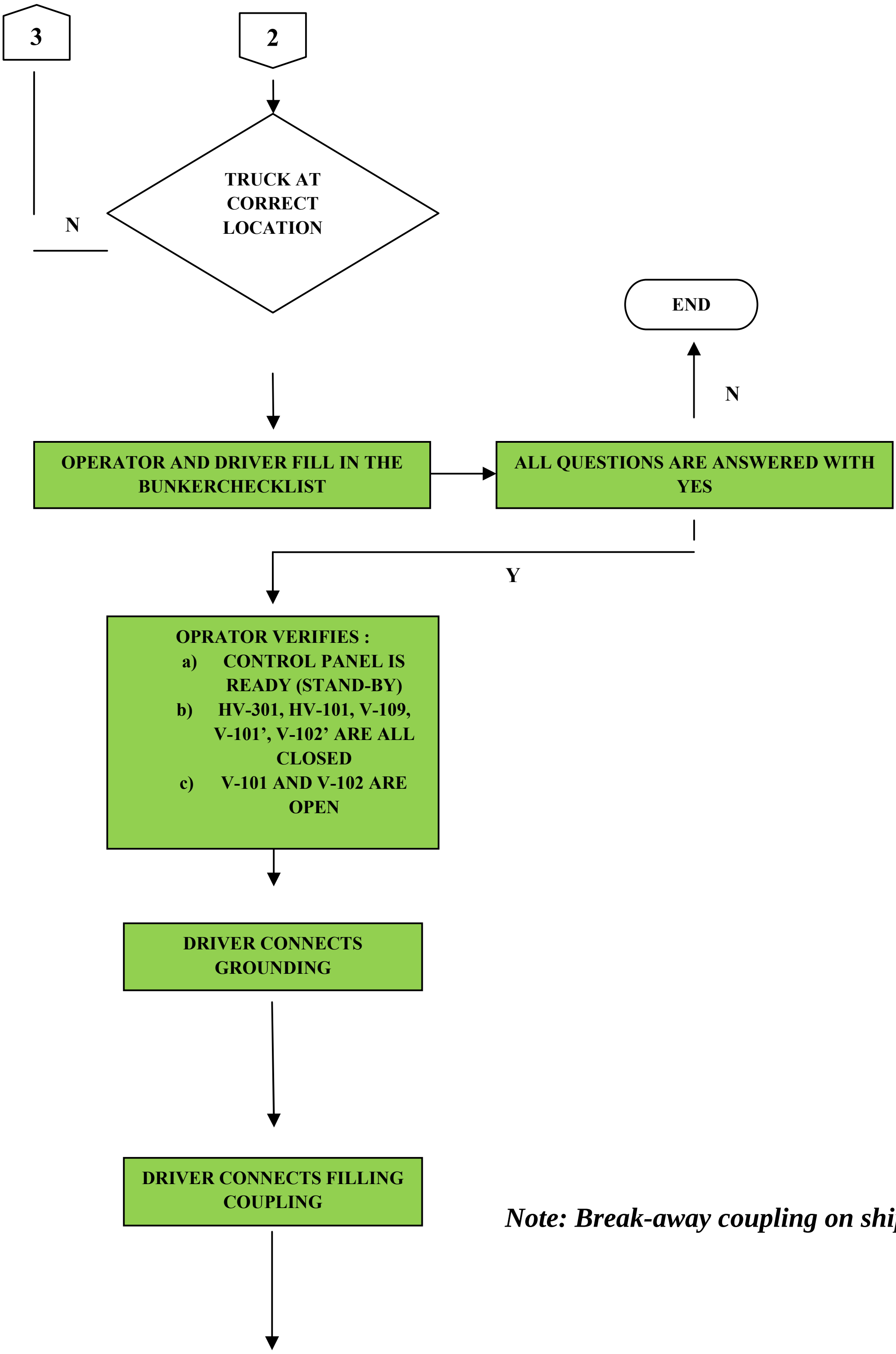
The following procedure describes the filling sequence and actions for filling the on-board Starboard storage tank with LNG coming from a road trailer, through the starboard bunker connection of the ship (through valve HV-301 and valve HV-101).

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.

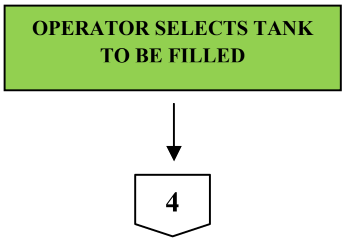


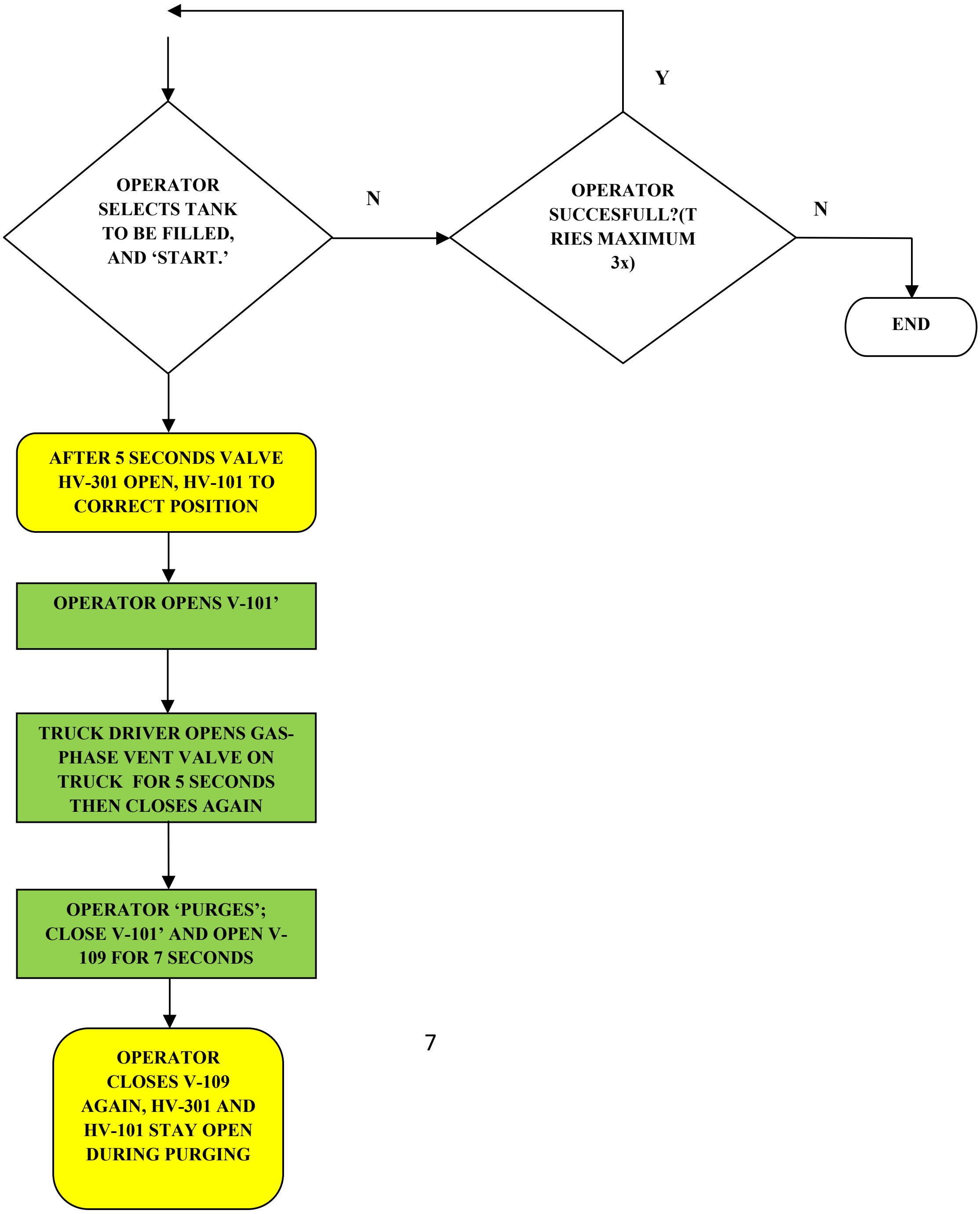


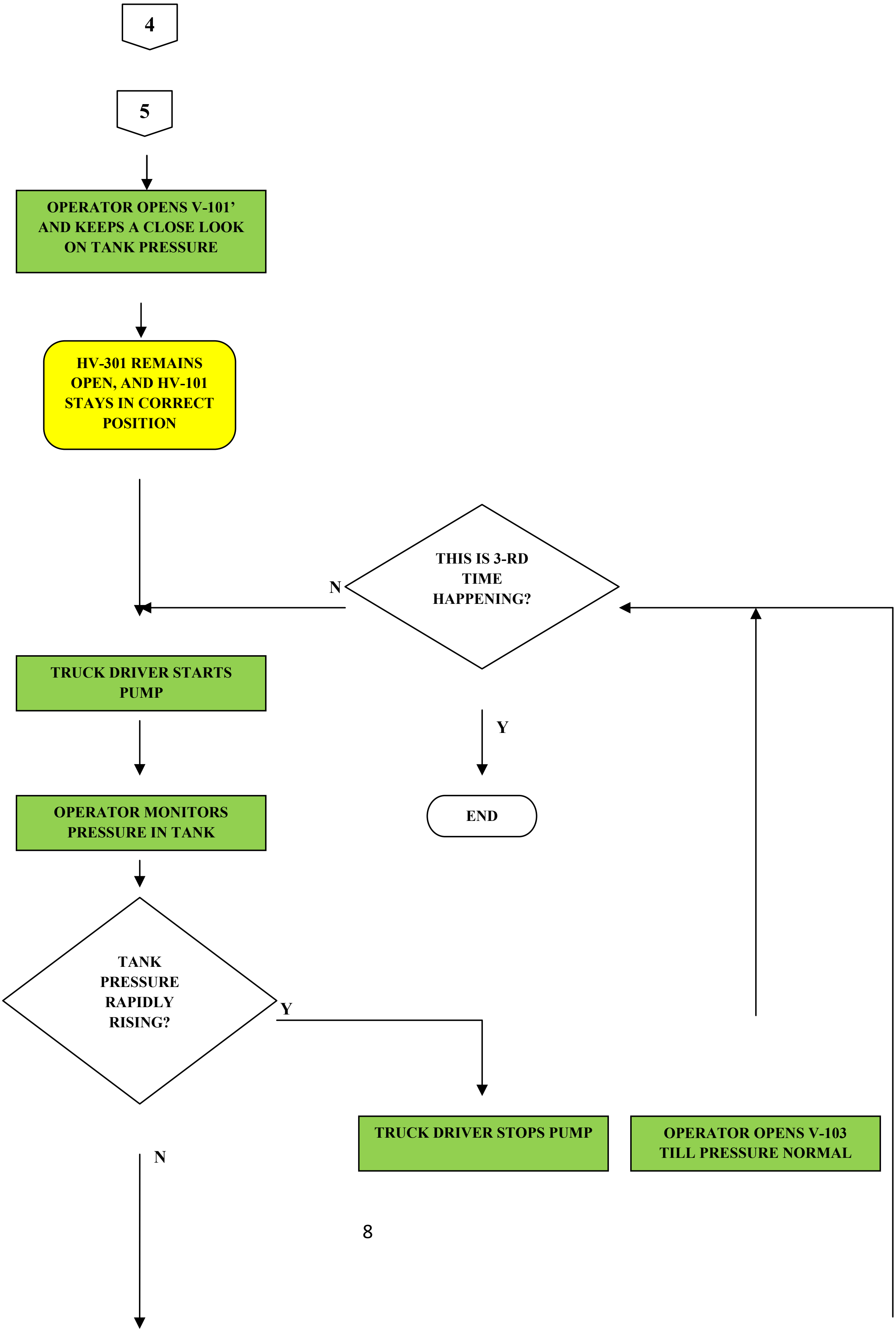
LNG CERTIFICATEA VAILABLE
N
END
Y
TRUCK MOVES TO LOADING POINT
3
2

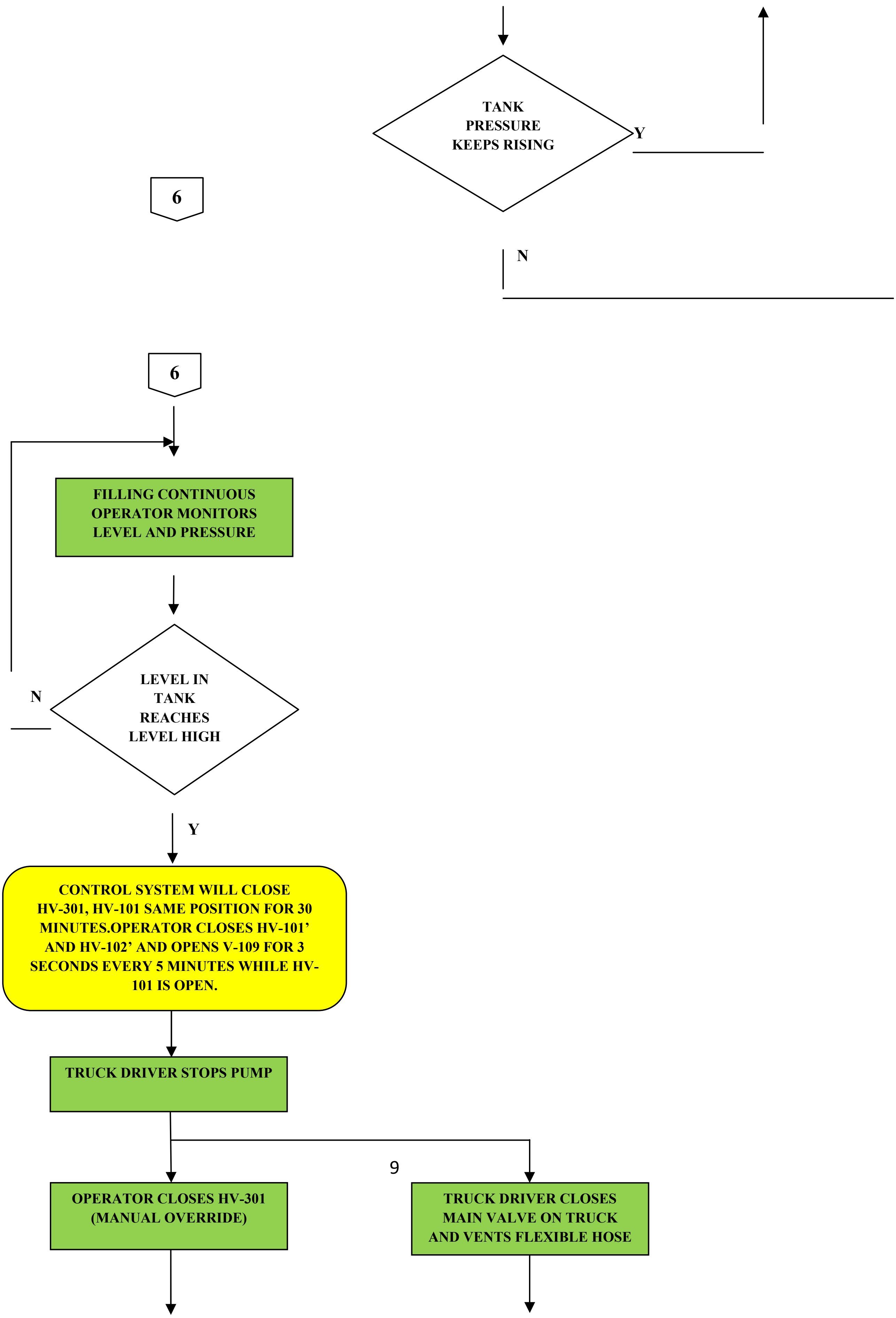


Note: Break-away coupling on ship’s side of hose


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
Y
END
TRUCK DRIVER STARTS
PUMP
OPERATOR MONITORS
PRESSURE IN TANK
TANK
PRESSURE
RAPIDLY
RISING?
Y
N
TRUCK DRIVER STOPS PUMP
OPERATOR OPENS V-103
TILL PRESSURE NORMAL


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: Procedures as required according ADN and instructions given by the owner should 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