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)

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Item 7 of the provisional agenda
Special authorizations, derogations and equivalents

Appendix 1 to document ECE/TRANS/WP.15/AC.2/2011/38 on the use of liquefied natural gas as a fuel

Transmitted by the Government of the Netherlands

UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE (UN-ECE)

RECOMMENDATIONS TO INSPECTION BODIES

RELATING TO THE ADN REGULATIONS

RECOMMENDATION No. xx/2011

of xx xx 2011

ad Article 7.2.3.31.1, Article 7.2.3.41.3, Article 9.3.x.31.1 and Article 9.3.x.41.2

Liquefied Natural Gas to be used as fuel for the vessels' propulsion

Pursuant to Article 7.2.3.31.1, Article 7.2.3.41.3, Article 9.3.x.31.1 and Article 9.3.x.41.2 of the ADN Regulations, the tanker vessel "Argonon" (yard no. 07 KHO 169 of Trico Shipyard Rotterdam, European vessel identification number to be obtained) is authorised to use Liquefied Natural Gas (LNG) as fuel for the propulsion installation, subject to the following conditions:

1. The vessel fully complies with the regulations of the ADN, except for the following.

2. Both diesel oil and LNG will be used for the vessels' propulsion installation. The flashpoint of LNG however, is below 55 degrees Celsius, as prescribed in Article 7.2.3.31.1, Article 7.2.3.41.3, Article 9.3.x.31.1 and Article 9.3.x.41.2. A HAZID assessment has been carried out by Lloyd's Register to determine the safety of the system and to adopt the measures to be taken to have a similar safety level as for diesel fuelled vessels. The HAZID report is attached.

Attachments:

- Report No. ROT/11.M.0080 Issue 2, dated May 23rd 2011, including drawings used during the HAZID assessment
- Drawing 30883-0000-G Rev. H Argonon General Arrangement
- Drawing 30883-0200-D-Argonon-B Arrangement LNG Pipelines Diagram
- Drawing 1002-110-11 PID Sh.1_2_3

Grounds for Recommendation

Procedure:

The vessel has to comply with all statutory regulations applicable for inland waterway vessels such as RVIR (or EU Directive 2006/87) and ADN. Also the Lloyd's Register Rules and Regulations for the classification of Inland Waterway Ships are applicable.

However, both RVIR and ADN don't allow the use of fuel with a flashpoint below 55 degrees Celsius. Arrangements not complying with the Regulations are to be proposed to the CCNR and UN-ECE and could be accepted provided the alternative arrangement is at least as safe as conventional arrangements accepted under RVIR; i.e. it needs to be demonstrated that the level of safety is the same as that of a diesel powered vessel.

The procedure as proposed by Lloyd's Register and discussed with the Netherlands Shipping Inspectorate is to examine the LNG system arrangements against existing legislation and requirements as far as applicable, such as IGF Code (IMO Resolution 285(86)) and the Lloyd's Register Provisional Rules for Methane Gas Fuelled Ships.

As part of the approval the safety of the LNG system has been assessed by performing a HAZID study which uses the 'What if Technique' as defined in IMO MSC 392 Appendix 3, Section 5.

This leads to the following steps being taken:

1. Concept design of the LNG propulsion system reviewed by Lloyd's Register.
2. Plans updates by the designer.
3. The hazards associated with the arrangements have been considered by a Hazard Identification Study (HAZID) which has been facilitated by Lloyd's Register. The influence of ship operations and conditions, environmental conditions, auxiliary systems (power, cooling water) and failure (human error, machinery, control) have been considered.
4. HAZID report issued by Lloyd's Register. It is considered that none of the issues raised in the HAZID prevent an acceptance in principle. Safety actions and other recommendations need to be resolved and are to be submitted to Lloyd's Register.
5. The engineering is continued and the plans are updated. New plans to be send to Lloyd's Register for plan approval in which Safety Actions and recommendations as reported by HAZID report are solved, added and incorporated.
6. Approval of plans in which the verification of compliance to the Lloyd's Register Rules, HAZID conclusions and other applicable requirements are being dealt with.
7. The system will be built under survey, and tested by Lloyd's Register.

LNG system:

The requirements used for the design of the LNG system are:

- Rules and Regulations for the Classification of Inland Waterways Ships, Lloyd's Register November 2008.
- Provisional Rules for the Classification of Methane Gas Fuelled Ships, Lloyd's Register January 2007.
- Interim Guidelines for Natural Gas-Fuelled engine installations in ships, IMO Resolution MSC 285(86) (IGF Code).
- Rules and Regulations for the Classification of Ships (Part 7, Chapter 16), Requirements for Machinery and Engineering Systems of Unconventional Design, Lloyd’s Register.
- Cryogenic vessel - Static vacuum insulated vessels Part 2: Design, fabrication, inspection and testing (EN13458-2).
- Classification of Hazardous areas: IEC 60079-1: Electrical apparatus for explosive gas atmospheres – Part 10.

It is allowed to use either single-walled or double-walled piping in LNG systems. In case of double-walled piping the outer wall is considered as a second barrier and for

insulation purposes. For this system single-wall piping is used. The stainless steel cold box is considered as second barrier. The cold box is of a very compact design resulting in maintaining the desired thermal insulation of the piping system.

The piping on deck is protected against mechanical damage. A second barrier is considered not necessary here because the piping is in the open air.

The piping in the engine room is also single-walled. The Computational Fluid Dynamics (CFD) Analysis has shown that in case of a gas leakage in the engine room there never will be an explosive atmosphere. The piping in the engine room is all welded without flanges.

The connection between the storage tank and the Pressure Build Up Unit is by means of piping in the tank bottom.

The piping system is designed in a way that the connection from the tank to the first valve is as short as possible:

- The valve is situated within the radius of the curved end of the storage tank and inside the cold box, so the risk of mechanical damage is minimized.
- All valves in piping which can contain fluids are redundant. The first valve is always manually operated.
- The second valve is automatically operated, and closes immediately in case of an alarm. The valves are situated inside the cold box, and can be operated from outside the cold box.

The cold box is fitted with temperature and gas detection alarms which automatically shut down the valves. All valves are of an approved cryogenic type.

During the normal operation of the LNG system it’s not necessary to enter the cold box. All valves used for operational and control devices are accessible from outside the cold box. The entrance to the cold box is only permitted to competent persons anyway.

The LNG system is designed in a way that LNG leakage will never occur. The used safety devices prevent the leakage of LNG in a single failure event.

LNG is used permanently during normal operational conditions of the vessel. This prevents a pressure build up in the storage tank.

The LNG piping system is suitable for inerting.

The bunkering manifold is situated more than 6 m from openings and entrances of the accommodation. The distance of the bunkering manifold from the ships' side is at least the same as the distance of the cargo manifolds.

LNG storage tank:

The LNG storage tank is situated on deck. To protect the LNG storage tank the tank is situated behind the bunkering crane or accommodation. The distance to the ships' side is at least 1/5 B.

The distance between the LNG storage tank and the accommodation or wheelhouse is such that additional measures for protecting these are not considered necessary.

The LNG storage tank consists of an inner shell and an outer shell. The space between these stainless steel shells is vacuum insulated and filled with Perlite. This space is fitted with a pressure relief valve to prevent intolerable high pressure in case of leakage from the inner tank.

All piping is located in the space between the two shells. The tank itself is fitted with a pressure relief valve which opens at a pressure of 8 Bar.

All connections are located within the cold box which contains drip tray arrangements to prevent spills on deck.

The open space between the tank bottom and the deck of the ship is sufficient to prevent the deck from being cooled down in an intolerable way.

The LNG storage tank complies with the requirements of EN13458-2, Cryogenic vessel - Static vacuum insulated vessels Part 2: Design, fabrication, inspection and testing. The LNG storage tank is used for storage of the ships' fuel and not as a transport tank. The standard was considered to be an acceptable standard provided additional loadings for installation on board an inland waterway vessel are taken into account. These loadings are based on the requirements for elevating wheelhouses as prescribed in the rules of Lloyd's Register. Baffle plates are fitted to prevent sloshing due to ship motions. According the statement of the tank manufacturer the tank can be considered equivalent to a tank used for transport by car or train.

Engine room:

Contrary to the Lloyd's Register Rules, the IMO Interim Guidelines accept two alternative concepts: gas safe machinery spaces and ESD-protected machinery spaces (Emergency Shut Down). (Refer to Section 2.6 of IMO Resolution MSC.285(86)). In a gas safe machinery space the arrangements are such that the space is considered gas safe under all conditions, normal as well as abnormal conditions; i.e. inherently safe. An ESD machinery space is considered non-hazardous under normal conditions but may have the potential to become hazardous. An emergency shutdown of non safe equipment is automatically executed upon detection of a gas hazard. The machinery space fully complies with the Lloyd's Register Rules.

The Lloyd's Register Provisional Rules for the Classification of Methane Gas Fuelled Ships are based on the gas safe machinery space concept and requires gas fuelled machinery to be located within designated gas safe machinery spaces.

To consider a machinery space in which gas fuelled machinery is located gas safe, Lloyd's Register has requirements on automatic shutdown of master valves outside the machinery space and block and bleed valves at the machinery, ventilation in the machinery space, and gas detection.

By placing the gas fuelled machinery inside a machinery space, this space may become gas hazardous. However, according to IEC standard, it is permitted to have different zone classification if specific arrangements are made for ventilation.

The minimum capacity of the ventilation system for a gas safe machinery space containing gas fuelled machinery is to be based on recognized hazardous area classification standard such as the Classification of Hazardous areas: IEC 60079-1: Electrical apparatus for explosive gas atmospheres – Part 10, and a Computational Fluid Dynamics (EFD) Analysis showing air flow patterns and absence of stagnant areas. In the calculation a leak from a flange is assumed to size the capacity of the ventilation such that if this happens the machinery space remains a safe space.

The ventilation is to be continuously in operation when there is gas fuel in the piping. The capacity of the ventilation system is at least 30 cycles per hour, and the system complies with the requirements for use in gas dangerous areas. The ventilation air is to sweep across the gas fuelled machinery, valves and pipes. When the required air flow can not be maintained, or in the event of total loss of ventilation, the LNG supply to the machinery will close automatically.

The engine room is designed according the ADN Zone requirements as specified on the drawing included as appendix.

Propulsion system:

The vessel is equipped with a redundant main propulsion system. The main engine is a dual-fuel engine and can run on diesel oil only in case the LNG system fails.

In a dead-ship condition the propulsion system can be started with a 24V back-up system. The starting procedures are mentioned in the engine manual.

All engines installed comply with the CCR-II standards.

The safety instructions of the engines are taken over from the manufacturers' manuals and will be included in the ships' safety manual.

The quality of the LNG used is determined by the engine manufacturer.

Alarms:

The engine room is equipped with a gas detection alarm, and the cold box is equipped with a gas detection alarm and a temperature alarm.

All alarms concerning the LNG installation are reported in the wheelhouse and on other places on board where the watch keeper is present.

Fire safety:

The water capacity for cooling of the LNG storage tank according MSC 285(86) is 10 l/min/m2 on horizontal surfaces and 4 l/min/m2 on vertical surfaces (for comparision: the water spray system for cargo tank cooling as prescribed in the ADN 9.3.2.28 is 50 l/hr/m2).

The calculated pump capacity for this cooling system is 48 m3/hr. The installed pump capacity complies with the requirements of this MSC circular.

The fire extinguishing system in the engine room will comply with the requirements of chapter 10 of the RVIR. When a fire in the engine room is detected, the LNG will be shut off. The amount of gas in the piping system in the engine room is too small to be of any influence on the fire. The manufacturer of the extinguishing system has confirmed that the medium used in this system don't need to be adjusted as a result of the presence of this small amount of gas.

Inspection and testing:

It is common industry practice that cryogenic tanks (both transport tanks and static tanks) are not fitted with manholes for internal inspection of the tank. Periodic visual inspection of the outside of the cryogenic tank is considered sufficient.

The tank is made of stainless steel and corrosion caused by the LNG is considered highly unlikely. If there are problems with the inner tank the loss of vacuum is immediately detected, and problems with the insulation are detected by icing on the outside. In either case no immediate danger will occur.

If manholes were fitted, the sealing of the manholes to ensure the vacuum between the inner and outer shell causes more problems than benefits and if this fails it will result in loss of insulation and condensation.

The LNG system will be annually surveyed by Lloyd's Register according the international standards for the storage and use of LNG.

The ships' crew will survey the LNG system visually on a weekly basis. This procedure will be included in the ships' safety manual.

Special equipment:

Personal protection equipment will fully comply with the requirements of the LNG data sheet.

The personal protection equipment, as well as all precautions to be taken will be mentioned in the several procedures as described in the ships' safety manual.

Training:

The ships' crew will be trained on the use of LNG. This is one of the basic assumptions of the HAZID study. The training will contain the hazards of LNG, the bunkering procedure, and the measures to be taken in case of calamities. The suppliers of the engines, the cryogenic storage tank and the LNG system will contribute to this training.

The requirement to follow this training will be included in the ships' safety manual.

Documentation:

The ships' safety manual will contain a separate chapter with all applicable procedures like bunkering, maintenance, inspection, etc. The bunkering procedure has already been discussed in the HAZID study.

All documents and procedures needed for the use of LNG will be established in close cooperation with the suppliers of the various parts of the whole system.

Evaluation:

All data during the operation of the LNG system will be collected. An annually evaluation report will be made and sent to the secretary of the UN-ECE.

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

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16. Summary

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

The objectives of the HAZID were to :-

1. Identify potential hazards associated with the use of LNG as fuel.
2. Comply with Part 7, Chapter16 of Lloyd's Register 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 Manufacturing 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	

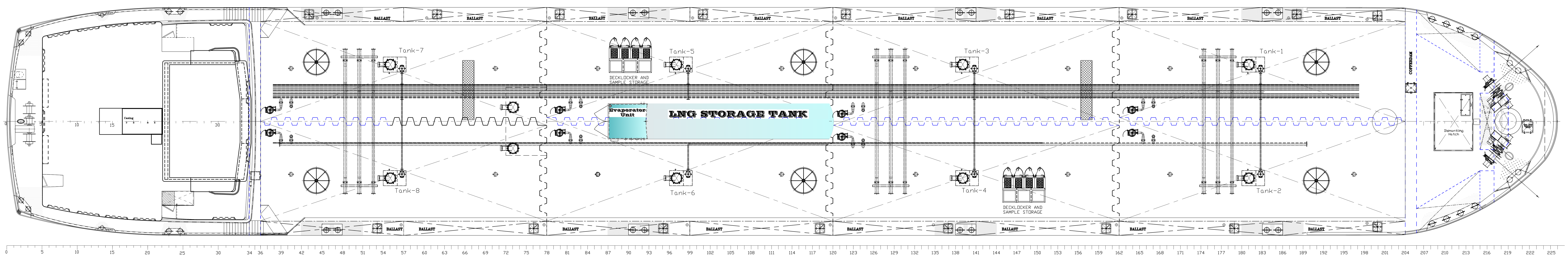
System: Dual fuel engine arrangement			Drawing: P&ID 3512DF Fuel Gas Line		HAZID sheet 7
Area: Machinery space			Revision: (-) (5-10-2010)		29 November 2010
Equipment : Dual fuel engine			Also: 400-00_LNG Pipeline Diagram (Rev B) and 1002-110_P&ID LNG Fuel System (Rev 8)		
ITEM/guide	CAUSE	HAZARD	POTENTIAL 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;	

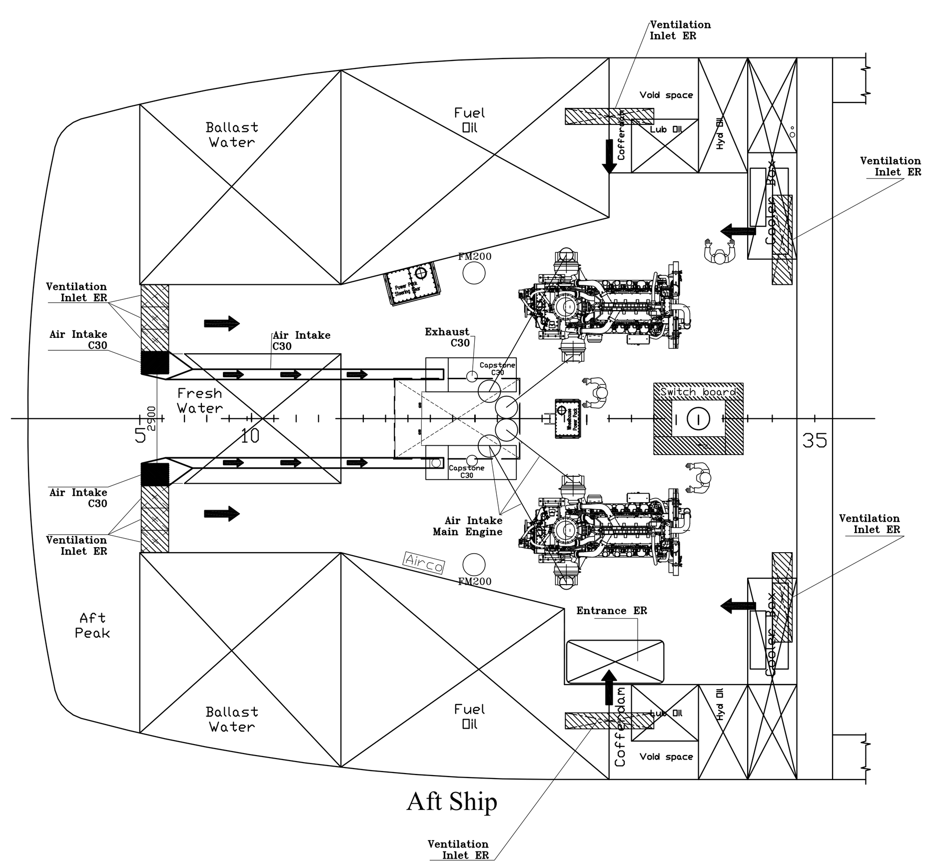
System: Dual fuel engine arrangement			Drawing: P&ID 3512DF Fuel Gas Line		HAZID sheet 7
Area: Machinery space			Revision: (-) (5-10-2010)		29 November 2010
Equipment : Dual fuel engine			Also: 400-00_LNG Pipeline Diagram (Rev B) and 1002-110_P&ID LNG Fuel System (Rev 8)		
ITEM/guide	CAUSE	HAZARD	POTENTIAL 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.	

SIDE VIEW

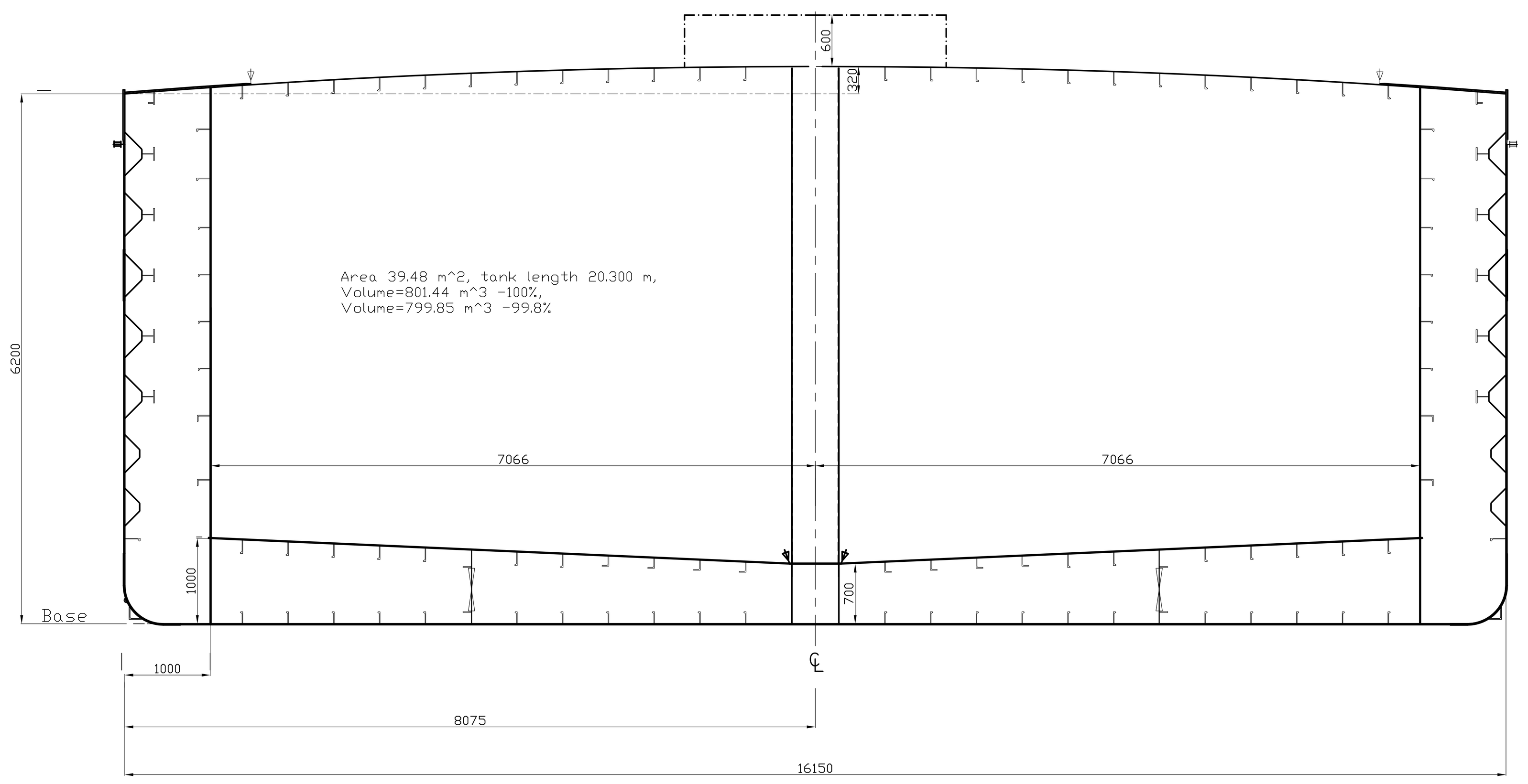
TOP VIEW



Aft Ship

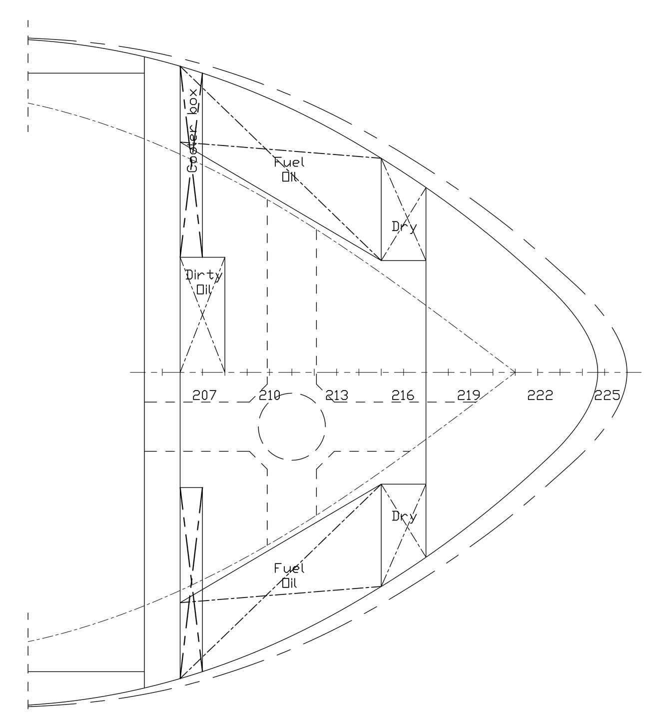


Cross Section



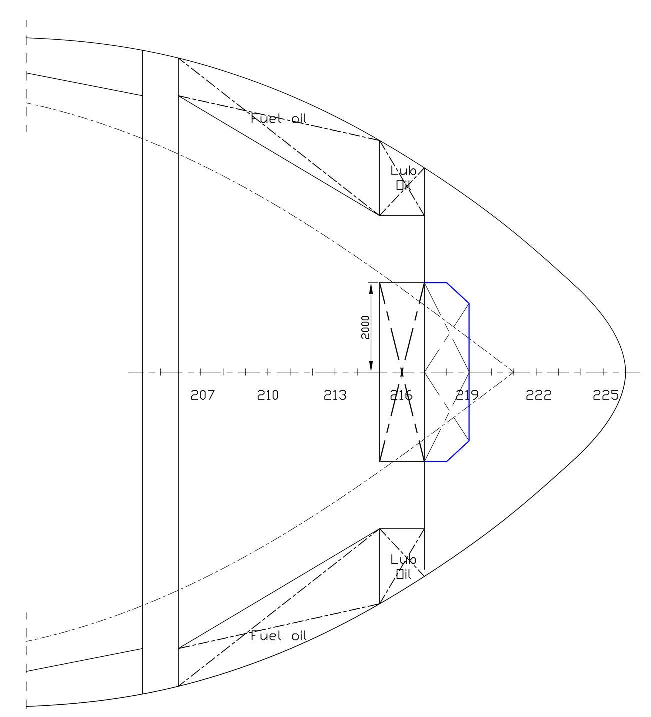
Fore ship

Below tween deck



Fore ship

Below main deck



Main particulars

Length for scantlings	abt.	130,850	m
Length o.a.	max.	110.000	m
Breadth mld.		16.150	m
Depth mld.		6.200	m
Draft – scantling		5.000	m
Draft – contract		5.000	m
Capacity of cargo tanks:		± 6400.000	m^3

CLASSIFICATION:

Lloyds Register of Shipping

Class notation:

✠A1 I.W.W.– Chemical Tanker Type C, s.g.1.0, p.v. +50 kPa in association with a List of Defined Cargoes, LS"T",LMC

Ver.	Date	Name	Revision Subject	Approved	Date
H	16.05.11.	PSN	Bunkerboom Added		
G	16.01.11.	NM	Adjustment according to ER Arrangement		
F	30.06.10	NM	LNG Tank Position		
E	12.06.10	NM	LNG storage tank with evaporator adjusted		
D	22.11.09	NM	LNG Tanks not at CL		
C	21.11.09	NM	Arrangement cryo tank adjusted		
B	19.07.09	NM	Ventilation ER aft aship, DRAFT MARKS		
A	27.06.09.	NM	Ship's name revised, ME-CAT		

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3087 AG Rotterdam (NL)

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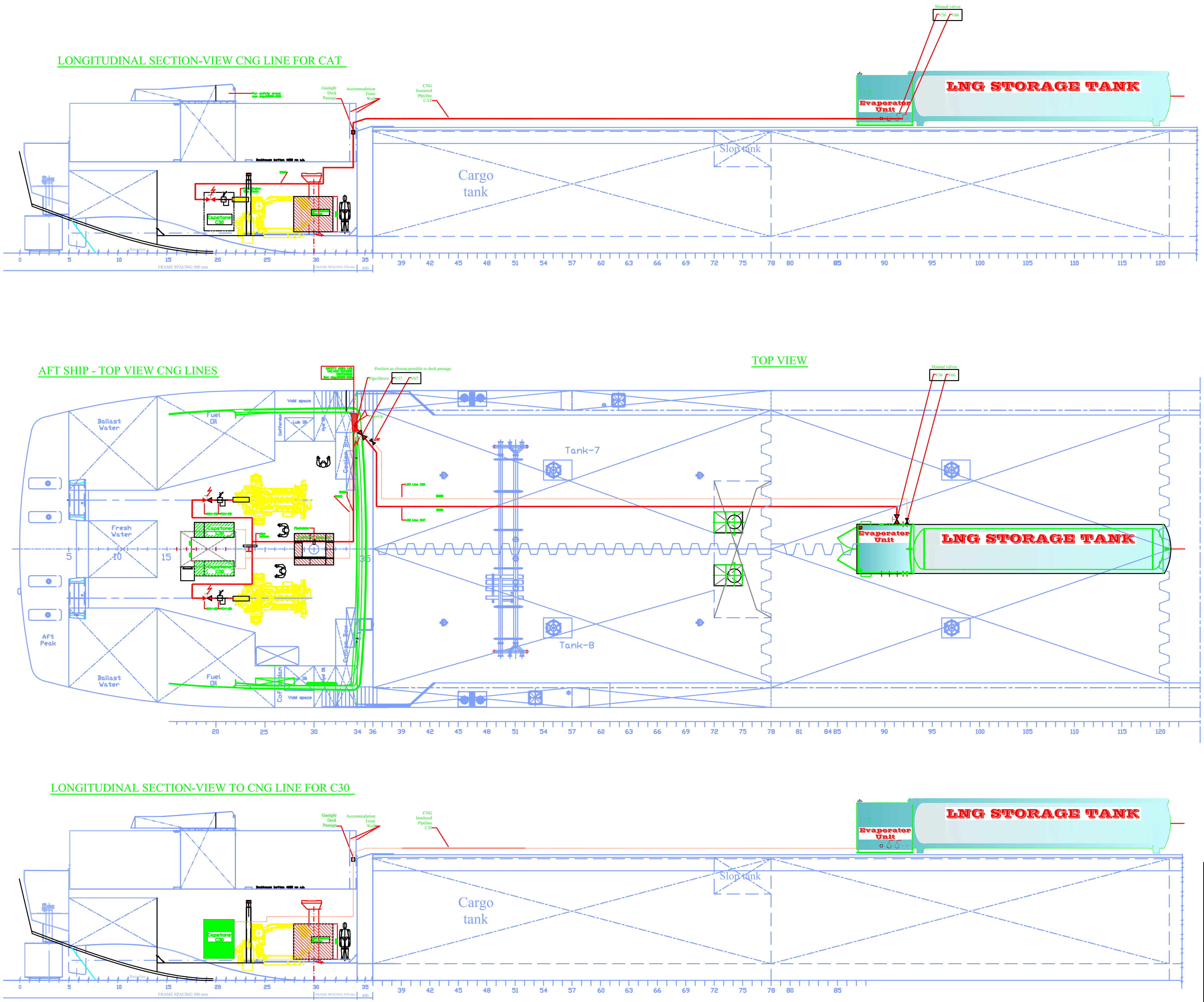
3331 LE Zwijndrecht
The Netherlands

Chemical Tanker - "ARGONON"
General Arrangement

Scale: 1 :100
N.Mihailovic dipl.ing.
26.01.2009.
Drawing No.: 30883-0000-G



Ver.	Date	Name	Revision Subject	Approved	Date
D	28.01.11.	HS	CRYONORM PROJECTS REMARKS INTEGRATED		
C	14.01.11.	NM	ARRANGEMENT ADJUSTED		
B	13.06.10	NM	GEN SET ADDED. TANK ADJUSTED		
A	22.01.10.	NM	DRAWING ADJUSTED		

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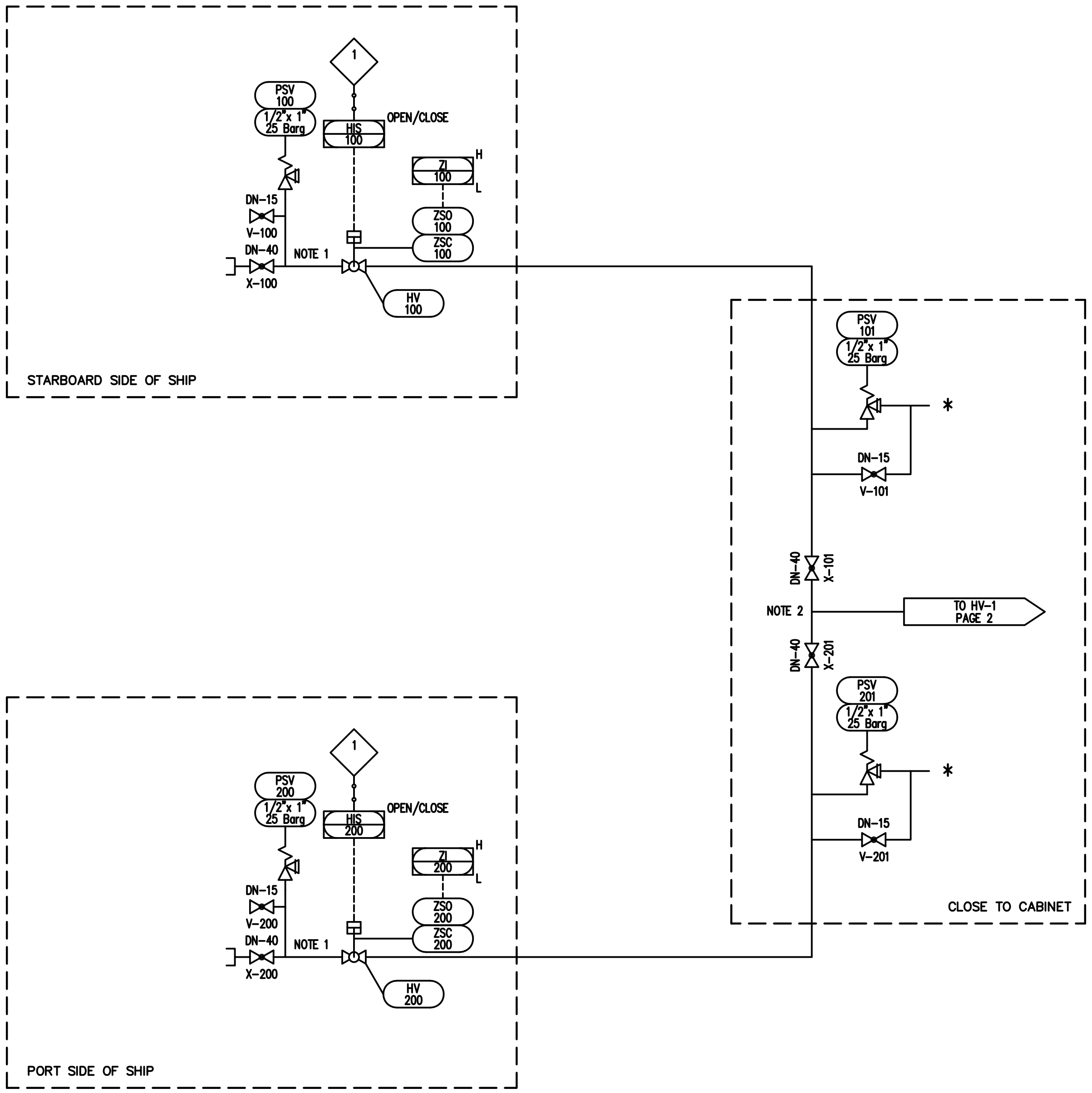
CHEMICAL TANKER - "ARGONON"
LNG PIPELINE DIAGRAM

SCALE: 1 :75

N.Mihailovic dipl.ing.

21.11.09

DRAWING NO.: 30883-0200-D



NOTES

'*' CONNECTS TO VENT HEADER UPSTREAM TE/TT-9
1. MANUAL VALVE AND AUTOMATIC VALVE AS CLOSE AS POSSIBLT TO EACH OTHER
2. VALVES X-101 AND X-201 DIRECTLY FITTED ON "T" PIECE WITH SHORTEST POSSIBLE DISTANCE

REV.	DESCRIPTION	DRWN	CHK.	DATE
11	PAGE 3 ADDED COMPLETELY	HJS		28-01-2011
10	VALVES V-1' + V-2' + V-9 AUTOMATED	HJS		05-01-2011
9	LINE NUMBERS ADDED	HJS		17-11-2010
8	TE-3 AND TE-9 ADDED + 2x TRUCK-LOADING POINTS	HJS		15-10-2010

P&ID LNG/CNG FUEL SYSTEM

DEEN SHIPPING

DRWN : HS		SCALE	NTS
CHECKED: HS		DATE	13-082010
REPLACES:			
CAD NR: 1002-110.dwg			

CRYONORM PROJECTS BV
KOPERWEG 3
2401 LH ALPHEN A/D RIJN
THE NETHERLANDS

1002-110

SHEET : 1/3

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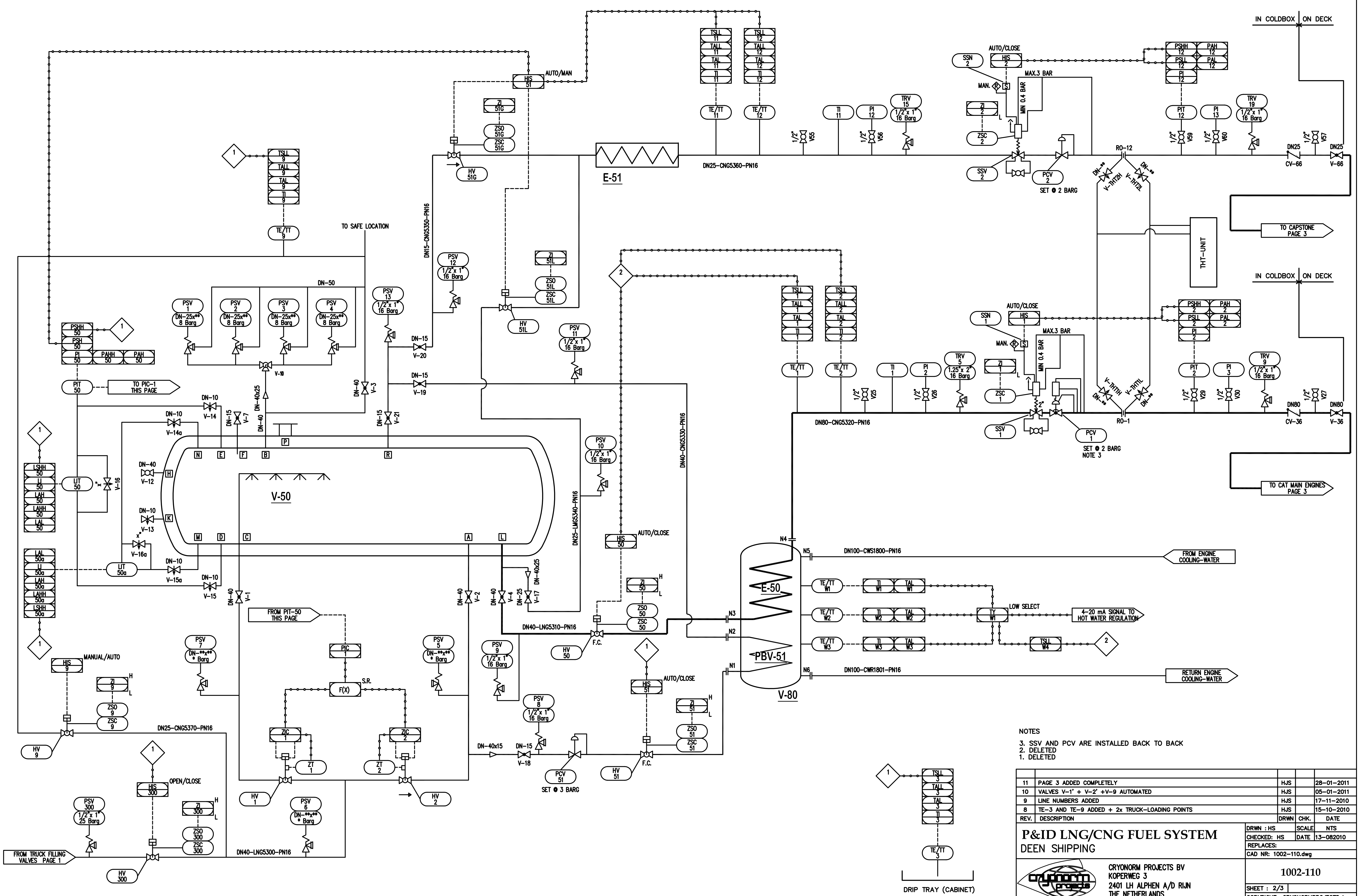

NOTES

3. SSV AND PCV ARE INSTALLED BACK TO BACK
2. DELETED
1. DELETED

REV.	DESCRIPTION	DRWN	CHK.	DATE
11	PAGE 3 ADDED COMPLETELY	HJS		28-01-2011
10	VALVES V-1' + V-2' +V-9 AUTOMATED	HJS		05-01-2011
9	LINE NUMBERS ADDED	HJS		17-11-2010
8	TE-3 AND TE-9 ADDED + 2x TRUCK-LOADING POINTS	HJS		15-10-2010

P&ID LNG/CNG FUEL SYSTEM

DEEN SHIPPING

DRWN : HS		SCALE	NTS
CHECKED: HS		DATE	13-082010
REPLACES:			
CAD NR: 1002-110.dwg			

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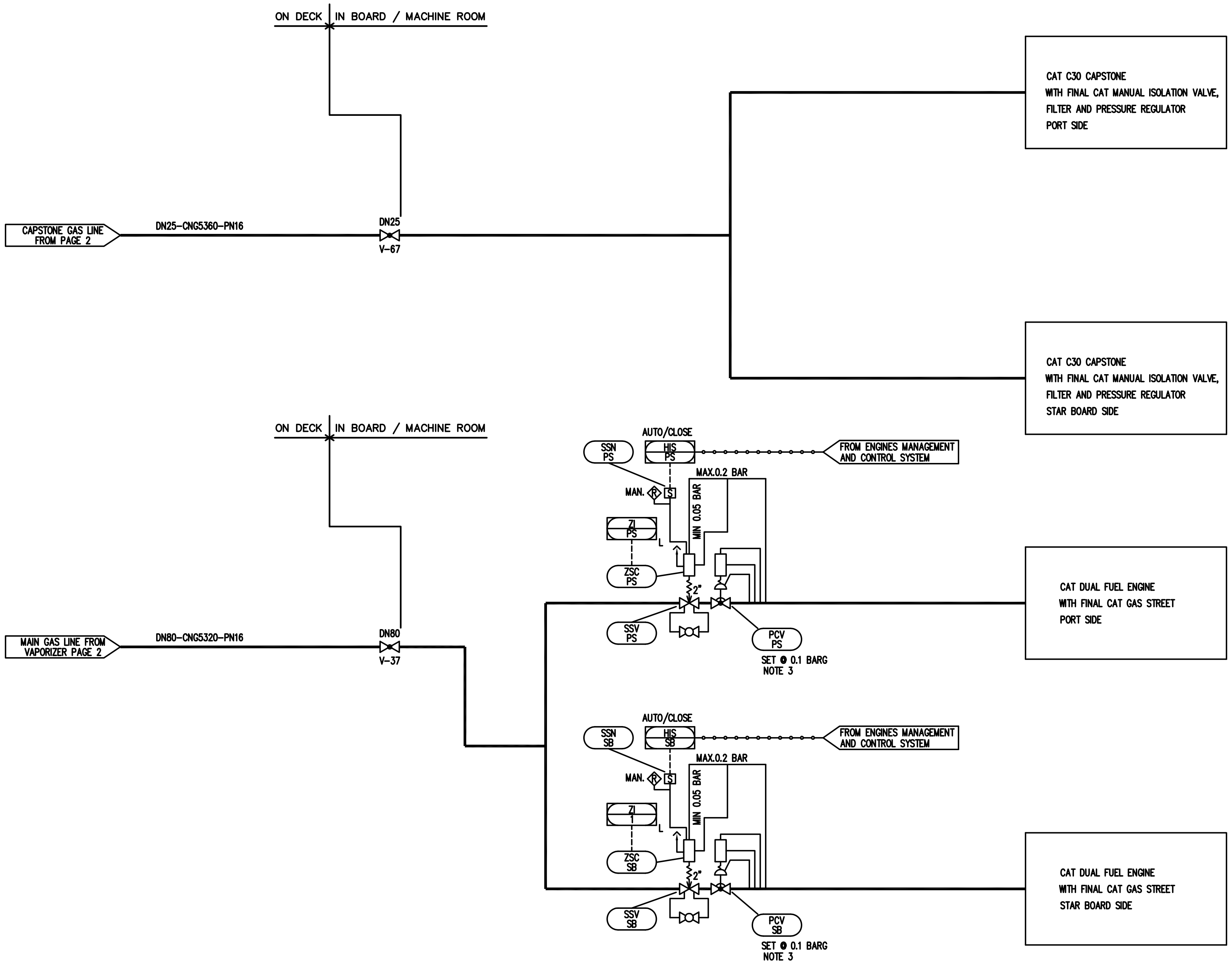

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