INF. 31

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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)

Twenty-fourth session
Geneva, 27–31 January 2014
Item 3b of the provisional agenda
Special authorizations, derogations and equivalents

Proposed text of derogations regarding the use of LNG for propulsion by Damen River Tankers

Transmitted by the Government of the Netherlands

Attached is the proposed text of possible derogations for two vessels regarding the use of LNG for propulsion. This derogation was also part of the agenda of the 23th session.

Decision of the ADN Administrative Committee relating to the tank vessel Damen River Tanker 1145 Eco liner 949

Derogation No. x/2014 of 31 January 2014

The competent authority of the Netherlands is authorized to issue a trial certificate of approval to the motor tank vessel *Damen River Tanker 1145 Eco liner*, (shipyard number 949, official ID number 55519), type C tanker, as referred to in the ADN, for the use of liquefied natural gas (LNG) as fuel for the propulsion installation.

Pursuant to paragraph 1.5.3.2 of the Regulations annexed to ADN, the above-mentioned vessel may deviate from the requirements of 7.2.3.31.1 and 9.3.2.31.1 until 30 June 2017. The Administrative Committee has decided that the use of LNG is sufficiently safe if the following conditions are met at all times:

1. The vessel has a valid ship’s certificate according to the Rhine Vessel Inspection Regulations, based on recommendation 3/2013 of the CCNR.

2. A HAZID study by the recognized classification society shows that the safety level of the LNG propulsion system is sufficient. This study covered but was not limited to, the following issues:

   - Interaction between cargo and LNG;
   - Effect of LNG spillage on the construction;
   - Effect of cargo fire on the LNG installation;
   - Different types of hazard posed by using LNG instead of diesel as fuel;
   - Adequate safety distance during bunkering operations.

3. The information that LNG is used as fuel is included in the dangerous goods report to traffic management and in emergency notifications;

4. All data related to the use of the LNG propulsion system shall be collected by the carrier. The data shall be sent to the competent authority on request;

5. An evaluation report shall be sent to the UNECE secretariat for information of the Administrative Committee. The evaluation report shall contain at least information on the following:

   (a) system failures;

   (b) leakages;

   (c) bunkering data (LNG);

   (d) pressure data;

   (e) abnormalities, repairs and modifications of the LNG system including the tank;

   (f) operational data;

   (g) inspection report by the classification society which classed the vessel.

Decision of the ADN Administrative Committee relating to the tank vessel Damen River Tanker 1145 Eco liner 951

Derogation No. x/2014 of 31 January 2014

The competent authority of the Netherlands is authorized to issue a trial certificate of approval to the motor tank vessel *Damen River Tanker 1145 Eco liner*, (shipyard number 951, official ID number 55520), type C tanker, as referred to in the ADN, for the use of liquefied natural gas (LNG) as fuel for the propulsion installation.

Pursuant to paragraph 1.5.3.2 of the Regulations annexed to ADN, the above-mentioned vessel may deviate from the requirements of 7.2.3.31.1 and 9.3.2.31.1 until 30 June 2017. The Administrative Committee has decided that the use of LNG is sufficiently safe if the following conditions are met at all times:

1. The vessel has a valid ship's certificate according to the Rhine Vessel Inspection Regulations, based on recommendation 2/2013 of the CCNR.

2. A HAZID study by the recognized classification society shows that the safety level of the LNG propulsion system is sufficient. This study covered but was not limited to, the following issues:

   - Interaction between cargo and LNG;
   - Effect of LNG spillage on the construction;
   - Effect of cargo fire on the LNG installation;
   - Different types of hazard posed by using LNG instead of diesel as fuel;
   - Adequate safety distance during bunkering operations.

3. The information that LNG is used as fuel is included in the dangerous goods report to traffic management and in emergency notifications;

4. All data related to the use of the LNG propulsion system shall be collected by the carrier. The data shall be sent to the competent authority on request;

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   (a) system failures;

   (b) leakages;

   (c) bunkering data (LNG);

   (d) pressure data;

   (e) abnormalities, repairs and modifications of the LNG system including the tank;

   (f) operational data;

   (g) inspection report by the classification society which classed the vessel.

Attached documents:

- Annex 1: HAZID Study
- Annex 2: Deviations from IGF Code
- Annex 3: Bunkering procedure
- Annex 4: Crew Training
- Annex 5: Project description
- Annex 6: TNO HAZID Assessment
- Annex 7: CCNR Recommendations

Attachment 1; Hazid study for Damen River tanker 1145 – Eco Liner

For the Ecoliner a Hazid study and a Root cause analysis were performed.
The purposes of the studies is to confirm the risks present to the specific system and ensure that safety systems have been considered and will be implemented in the design according the preventive measures mentioned in the hazid.

In the Hazid (table 2) all possible hazards for this LNG propulled vessel are identified and checked for their potential effects to the vessel, crew and environment. The study was performed on several days with people with different experience related to LNG systems. In table 1 dates and participants can be found.

Table 1: List of participants

Name	Company	Role	11/04/11	21/04/11	16/05/11	19/05/11	24/05/11
Jan Huis	Bureau Veritas	Principal Surveyor Machinery & Safety	X	X	X	X	X
Frank Kersbergen	Bureau Veritas	Manager Statutory Affairs		X			X
Liesbeth den Haan	Bureau Veritas	Manager Inland Navigation		X		X	X
Wim van Gemeren	Bureau Veritas	Senior surveyor			X		
Guy Jacobs	Bureau Veritas	Principal Surveyor at Head Office	X				
David Rodriguez-Codina	Bureau Veritas	Surveyor at Head Office	X				
Rob Schuurmans	Bodewes Millingen	Ship yard Director				X	
Willem Kroon	Bodewes Millingen	Ship yard Project manager	X		X	X	
Koert van der Ploeg	MAN Rollo	Technical Engineer	X		X		
Gertjan Boer	MAN Rollo	Sales Manager	X				
Jan van der Voort	MAN Rollo	Specialist Gas Engines			X		
Theo Baars	TOPEC	Sales Manager	X		X		
Walter Sterkenburg	TOPEC				X		
Ton Hoving	IVW – Dutch Authority	Senior Advisor			X		
Fabian van Damme	Dohmeyer	CEO				X	
Jan van Houwenhove	VRV – cryogene tanks	Sales Director Europe				X	

The Hazid is divided into two sections, the LNG-system on the aft deck and the engine rooms with their specific systems.
In the table of the Hazid we have the following columns:

- Cause; what leads to the hazard
- Hazard; what will happen
- Potential Effects; what can be the effect to vessel, crew, environment
- Preventive measures; what should be done to avoid the hazard
- Safeguards; when the hazard occurs what is done to minimize the effects

During the hazid only single failure was considered as is normal practice.
The preventive measures from the hazid will serve as recommendations of the design.

In the hazid study and root cause analysis you will find references to the questions asked by several delegations as mentioned in chapter 1 of the project description.

After the Hazid study a root cause analysis was done (table 3). All external events that might occur and has impact on the LNG system are listed. In the second column is the cause from the Hazid study related to the event. Also for each root cause preventive measures are mentioned and where applicable safeguards.

Table 2: Hazid

1. LNG Tanks on Aft ship deck					
Nb	**Cause**	**Hazard**	**Potential Effects**	**Prevention measures**	**Safeguards**
1.1	Rupture of tank	Leakage of LNG	Damage to deck & construction Fire/Explosion Gas entering gas safe spaces	Protection of deck & ship construction by drip trays for 100% of one tank contents as stated in IGF Code Openings of gas safe spaces outside gas dangerous zones	Tanks are provided with a waterspray installation according IGF Code. Installation is used for dillution and evaporation of the NG and/or cooling the non ruptured tank For fire: ships fixed fire fighting installation
1.2	Overpressure in tank	Rupture of tank	Damage to deck & construction Fire/Explosion Gas entering gas safe spaces	Safety valves on tanks icw IGF Code (also designed for liquid discharge) Openings of gas safe spaces outside gas dangerous zones	See 1.1
1.3	Rupture & external leakage of piping system on open deck	Release of LNG or NG	Damage to deck & construction Fire/Explosion Gas entering gas safe spaces	Protection of deck & ship construction by drip tray Openings of gas safe spaces outside gas dangerous zones	Close ESD valve on tanks to stop LNG/NG release See 1.1
1.4	Internal leakage of piping system	uncontrolled flow of LNG	loss of control	Number of shut off valves in series	Gas shut off by ESD valves

Nb	Cause	Hazard	Potential Effects	Prevention measures	Safeguards
1.5	Heat build-up in tank	Pressure increase in tank & tank liquid full	Tank rupture	See 1.2	See 1.1
1.6	Tank liquid full	Pressure increase in tank	Tank rupture	See 1.2	See 1.1
1.7	Tank overboard	Release of LNG	Environmental pollution	Approved fixation on ship structure	ESD on board for piping
2. Engine room					
Nb	**Cause**	**Hazard**	**Potential Effects**	**Prevention measures**	**Safeguards**
2.1.	Rupture or leakage of inner pipe	Gas release into double wall of pipe		Piping is designed, inspected and tested icw IGF Code	Gas detection which will lead to automatic ESD of the concerned supply line
2.2	Rupture or leakage of complete piping system including gas train and single walled combustion air parts of engine	Gas release into engine room	Fire & explosion Danger for human health	Piping is designed, inspected and tested icw IGF Code	Gas detection which will lead to automatic ESD Ventilation increase further to gas detection. Possible switch off of only in case of fire

Nb	Cause	Hazard	Potential Effects	Prevention measures	Safeguards
2.3	Backfire of engine caused by incorrect air-fuel mixture, leaking inlet valve or incorrect ignition timing May occur in particular during starting of engine.	Flame from inlet system Scattered parts from inlet system caused by pressure wave Flame in gas train	Damage to inlet system engine or engine room & operators	Design of inlet system such that it can withstand pressure wave Flame arrestor in gas train Appropriate starting procedure with flushing of inlet and exhaust system prior to switching on ignition Appropriate flush procedure of gas piping with natural gas to prevent high air concentration which may result in potential combustible mixture in gas piping. Flushing at first start-up or after service work (when piping has been disassembled)	System to detect backfire and shut-down engine immediately to prevent new backfires
2.4	Explosion in exhaust system caused by unburnt gas	Rupture of exhaust gas system	Fire/explosion in engine room Danger to human health	Design of exhaust system such that it can withstand pressure wave Flame arrestor in exhaust silencer	

Nb	Cause	Hazard	Potential Effects	Prevention measures	Safeguards
2.5	Severe engine damage	Gas release into engine room	Fire/explosion in engine room Danger to human health	Use of class approved main components (engine block, crankshaft, connecting rods)	Appropriate generating set monitoring and control Gas detection which will lead to automatic or manual ESD Ventilation increase further to gas detention. Possible switch off only in case of fire
2.6	Failure or leaking of double valve block with stalled engine	Gas in inlet system engine and/or crank case via closed crankcase ventilation (CCV) system. Gas in engine room	Backfire during starting (see 2.3) Fire/explosion, Danger of human health	Appropriate CCV (closed crankcase ventilation) design Sufficient engine room ventilation Gas detection which will lead to ESD Appropriate starting procedure with flushing of inlet and exhaust system prior to switching on ignition	CCV as standard on top of engine. Natural gas has lower density than air. Natural gas will never reach crankcase. Closed main adjusting screw which serves as a 2nd barrier. Leakage test of double valve block after normal shut-down. Alarm in case of leakage valve.

Nb	Cause	Hazard	Potential Effects	Prevention measures	Safeguards
2.7	Gas in crankcase via CCV system with running engine	Explosive mixture in crankcase	Fire/explosion, Danger to human health		During operation crankcase is permanently vented into inlet system (near air filter) via under pressure or piston blow-by. Natural gas will never accumulate in crankcase
2.8	Gas temperature out of range at inlet gas train (<+10°C or >+40°C)	Incorrect air-fuel mixture Ice in intake system engine Failure of gas train	Gas in engine room	Selection of a proper evaporation system (including cold start)	Gas detection will lead to shut down ESD valve Ventilation increase further to gas detection
2.9	Liquid phase gas at inlet gas train/engine	Pressure built-up when both double valve block and main adjusting screw are closed Failure of gas-piping resulting in release of gas in engine room See 2.9	Fire & Explosion	Selection of a proper evaporation system (including cold start)	Gas detection will lead to shut down ESD valve Ventilation increase further to gas detention Possible shut off in case of fire

Nb	Cause	Hazard	Potential Effects	Prevention measures	Safeguards
2.10	Gas pressure out of range (<10 mbar or >50 mbar) upstream of gas train	Failure of components gas train (high gas pressure) Gas leakage into engine room when gas train parts fail	Bad engine performance Fire & Explosion		Over pressure safety valve in gas supply line upstream of gas train Gas detection will lead to shut down ESD valve Ventilation increase further to gas detention Possible shut down
2.11	Gas in cooling system when cylinder head gasket fails	Accumulation of gas in surge tank resulting in explosive mixture	Fire/explosion,		Cooling system pressure greater than maximum pressure inlet system engine: gas can not reach cooling system via leaking gasket

Table 3: Root Cause Analysis

Nb	Root cause	Leads to	Hazid ref.	Prevention measures	Safeguard
RC1	Collision or grounding	Rupture of LNG tank Rupture of piping system on deck Rupture of piping system in engine room	1.1 1.3 2.2	Within 1 meter of ship side and stern no gas containing components will be placed. Tanks are of the same design as tanks used for transport by road, ie EN 13530 and ADR. Design, inspection and testing is also in accordance with IGF Code. Pipe routing as short as possible The tank are fitted with baffle plates to prevent sloshing at partial filling. Tank is designed for 10 deg. static roll, 2g axial acceleration, 1 g transversal	
RC2	Degradation of system parts	Internal & external leakage Heat built up	1.3/1.4 2.1/2.2 1.5	Class approved Inspection & survey scheme Maintenance programm Gas installation under class	

RC3	Human error during normal operations			Recognised training of crew	Automatic monitoring, control and safety systems
RC4	Human error during bunkering	Overpressure Tank liquid full Rupture & leakage of piping system on deck	1.2 1.6 1.3	Approved bunkerprocedure	Approved bunkerprocedure Safety valve arrangement
RC5	Human error during start-up and shut down of system	Backfire	2.3	Recognised training of crew	Automatic monitoring and control systems
RC6	Vessel moves during bunkering	Rupture & leakage of piping system on deck	1.3	Approved bunkerprocedure Recognised training of crew	Approved bunkerprocedure
RC7	Fire on deck	Heat build up in tank Tank liquid full	1.5 1.6	Tanks are of the same design as tanks used for transport by road, ie EN 13530 and ADR. Design, inspection and testing is also in accordance with IGF Code.	Waterspray installation Safety valve arrangement
RC8	Quality of LNG	Malfunctioning system	2.9/ 2.10	Quality control with delivering note of LNG	
RC9	Fire in engine room not due to LNG	Rupture & leakage of piping system in engine room	2.2		Fire detection ESD Fixed fire extinguishing in engine room
RC10	Extended non sailing period	Heat build up in tanks Tank liquid full	1.5 1.6	Tanks are of the same design as tanks used for transport by road, ie EN 13530 and ADR. Design, inspection and testing	Safety valve arrangement

				is also in accordance with IGF Code, in particular insulation Minimum quantity of consuming LNG	
RC11	Sinking	Rupture & leakage of piping system on deck Tank overboard	1.3 1.7		
RC12	Vibrations	Rupture & leakage of piping	1.3/ 2.1/ 2.2	Built under class (limitation of vibrations) & Maintenance	

Annex 2

Overview of deviations from the IGF code

(IMO Resolution MSC 285(86), June 1st 2009).

This document is applicable to the Damen River Tanker – Ecoliner (ID 54314).

IGF code	**DRT Ecoliner**	**Relation to project description**
2.8.1 LNG Tank design:	The LNG tank design is according PED/EN 13530. The tank is connected to the vessel in a way that ensures that the tank shall remain attached to the vessel under all circumstances.	See paragraph 2.1

Annex 3

LNG Bunkering Procedure

1. PURPOSE

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

2. GENERAL

Before the vessel's LNG storage tanks can be filled, the competent authority shall be informed. The authority could demand for extra safety precautions. The authority's approval for the bunker transfer must be available before bunkering is started.

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

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

3. PRE-FILLING

Before LNG transfer is commenced, warning signs shall be placed, the bunker checklist in appendix A has to be filled in and signed both by a vessel's representative and the delivery truck driver.

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

4. FILLING:

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

During transfer the following items shall continuously be checked:

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

5. POST-FILLING:

After LNG transfer, and after the transferhose is disconnected, warning signs on the shore can be removed. At this time the vessel's representative shall inform the crew and the competent authorities that the transfer is finished.

APPENDIX A (template)

LNG bunker checklist	
Precautions and appointments made for transfer of LNG	
- Vessel's particulars ………………………………….. (vessel's name)	………………………………………. (vessel's European Identification number)
- Truck's particulars …………………………………… (Companyname)	………………………………………. (plate number)
- Bunker location …………………………………… (adress) …………………………………… (date)	………………………………………. (place) ………………………………………. (time)
LNG related particulars	
Quantity in m^3: …………………….	
Emergency procedure	
Filling must be stopped immediately in case of any leakage. All valves have to be set in their safe position. A red flashlight on the vessel will indicate the abnormal situation described. The truck driver shall stop the LNG transfer immediately. All personnel shall evacuate the bunker area immediately according to the safety rota.	

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

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

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

Vessel's representative:	Tank truck representative:
……………………………………..	……………………………………..
(Name in capitals)	(Name in capitals)

<table>
<tr><th colspan="3">LNG Bunker Checklist</th></tr>
<tr><td></td><td>Ship</td><td>Truck</td></tr>
<tr><td>…………………………………….
(Signature)</td><td colspan="2">…………………………………….
(Signature)</td></tr>
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Annex 5

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

A. Introduction

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

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

The selection of a suitable training institute and the extend of the training in accordance with the competent authority. The training institute and the extend of the training shall be determined with the competent authority. Every 2.5 years, the training shall be repeated.

After successful participation, the student shall be issued with a certificate by the training institute.

B. The LNG course will cover the following topics:

1. Legislation

1.1 General legislation / best practice for ADN, ROSR, European Directive EU 2006/87 and new developments

1.2 Available international legislation concerning LNG (for seagoing / best practices) IMO, IMDG and new developments

1.3 rules of the recognized classification societies

1.4 Legislation concerning health and safety

1.5 Local regulations and permits

1.6 Recommendations according to ADN and ROSR

2. Introduction to LNG

2.1 The definition of LNG, critical temperatures, LNG hazards, atmospheric conditions

2.2 Compositions and qualities of LNG, LNG- quality certificates

2.3 MSDS (safety sheet): physical / product characteristics

2.4 Environmental properties

3. Safety

3.1 Hazards and risks

3.2 Risk management

3.3 The use of personal protection

4. The techniques of the installation

4.1 General configuration

4.1 Explanation of the effects of liquefied natural gas

4.2. Temperatures and pressures

4.3 Valves and automatic controls, ATEX

4.4. Alarms

4.5 Materials (hoses, pressure relief valves)

4.6 Ventilation

5. Service & checks of the LNG installation

5.1 Daily maintenance

5.2 Weekly maintenance

5.3 Periodical maintenance

5.4 Failures

5.5 Documentation of maintenance work

6. Bunkering of LNG (see attached procedure)

6.1 Bunkering procedure LNG

6.4 Gas freeing / flushing of the LNG system

6.5 Check lists and delivery certificate

7. Maintenance

7.1 Gas free certificate

7.2 Gas freeing / flushing of the LNG system before docking

7.2 Inerting of the LNG system

7.3 Procedure de-bunkering of the bunker tank

7.4 First filling of the LNG bunker tank (cool down)

7.5 Start up after dock period

8. Emergency Scenario's

8.1 Emergency plan

8.2 LNG Spill on deck

8.3 LNG skin contact

8.4 Release of natural gas on deck

8.5 Release of natural gas in enclosed spaces (power stations)

8.6 Fire on deck in the vicinity of the LNG storage tank.

8.7 Fire in engine rooms

8.8 Specific hazard in case of transport of dangerous goods

8.9 Grounding/collision of the vessel

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

9. Description of practical training on board:

9.1 Get familiarised with the content of the ships management system, in particular the chapters concerning the LNG installation.

9.2 Check safety awareness and the use of safety equipment for LNG

9.3 Awareness of monitoring, controls and alarms of the LNG installation on board.

9.4 Awareness of maintenance and control procedures of the LNG installation.

9.5 Awareness and familiarisation with the bunker procedure (preferable in practice)

9.6 Awareness of the maintenance procedures for docking

9.7 Awareness of the emergency scenarios

Description of project
Damen River Tanker 1145
Ecoliner

Content

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    2.2 Engine rooms 3
3. Use of LNG 4
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1. Introduction

In this document the design of the vessel is described in chapter 2, which focuses on the LNG storage and the design of the engine room. In chapter 3 the advantages of LNG are described and specific requirements for LNG propulsed vessels outside the technical design as mentioned in the previous chapter. An important part of the project is the risk analysis which can be found in Annex 1 of the recommendation.

2. Design of vessel

The specific demands for LNG propulsion will be focussed on the aft ship. Midship (cargo area) and fore ship will be 100% similar to a conventional tanker according ADN and EU regulations. Therefore this design can be easily adapted for other type of vessels. For LNG propulsed vessels no specific requirements are foreseen in case of berthing etc.. The design requirements from the Hazid are dealt with in the ships design. The classification society will survey the vessel during its construction.

In attachment 1 the general arrangement of the Ecoliner can be seen.

2.1 LNG storage

Natural gas will be stored as Liquefied Natural Gas (LNG) in two cryogenic tanks with a temperature of about -162 °C and with a maximum pressure of about 2 bar (design pressure 6 bar). The tanks and LNG pipelines are provided with safety relief valves (setpoint 5 bar) discharging in a riser with its open end in a safe place and height above deck according IGF code. The tanks used are similar to the tanks used for road transport and are conform ADR and EN 13530. The inner tank is of stainless steel and the outer tank is made of ordinary steel. In the double wall a white powder called perlite protects the inner tank for heating by infrared radiation. The inner space between the two tanks is under vacuum so there is no heating by convection as well. The inner and outer tanks are connected in a way that heating through conduction is minimised.

After the TNO analysis it was decided that the Ecoliner will use smaller tanks so the distance from the vessel's side to the tanks will be 2.28 meter which equals the distance B/5. With this capacity the vessel will have enough fuel for one round-trip Rotterdam - Basel.
The TNO analysis can be found in attachment 9. Attachment 10 gives an answer to the outstanding item found by TNO. Attachment 11 gives TNO's final conclusion.
The top of the tanks and the equipment will always be below the restricted air draft of the vessel. No part of the LNG system will enter the cargo area of the vessel. The distance between the tanks and the accommodation openings are according ADN, see attachment 2.

The two tanks with their ancillaries each form redundant systems. The tanks are rigid mounted outside on the aft deck, together with all the ancillaries required to convert the LNG into NG with ambient temperature and low pressure. From the cryogenic tanks the LNG is led to the vaporizers. After the vaporizers the NG will be led inside each independent P.S. and S.B. engine room. In case of an emergency in one of the engine rooms the NG will be directly shut off.

Lay out of the engine rooms complies with:

- Rhine Vessels Inspection Regulations;
- ADN;
- Bureau Veritas Rules for the Classification of Inland Navigation Vessels NR 217 of April 2009;
- IMO International Code on Safety for Gas-Fuelled Ships (IGF Code) under development (ref. MSC/.285(86), june 1st 2009);
- Bureau Veritas Rule Note NR 529 DTM R00 E Safety Rules for Gas-Fuelled Engine Installations in Ships of February 2007.

Deviations from RVIR and ADN are listed in the specific recommendations. [Deviations from the IGF Code are listed in annex 2 to each recommendation.]

Each independent LNG tank and LNG system will supply the installations of one engine room whereas back-up provisions of serving the other engine room are provided. Therefore a manifold will be provided from which each engine room is supplied through a remote closable main valve (ESD - Emergency Shutdown Valve), also located on open deck. In case of emergency either ESD valve can be closed remotely or automatically when required.

The evaporators, necessary to evaporate the LNG into NG, are also located on open deck, close to the tanks. Each main supply line to an engine room will have it's own independent evaporator.

On the deck of the aft ship a stainless steel drip tray is made to avoid damage to the deck in case of leakage of LNG. The drip tray can store the contents of one full tank and is in accordance with the IGF code.

In case of fire or pressure built up a water spray installation acc to IGF code (attachment 3) will cool the tank. The water spray installation is also used for diluting the NG in case of blow-off.

In case of a calamity, alarms which are installed in the wheelhouse in compliance with the IGF Code (attachment 4), will be activated.

2.2 Engine rooms

PS and SB engine room will be separated from each other by a longitudinal bulkhead which is watertight as well as gastight and has an A60 fire integrity. In this bulkhead a emergency escape watertight, A-60 isolated, self closing with open-close monitoring, door is provided.

The engine-generator sets and main switchboards will be located in both engine rooms. The installation in either engine room can run independently from the other.

All NG supply piping running within each engine room up to the engines and heater will be enclosed in a gastight enclosure (double wall piping). This gastight enclosure (acc IGF with ESD; attachment 5) Both engine rooms will be equipped with mechanical under-pressure ventilation with a capacity of not less than 30 air changes per hour and a fixed gas detection system. The fans will be of the non-sparking type, their motors being of the required safety execution. The outlet of these ventilation systems will be located in a safe area. In case of any system failure, the gas supply to this engine room will be stopped.

As, gas-safe certified engines in this output range and burning units are not (yet) available, the lack of this certification will be covered by the emergency shut down (ESD) protection of the engine rooms in compliance with the IGF Code and BV Rule Note. ESD will shut down one entire engine room except for some emergency lights, emergency equipment and Eex equipment as described in the IGF Code.

Heat recovery from the cooling water and the exhaust gases will be used for the cargo tank heating and domestic heating. The propulsion arrangement will be with electrical driven multi propeller (2 x) azimuth drives with one electrical bow thruster.
Electric power generation will be according the gas - electrical system. For redundancy and international regulation requirements 2 x independent engine rooms will be installed. Design of the Engine Room will be according the E.S.D. (emergency shut down) machinery space lay out.

In case of a fire in the engine room the LNG flow will be closed. The fire in the engine room can therefore be dealt with as on board a conventional vessel.
Attachment 6 shows the lay-out of the engine rooms.

Power management system
The design of the electrical generating system in combination with a power management system is such that each two of the four (about 50% of the required electrical power) generator sets are located in a separate compartment. In case of fire or flooding of one compartment the operation of the other electrical generating system is not affected.
The power management system is designed such that the generating power (generator sets at work) will be in balance with the required power consumers.
It complies with the IGF guidelines and the rules of Bureau Veritas for redundant electrical power generation and it also complies with the RVIR rules for emergency propulsion. See attachment 7

Alarms in the wheelhouse will be according table 1 from the IGF code, see attachment 4.

3. Use of LNG

3.1 Advantages & use

The main motives to use LNG as fuel in inland navigation are the advantages for the environment:

- Fuel consumption reduction, using the higher efficiency of the electrical driven aft – propellers in combination with the power management system.

- For redundancy less power/engines need to be installed leading to less emission and less fuel consumption.
- Further more it opens the route to fully gas electric propulsion enabling the use of much cleaner engines then presently possible, fixed rotations per minute.
- Heat recovery is applied, again leading to less fuel / emission consumption.

- Emission reduction natural gas in regard to gas oil about (equal installed kW.):
  - CO_2 24 %
  - NOx 84 %
  - SO_2 100 %
  - Particles95 %

  LNG fuelled ships comply at least with Euro 5 (more severe then current CCNR regulations)

More information can be found on the LNG information sheet from the supplier (attachment 8).

3.2 Specific requirements

Specific requirements for bunkering are laid down in the bunkering procedure as listed in annex 3 of the recommendation.

All crew members will be trained on how to handle the LNG propulsion system (including bunkering) and what to do in case of accidents. The training procedure can be found in annex 4 to the recommendation. The training will be laid down in the ships operational manual.

For all crew members personal protection equipment in relation to LNG (UN 1972) will be on board, in conformity with the ships safety plan.

3.3 Inspection & evaluation

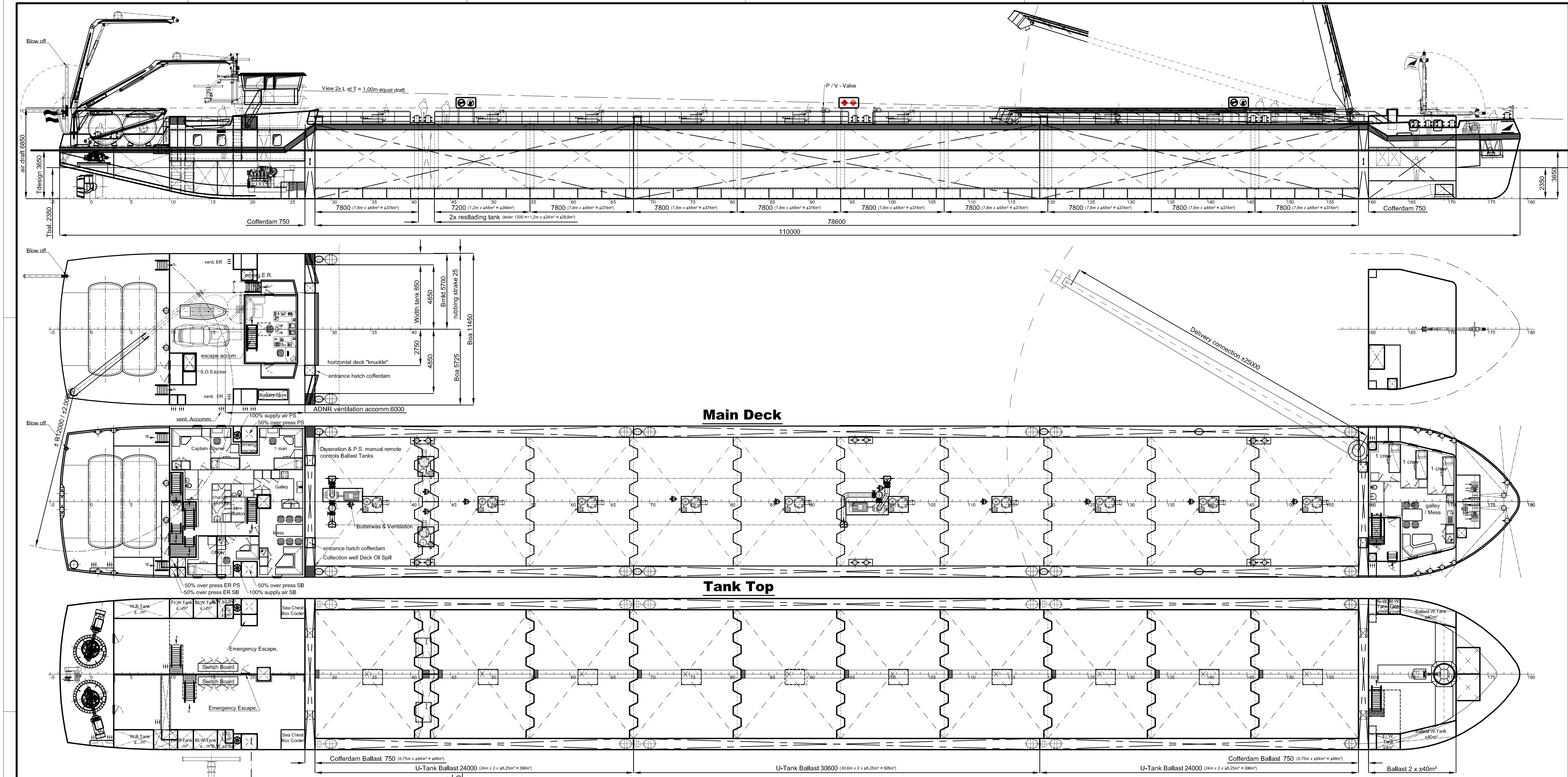
The vessel will be built under class and when in service will be surveyed every 2,5 years according normal survey scheme. The LNG system will be surveyed every year by a class surveyor.

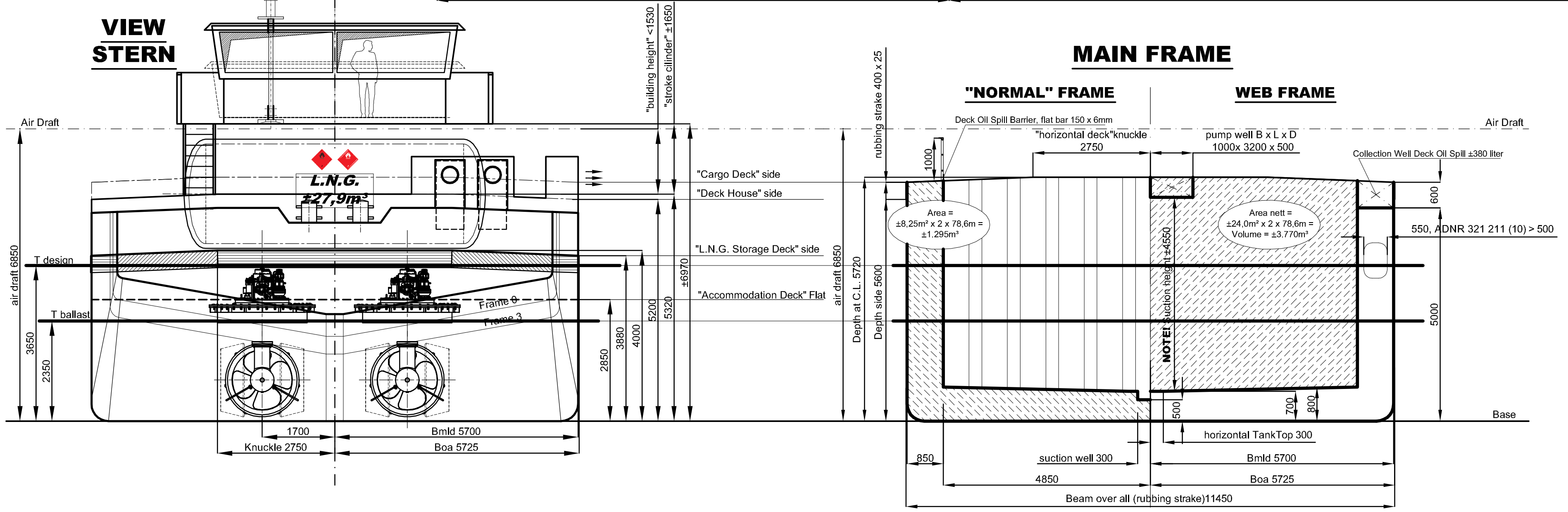
The LNG system will be evaluated every year by owner, ship yard and class society when in service and a report will be send to the CCNR and the UNECE, as laid down in the recommendation.

List of Attachments

Nr.	Description	Manufacturer	Document Nr.
1	General Arrangement	Bodewes	000-000
2	LNG storage in relation to safe zones of accommodation	Bodewes	000-003/a/b
3	Sprinkler installation		675-000
4	Monitoring of Gas supply systems acc IGF Code		
5	LNG-NG Diagram with gastight enclosure		321-000
6	Layout engine room and ventilation		200-000
7	Power Management	Bodewes	400-000
8	Safety sheet LNG		
9	TNO report	TNO	
10	Reply to TNO report by Bureau Veritas	Bureau Veritas	
11	Final TNO summary	TNO	

end





DRT - 1145 - EL

Main Dimensions

Length	o.a.	approx.	110,00	m.
Breadth	moulded		11,40	m.
Breadth	o.a.	approx	11,45	m.
Depth	at side midship		5,60	m.
	at center line		5,72	m.
Air draft	above base line	approx.	6,85	m.
Airdraft	at T = 2,35 m.	approx.	4,50	m.
Draft	scantling		3,65	m.
Draft	ballast	approx.	2,35	m.

Cargo Tanks

Dead Weight	at T = 3,30 m.	approx.	2.600	tons
10x Volume Cargo Tanks (including slob)		approx.	3.770	m³
2x Volume Slob Tanks		approx.	2x 28	m³

Tank Volumes

L.N.G. Tanks (2x)		approx.	55,8	m³
Fresh Water	aft ship	approx.	2x 5	m³
	fore ship	approx.	4	m³
Water Ballast	aft ship	approx.	....	m³
	mid ship	approx.	1.390	m³
	fore ship	approx.	120	m³
Grey Water	aft ship	approx.	2	m³
	fore ship	approx.	2	m³
Black Water	aft ship	approx.	2	m³
	fore ship	approx.	2	m³
Lubrication Oil	aft ship	approx.	2	m³
Dirty Oil	aft ship	approx.	2	m³

Class / Authorities

I.V.W. (Directive 2006/87/EC)
- "Richtlijnen C.E. markering"
- R.O.S.R.
- "Continue vaart"
- "aantekening één mansradar vaart"

A.D.N. (Directive 2008/68/EC)
- type C
- 50 kPa

Bureau Veritas
- ✠ 5 IN (0.6) Z
- Tanker / Double Hull
- DP = 57.5 kPa / TP = 65 kPa
- A.D.N. Type C
- ✠ M.C.

rev.	date	inspected
REV1	DATE	INSPECT

- ☐ For approval
- ☐ For information
- ☐ For construction
- ☐ Stamped approved by class

BODEWES MILLINGEN a/d RIJN Nederland
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Telephone 0481438 238 Telefax 0481 433 166
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Damen River Tanker - Eco Liner
DRT-1145- EL, Type C

drawn:	WK	date:	2011-12-07	scale:	....
proj. no.:	Sneekes	ident. to drw. no.:	....		
yard no.:	....	derived fr. drw. no.:	....		
Copyright by willemkroon@home.nl		drw. no.:	000-000, 2011-12-07		

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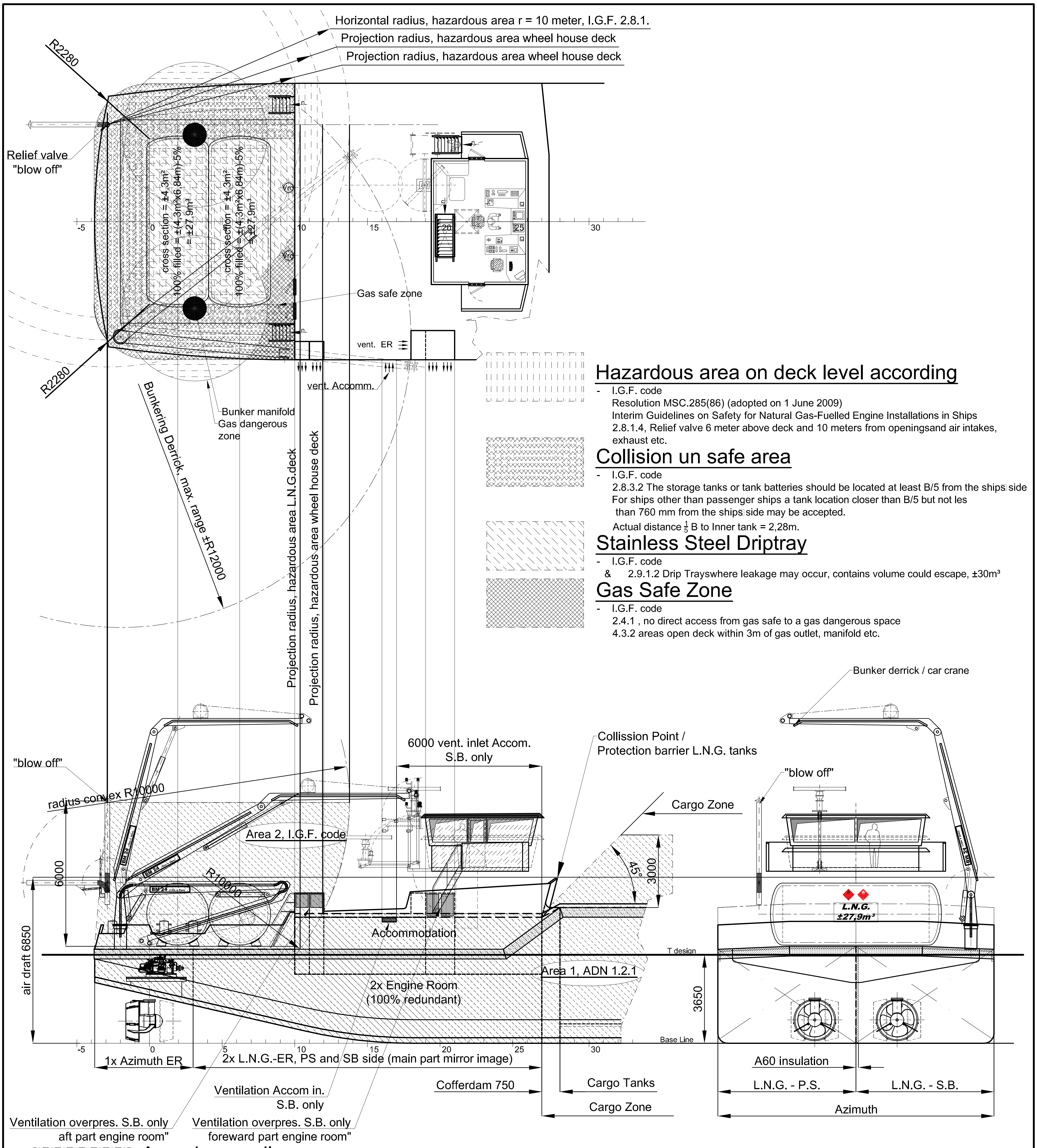

Hazardous area on deck level according

- I.G.F. code
  Resolution MSC.285(86) (adopted on 1 June 2009)
  Interim Guidelines on Safety for Natural Gas-Fuelled Engine Installations in Ships
  2.8.1.4, Relief valve 6 meter above deck and 10 meters from openingsand air intakes, exhaust etc.

Collision un safe area

- I.G.F. code
  2.8.3.2 The storage tanks or tank batteries should be located at least B/5 from the ships side
  For ships other than passenger ships a tank location closer than B/5 but not les
  than 760 mm from the ships side may be accepted.
  Actual distance $\frac{1}{5}$ B to Inner tank = 2,28m.

Stainless Steel Driptray

- I.G.F. code
& 2.9.1.2 Drip Trayswhere leakage may occur, contains volume could escape, ±30m³

Gas Safe Zone

- I.G.F. code
  2.4.1 , no direct access from gas safe to a gas dangerous space
  4.3.2 areas open deck within 3m of gas outlet, manifold etc.

Area 1 according

- A.D.N.
- 30.12.2006 EN Official Journal of the European Union
  DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
  of 12 December 2006
  laying down technical requirements for inland waterway vessels and repealing Council Directive 82/714/EEC (2006/87/EC)

  Area 1 Cargo Zone / Area
  2 Wheel House
  3 Accommodation
  4 2x L.N.G Engine Room (P.S. & S.B.)
  5 1x Azimuth Engine Room

Area 2 according

- I.G.F. code
  Resolution MSC.285(86) (adopted on 1 June 2009)
  Interim Guidelines on Safety for Natural Gas-Fuelled Engine Installations in Ships

  Area 1 Accommodation
  2 2x L.N.G Engine Room (P.S. & S.B.)
  3 1x Azimuth Engine Room
  4 Aft Deck / L.N.G. Area

Combination Area 1 & 2

Area 1 Accommodation
2 2x L.N.G Engine Room (P.S. & S.B.)
3 1x Azimuth Engine Room

Area Divisions according:

1. **I.M.O.: Resolution M.S.C. 285 (86) (adopted om 1 June 2009) (I.G.F. guidelines, Interim Guidelines On Safety for Natural Gas-Fuelled Engine Installations in Ships)**
2. **European Regulations: Code 2006 / 87 / EC**
3. **European Regulations: Code 2008 / 68 / EC**

Drw.Nr. 000-003 (1of 3)

rev.	date	inspected
REV1	DATE	INSPECT

BODEWES
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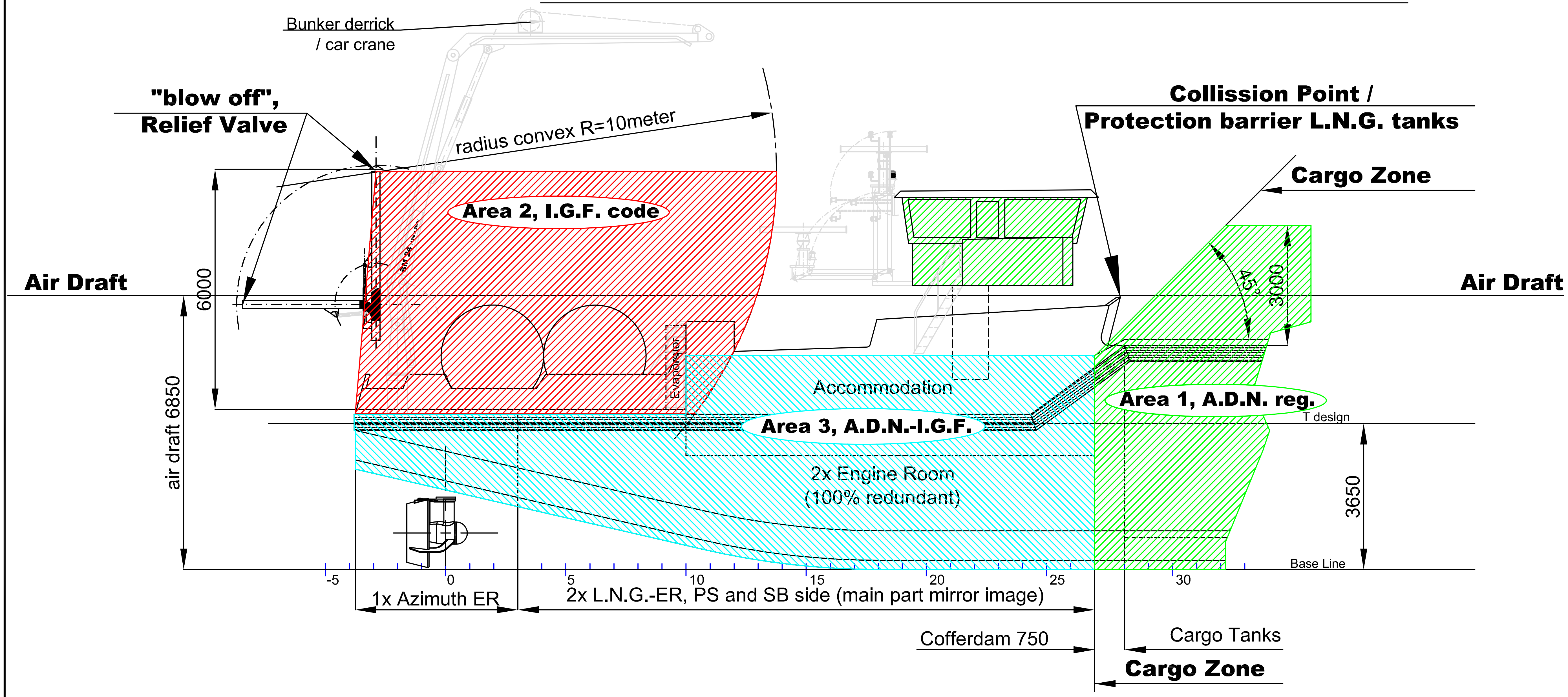
Damen River Tanker
Safety Division with regard to IMO & European Regulations

☐ For approval
☐ For information
☐ For construction
☐ Stamped approved by class

drawn: WK | date: 2011-12-07 | scale: ......
proj. no.: Sneekes | ident. to drw. no.: ....
yard no.: .... | derived fr. drw. no.: ....
drw. no.: 000-003 (1of3), 2011-12-07

Cargo Zone (E.U. / A.D.N.regulations) 100% separated from the L.N.G.-N.G. Zone (I.G.F.code)



Area 1 according

- A.D.N. regulations
- 30.12.2006 EN Official Journal of the European Union
  DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL
  of 12 December 2006
  laying down technical requirements for inland waterway vessels and repealing
  Council Directive 82/714/EEC (2006/87/EC)
  Area 1 Cargo Zone / Area
  2 Wheel House
  3 Accommodation
  4 2x L.N.G Engine Room (P.S. & S.B.)
  5 1x Azimuth Engine Room

Area 2 according

- I.G.F. code (guidelines)
  Resolution MSC.285(86) (adopted on 1 June 2009)
  Interim Guidelines on Safety for Natural Gas-Fuelled Engine
  Installations in Ships
  Area 1 Accommodation
  2 2x L.N.G Engine Room (P.S. & S.B.)
  3 1x Azimuth Engine Room
  4 Aft Deck / L.N.G. Area

Area 3 combination 1 & 2

(in compliance with A.D.N. regulations and I.G.F. code)
Area 1 Accommodation
2 2x L.N.G Engine Room (P.S. & S.B.)
3 1x Azimuth Engine Room

Drw.Nr. 000-003-a (2 of 3), 2011-12-07

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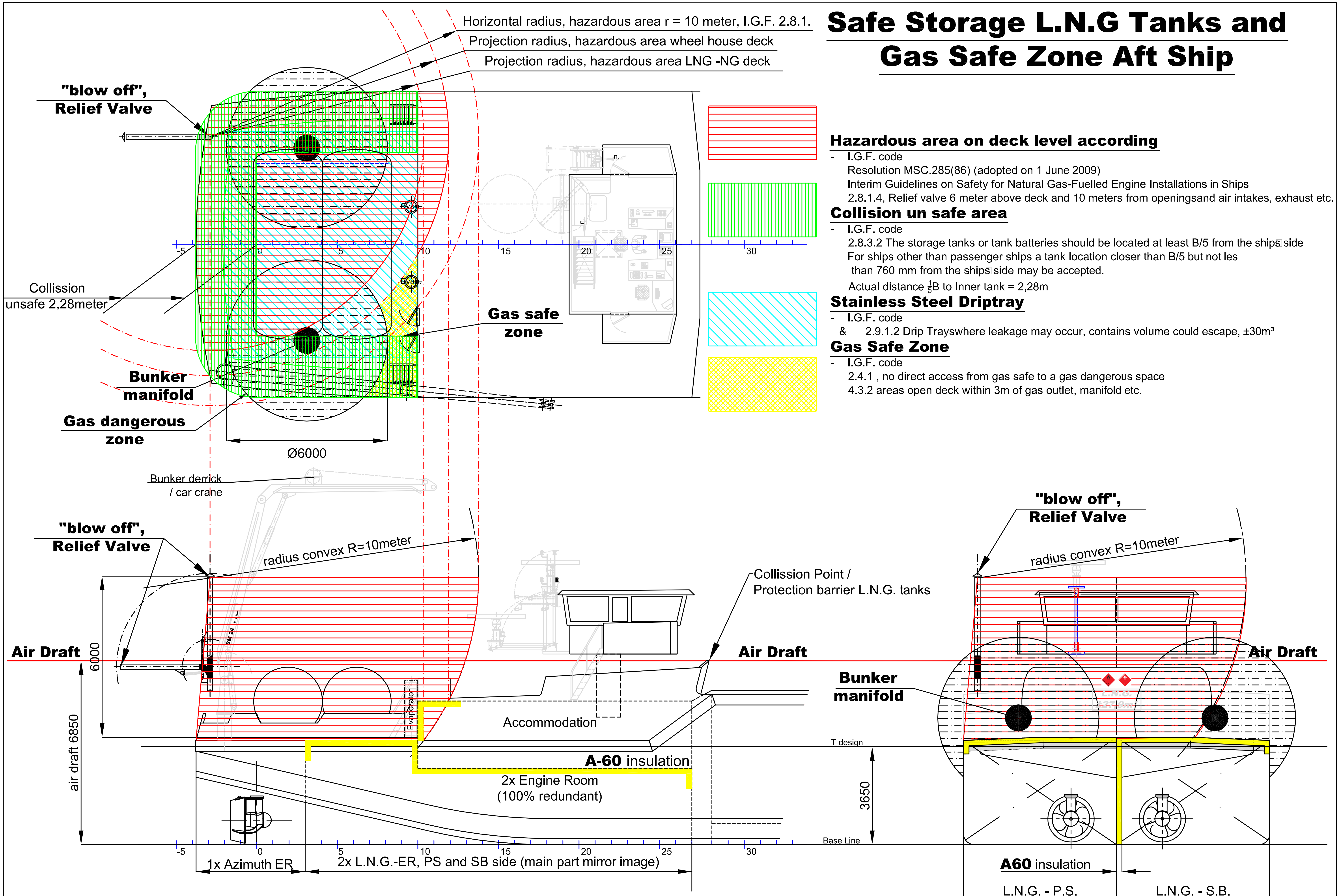
Safe Storage L.N.G Tanks and Gas Safe Zone Aft Ship



Hazardous area on deck level according

- I.G.F. code

  Resolution MSC.285(86) (adopted on 1 June 2009)

  Interim Guidelines on Safety for Natural Gas-Fuelled Engine Installations in Ships

  2.8.1.4, Relief valve 6 meter above deck and 10 meters from openingsand air intakes, exhaust etc.

Collision un safe area

- I.G.F. code

  2.8.3.2 The storage tanks or tank batteries should be located at least B/5 from the ships side

  For ships other than passenger ships a tank location closer than B/5 but not les than 760 mm from the ships side may be accepted.

  Actual distance $\frac{1}{5}$B to Inner tank = 2,28m

Stainless Steel Driptray

- I.G.F. code

& 2.9.1.2 Drip Trayswhere leakage may occur, contains volume could escape, ±30m³

Gas Safe Zone

- I.G.F. code

  2.4.1 , no direct access from gas safe to a gas dangerous space

  4.3.2 areas open deck within 3m of gas outlet, manifold etc.

Drw.Nr. 000-003-b (3 of 3), 2011-12-07

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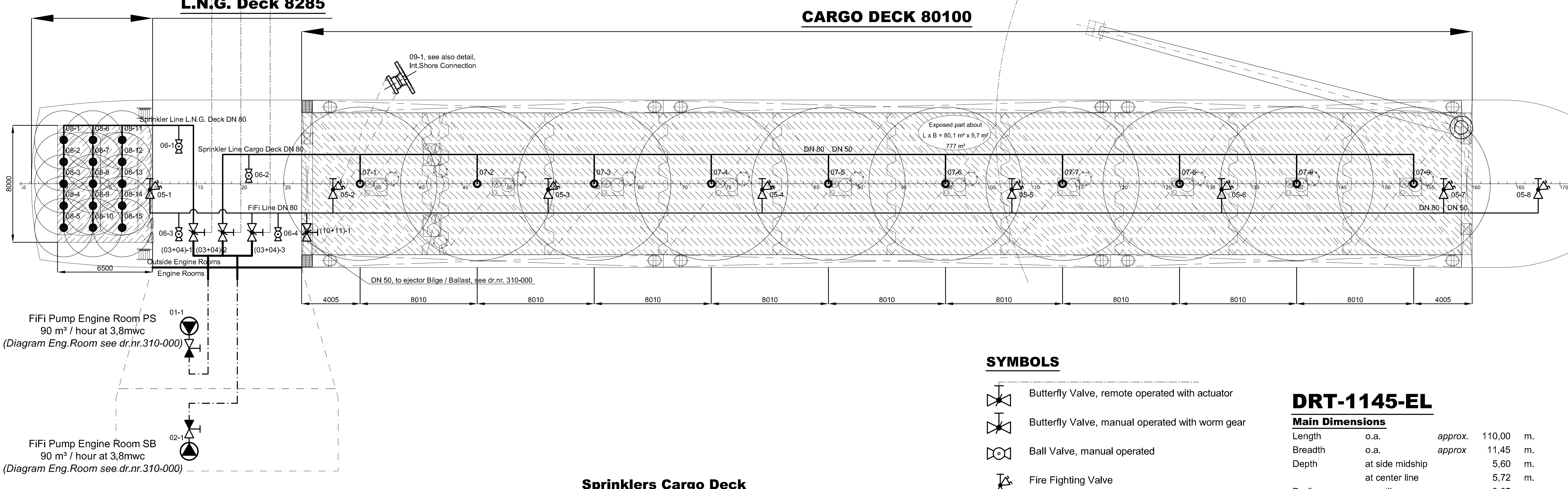
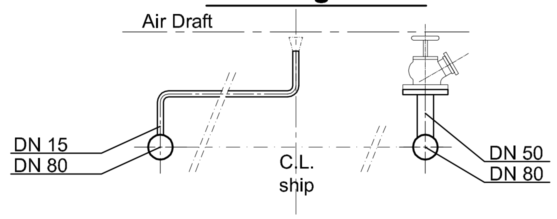
WHEELHOUSE Remote Controls
Valve and Start Pump
FiFi Line
Spray Line Cargo Deck
Spray Line L.N.G. Deck

CARGO DECK Remote Controls
Valve and Start Pump
Spray Line Cargo Deck

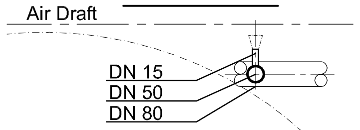
NOTE!
Risk Bunkering Derrick / Collision with Pipe Lines



Detail Sprinkler / FiFi Cargo Deck



Detail Sprinkler / L.N.G.Deck



Sprinklers Cargo Deck

Requirements	A.D.N. 9.3.2.28
	50 l / hr / m² cargo area
	start from wheel house and deck
	connection with shore
Cargo Deck Area	L x B = 80,1m x 9,7 m = 777 m²
Water needed to spray	777 m² x 50 l / hr. = 39.000 l / hr = 650 l / min.
Spray Nozzle Type	type TF 24 XW
	volume 125 l / min
	pressure 2,8 bar
	diameter ± 10,5 m
Number of nozzles required	10 pieces
Pump required	10 x 125 l / min x 60 min
	= 75 m³ / hour at 2,8 bar

Sprinklers L.N.G. Deck

Requirements	I.G.F.code 3.3.2 Water Spray System
	coverage exposed part gas storage tanks above deck
	application rate
	horizontal 10 l / min / m²
	vertical 4 l / min / m²
	start readily accessible position => wheel house
Cargo Deck Area	L x B = ± 6,1 m x ± 9,225 m = ± 56,3 m²
Water needed to spray	56,3 m² x 600 l / hr. = 33.763 l / hr = 562,7 l / min
Spray Nozzle Type	type MP 250 N * 4
	volume 41 l / min.
	pressure 3,5 bar
	cone diameter ± 4 m .
	cone height ± 2 m.
Number of nozzles required	15 pieces
Pump required	15 x 41 l / min x 60 min
	37 m³ / hour at 3,5 bar

SYMBOLS

- Butterfly Valve, remote operated with actuator
- Butterfly Valve, manual operated with worm gear
- Ball Valve, manual operated
- Fire Fighting Valve
- Spray Nozzle Cargo Deck
- Spray Nozzle L.N.G. Deck

PIPES

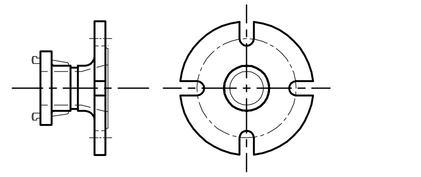
Mild Steel, Grade A

12"	DN 300	- Ø 323,9 x 7,1
10"	DN 250	- Ø 273,0 x 6,3
8"	DN 200	- Ø 219,1 x 6,3
6"	DN 150	- Ø 168,3 x 4,5
5"	DN125	- Ø 139,7 x 4,0
4"	DN 100	- Ø 114,3 x 3,6
3"	DN 80	- Ø 88,9 x 3,2
2½"	DN 65	- Ø 76,1 x 2,9
2'	DN 50	- Ø 60,3 x 2,8
1½"	DN 40	- Ø 48,3 x 2,9
1¼"	DN 32	- Ø 42,4 x 2,6
1"	DN 25	- Ø 26,9 x 2,6
½"	DN 15	- Ø 21,3 x 2,3

PIPES, galvanized with 3.1B certificate

made from mild steel ("old"DIN 2448 "new" EN 10216-1)

09-1, 1x "Loose" International Shore Connection



DRT-1145-EL

Main Dimensions

Length	o.a.	approx.	110,00	m.
Breadth	o.a.	approx	11,45	m.
Depth	at side midship		5,60	m.
	at center line		5,72	m.
Draft	scantling		3,65	m.

Cargo Tanks

Dead Weight	at T = 3,30 m.	approx.	2.600	tons
10x	Volume Cargo Tanks (including slob)	approx.	3.770	m³
2x	Volume Slob Tanks	approx.	2x 28	m³

Class / Authorities

I.V.W. (Directive 2006/87/EC)

- "Richtlijnen C.E. markering"
- R.O.S.R.
- "Continue vaart"
- "aantekening één mansradar vaart"

A.D.N. (Directive 2008/68/EC)

- type C
- 50 kPa

Bureau Veritas

- ✠ 5 IN (0.6) Z
- Tanker / Double Hull
- DP = 57.5 kPa / TP = 65 kPa
- A.D.N. Type C
- ✠ M.C.

☐ For approval
☐ For information
☐ For construction
☐ Stamped approved by class

rev.	date	inspected
REV1	DATE	INSPECT

BODEWES MILLINGEN a/d RIJN Nederland

DRT-1145- EL, Type C
Sprinkler Diagram
Cargo-, and L.N.G. Deck

drawn: WK — date: 2011-12-07 — scale: ......
proj. no.: Sneekes
dwg. no.: 675-000, 2011-12-07

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INTERIM GUIDELINES ON SAFETY FOR NATURAL GAS-FUELLED ENGINE INSTALLATIONS IN SHIPS

Parameter	Applicable for DRL 1145 EL	Alarm	Automatic shutdown of main tank valve	Automatic shutdown of gas supply to machinery space containing gas-fuelled engines	Comment
Gas detection in tank room above 20% LEL	No Tankroom	X			
Gas detection on two detectors 1) in tank room above 40% LEL	No Tankroom	X	X		
Fire detection in tank room	No Tankroom	X	X		
Bilge well high level tank room	No Tankroom	X			
Bilge well low temperature in tank room	No Tankroom	X	X		
Gas detection in duct between tank and machinery space containing gas-fuelled engines above 20% LEL	No duct	X			
Gas detection on two detectors 1) in duct between tank and machinery space containing gas-fuelled engines above 40% LEL	No duct	X	X 2)		
Gas detection in compressor room above 20% LEL	No Compr.	X			
Gas detection on two detectors1) in compressor room above 40% LEL	No Compr.	X	X 2)		
Gas detection in duct inside machinery space containing gas-fuelled engines above 30% LEL	yes	X			If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection on two detectors1) in duct inside machinery space containing gas-fuelled engines above 40% LEL	No double pipe	X		X 3)	If double pipe fitted in machinery space containing gas-fuelled engines
Gas detection in machinery space containing gas-fuelled engines above 20% LEL	yes	X			Gas detection only required for ESD protected machinery space
Gas detection on two detectors1) in machinery space containing gas-fuelled engines above 40% LEL	yes	X		X	Gas detection only required for ESD protected machinery space containing gas-fuelled engines. It should also disconnect non certified safe electrical equipment in machinery space containing gas-fuelled engines
Loss of ventilation in duct between tank and machinery		X		X 2) 4)	
Loss of ventilation in duct inside machinery space containing gas-fuelled engines	No duct and / or double pipe	X		X 3) 4)	If double pipe fitted in machinery space containing gas-fuelled engines
Loss of ventilation in machinery space containing gas-fuelled engines	yes	X		X	ESD protected machinery space containing gas-fuelled engines only
Fire detection in machinery space containing gas-fuelled engines	yes	X		X	
Abnormal gas pressure in gas supply pipe	yes	X		X 4)	
Failure of valve control actuating medium	yes	X		X 5)	Time delayed as found necessary
Automatic shutdown of engine (engine failure)	yes	X		X 5)	
Emergency shutdown of engine manually released	yes	X		X	

1) Two independent gas detectors located close to each other are required for redundancy reasons. If the gas detector is of self monitoring type the installation of a single gas detector can be permitted.

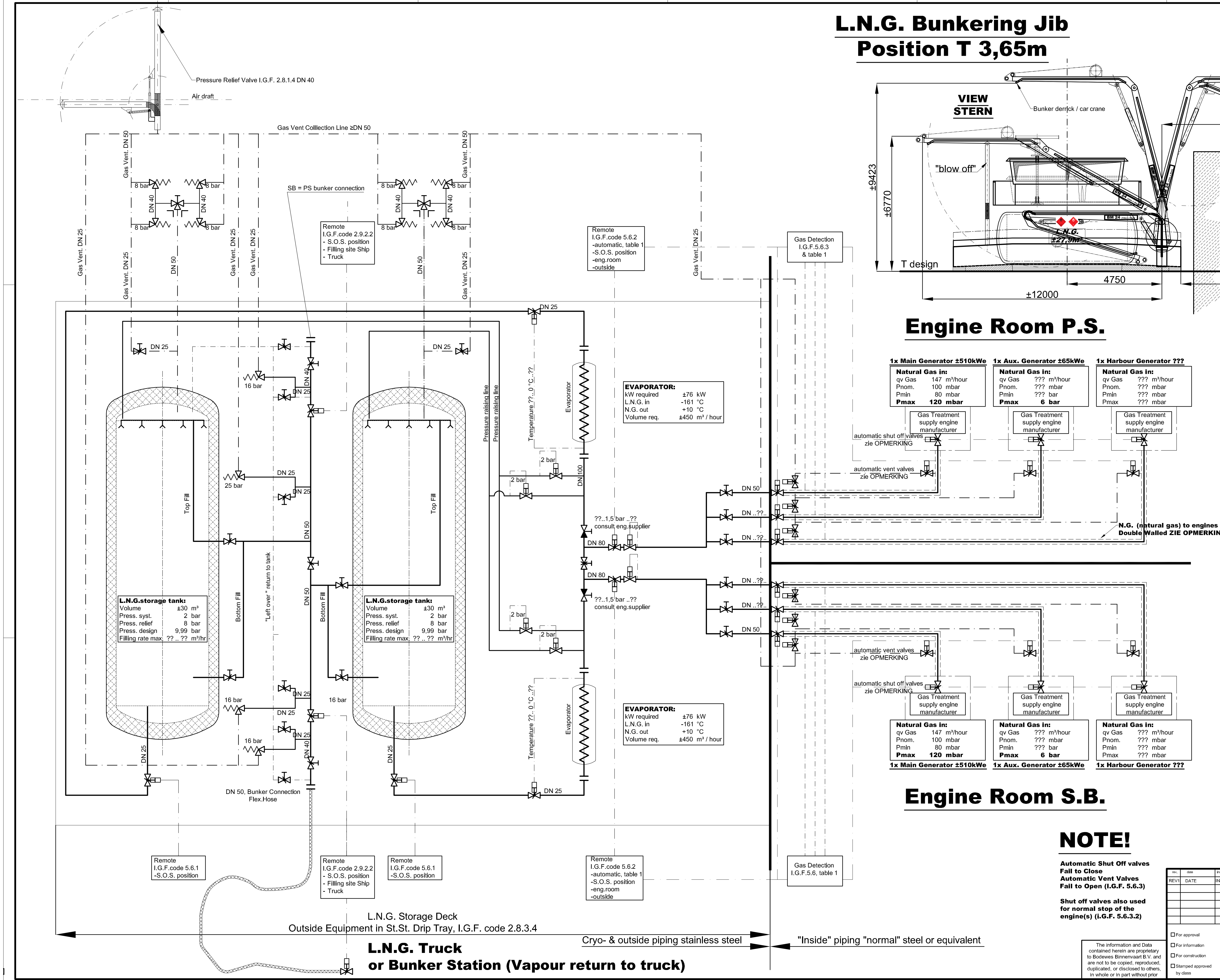
2) If the tank is supplying gas to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

3) If the gas is supplied to more than one engine and the different supply pipes are completely separated and fitted in separate ducts and with the master valves fitted outside of the duct and outside of the machinery space containing gas-fuelled engines, only the master valve on the supply pipe leading into the duct where gas or loss of ventilation is detected is to close.

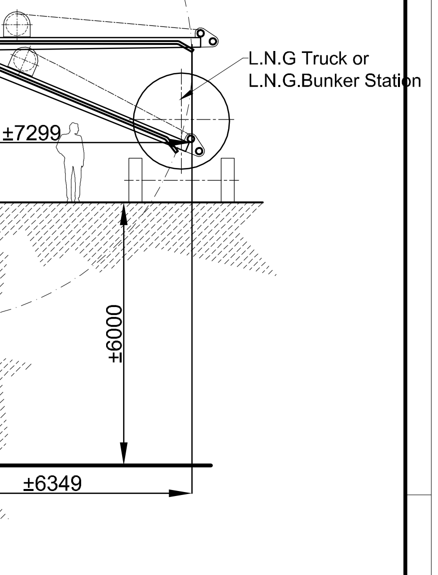
4) This parameter is not to lead to shutdown of gas supply for single fuel gas engines, only for dual fuel engines.

5) Only double block and bleed valves to close.

6) If the duct is protected by inert gas (see 2.7.1) then loss of inert gas overpressure is to lead to the same actions as given in this table.



L.N.G. Bunkering Jib
Position T 3,65m



L.N.G. TANKS

Cryogenic tank constructed following the
E.N. 13530 (T.P.E.D.) code
Approved according to the
A.D.G. and I.M.O. - I.M.D.G. code

SYTEM DESIGN PRESSURE 2 bar

100% LNG-NG COMBUSTION; REDUNDANT SYSTEM

Total installed power

3x Gen.Set 400 kWe	=	1.200 kWe
1x Gen Set 69 kWe	=	69 kWe
1x Boiler 600 kW	=	600 kWe
Power total per system	=	1.869 kWe

Max. Fuel consumption

Gasoil	=	42,50 MJ/kg
LNG	=	49,51 MJ/kg
Fuel consumption gasoil	=	± 190 g/kW/hour (gasoil)
1,880 kW	=	± 358 kg/hour gasoil
= ± 306		kg/hour LNG
specific gravity LNG	=	430 kg/m³
306 kg LNG	=	± 710 liter/hour LNG
specif gravity NG	=	0,68 kg/m³
306 kg NG	=	± 450 m³/hour NG

Maximum velocity piping

Velocity LNG Filling	=	± 7 m/sec
Velocity LNG Combustion	=	± 2 m/sec
Velocity NG (gas)	=	± 15 m/sec

Filling

DN		Filling rate
DN 50 mm	=	± 50 m³ LNG / hour

Combustion LNG

710 liter LNG / hour	=	0,012 m (diameter)

Combustion NG

450 m³ NG / hour	=	0,103 m (diameter)

Required capacity Evaporator

Heat of Evap. LNG-NG	=	510 kJ/kg
Specific heat NG	=	2,2 kJ/kgK

Evaporation of LNG-NG
306kg x 510 kJ/kg = 156.060 kJ = 44 kW
Heating NG of -161°C up to NG of ±10°C
306kg x 2,2kJ/kgKx171° = 115.120 kJ = 32 kW
Required capacity = 76 kW

NOTE!

Automatic Shut Off valves
Fail to Close
Automatic Vent Valves
Fail to Open (I.G.F. 5.6.3)

Shut off valves also used for normal stop of the engine(s) (I.G.F. 5.6.3.2)

☐ For approval
☐ For information
☐ For construction
☐ Stamped approved by class

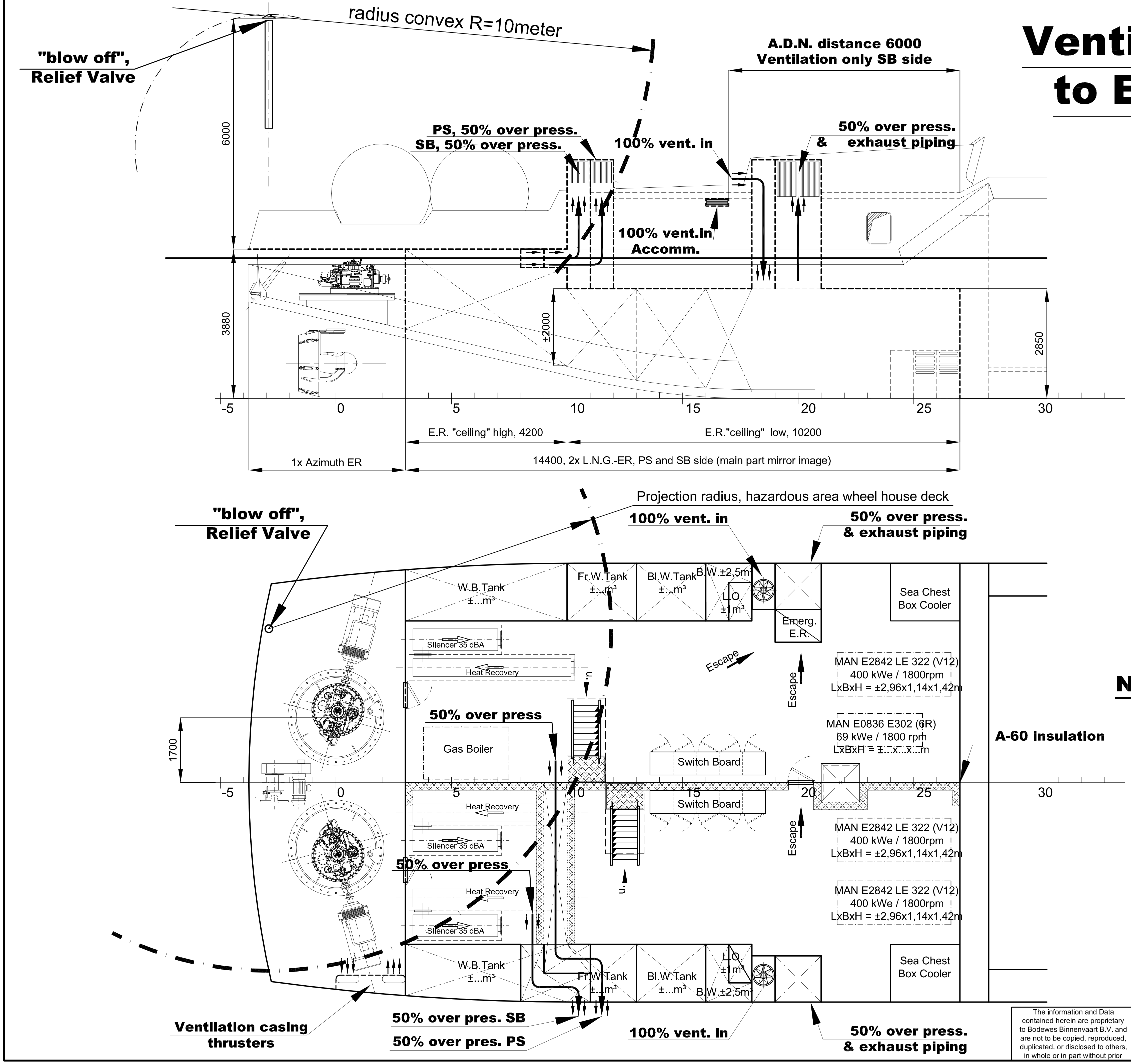
rev.	date	inspected
REV1	DATE	INSPECT

BODEWES MILLINGEN a/d RIJN Nederland

Principal One Line LNG Diagram

drawn:	WK	date:	2011-12-07
proj. no.:	Sneekes		
yard no.:			
		drw. no.:	321-000, 2011-12-07

Ventilation in relation to E.U. / A.D.N. and I.G.F. code



Note: Brand & Type Engines not yet Final

Ventilation according:

1. **I.M.O.: Resolution M.S.C. 285 (86) (adopted om 1 June 2009) (I.G.F.guidelines, Interim Guidelines On Safety for Natural Gas-Fuelled Engine Installations in Ships)**
2. **European Regulations: Code 2006 / 87 / EC**
3. **European Regulations: Code 2008 / 68 / EC**

rev.	date	inspected
REV1	DATE	INSPECT

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DRT-1145-EL
Eng.Room Lay Out & Ventilation in relat. to A.D.N. & I.G.F.

drawn:	WK	date:	2011-12-07	scale:	....
proj. no.:	Sneekes	ident. to drw. no.:	....		
yard no.:	....	derived fr. drw. no.:	....		
Copyright by willemkroon@home.nl		drw. no.:	200-000, 2011-12-07		

C:\Users\User\Documents\Documenten Willem\Bodewes\Bodewes Tekeningen en Documenten\000 Tekeningen\200 Engine Room Lay Out\200-000, 2011-12-07, Motorkamer Indeling en Ventilatie.dwg, 7-12-2011 14:59:31

EFFECT ANALYSIS LNG SPILL DRT 1145 EL

-

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1. INTRODUCTION

Bodewes Binnenvaart B.V. has developed an inland waterway Type C tanker design that uses liquefied natural gas as bunker fuel. The ship will sail in European waters, mostly the ARA (Amsterdam Rotterdam Antwerp) waterways and the river Rhine with adjacent rivers and canals. The natural gas will be stored in liquefied condition in insulated pressure vessels.

This report contains an effect analysis for an accidental spill scenario in the case of a ship collision with the LNG pressure vessel. The same accident scenarios will be taken into account as used for the effect analysis carried out for Type C tankers with enlarged cargo tanks. A comparison will be made with effect distances found for conventional Type C tanker cargo outflow in the event of a collision.

2. SCENARIOS

The different accident scenarios considered in the study on the effect for enlarged cargo tanks [1] concern a collision at the location of the cargo tank where the tank boundary is breached. As a result of the collision release of product is taking place.
For the DRT 1145 EL a collision at the location of the LNG tanks will be assumed where both the stainless steel drip tray as the tank boundary are breached. The amount of release depends on the size of the hole in the LNG tank, the amount of LNG leaving the cargo tank and the place of the hole.
The most severe scenario that has been assessed concerns a hole size in the tank of $2m^2$.
The most severe location of the hole for the LNG tank would be a $2m^2$ hole located at the bottom of the tank. When it is further assumed that the LNG driven tanker sails at ballast draft with 100% filled LNG tanks the worst case scenario is considered.

Two hazards associated with LNG bunker fuel in the environment have been given consideration:

- Maximum pool radius on the water [m], assuming that direct contact with the cargo is lethal
- 10 kW/m^2. This is the quantity for heat radiation intensity. The calculated effects are the effects of a ‘late pool fire’ (pool fire of the maximum pool).

3. MODELLING OF PHYSICS

In Sandia report SAND2004-6258 [2] a procedure is given for the effect analysis of an LNG spill over water.

The diameter of the spill can be determined by assuming a steady state where the mass coming in is balanced by the mass going out, due to the heat flux from the heating of the water below and from the fire above. According to Cook et al. [3] the burning rate on water is 2.5 times greater than the burning rate on land. For LNG a mass burning rate of 0.353 [kg/m^{2}s] is used.

$$(\rho A v)_{in} = (\rho A v)_{out}$$

$$\left(\frac{dV}{dt}\right)_{average} = \frac{-(Av)_{out}}{2} = -\frac{C_d A_0}{2}\sqrt{2gh_i}$$

$$D = \sqrt{\frac{4}{\pi v_{total}}\left(\frac{dV}{dt}\right)_{average}}$$

Where:

0.6	C_D	- Dicharge coefficient	[-]		
2	A_0	- Cross sectional area of hole	[m^2]		
9.81	g	- Gravity accelaration	[m/s^2]		
4.5	h_i	- Initial height of fluid	[m]	(air draft - Tballast)	
21.98	A_t	- Cross sectional area of tank	[m^2]		
7.84E-04	v_{total}	- burn rate	[m/s]		

The diameter of the spill becomes

diameter spill	96	[m]

A right cylinder, solid flame model is used to model the pool fire. The effect of wind on the flame is considered negligible. The Moorhouse correlation for LNG was used to calculate the flame height [4].

$$H = 6.2D\left(\frac{\dot{m}''}{\rho_a\sqrt{gD}}\right)^{0.254} u_{10}^{*-0.044}$$

Where:

0.353	m"	- Mass burning rate per unit area	[kg/m²s]
1.25	rho_a	- ambient air density	[kg/m³]
1	u_{10}	- non dimensional wind speed	[-]

The Flame height becomes

flame height	180	[m]

The radiative flux incident upon an object can be determined by:

$$q'' = E_p \tau_{atm} F$$

Where:

10	q"	- thermal radiation intensity	[kW/m²]
220	E	- average emmissive power	[kW/m²]
	F_{12}	- view factor	
	τ_{atm}	- atmospheric transmissivity	

Both the transmissivity and the view factor are dependent on the distance the object is away form the source. The distance to 10 kW/m^2 can be calculated using the following relations

$$F_{12,\max} = \sqrt{F_{12,H}^2 + F_{12,V}^2}$$

$$F_{12,H} = \frac{(B-1/S)}{\pi\sqrt{B^2-1}}\tan^{-1}\sqrt{\frac{(B+1)(S-1)}{(B-1)(S+1)}} - \frac{(A-1/S)}{\pi\sqrt{A^2-1}}\tan^{-1}\sqrt{\frac{(A+1)(S-1)}{(A-1)(S+1)}}$$

$$F_{12,V} = \frac{1}{\pi S}\tan^{-1}\left(\frac{h}{\sqrt{S^2-1}}\right) - \frac{h}{\pi S}\tan^{-1}\sqrt{\frac{(S-1)}{(S+1)}} + \frac{Ah}{\pi S\sqrt{A^2-1}}\tan^{-1}\sqrt{\frac{(A+1)(S-1)}{(A-1)(S+1)}}$$

$$A = \frac{h^2+S^2+1}{2S} \qquad B = \frac{1+S^2}{2S}$$

$$S = \frac{2L}{D} \qquad h = \frac{2H}{D}$$

Where:

L	- distance between the center of the cylinder to the target	[m]
H	- height of the cylinder	[m]
D	- cylinder diameter	[m]

$$\tau_{atm} = 1.5092 - 0.0708\ln[sP_{w,sat}(T_a)RH/100]$$

Where:

288	T_a	- atmospheric temperature	[K]
80	RH	- humidity	[%]
	s	- distance traveled	[m]

$$P_{w,sat} = \exp\left[25.897 - \frac{5319.4}{T_a}\right]$$

The distance to10 kW/m^2 becomes

10 kW/m^2	255	[m]

4. RESULTS AND CONCLUSION EFFECT CALCULATIONS

In the following table the results of the LNG spill effect calculation are shown together with the results for the 380 m^3 Type C tanker cargo tank for the typical products as used in reference [1].

		Max pool radius [m]	10 kW/m^2
2 m^2 hole size	Benzene	234	263
	Acrylonitrite	249	575
	n-Hexane	235	264
	n-Nonane	236	283
	Acetic acid	234	261
	LNG	95	255

Comparing the effects it can be concluded that the calculated maximum pool radius and the distance related to the 10 kW/m^2 heat radiation intensity are the lowest for the LNG spill. Therefore it can be concluded that for the Type C tanker DRT 1145 EL no additional effect distance can be associated with LNG. It is further noted that the DRT 1145 EL has a stainless steel drip tray installed underneath the LNG tanks that can contain 100% of one tank volume. This decreases the pool radius to the dimensions of the drip tray and the 10 kW/m^2 distance will be decreased accordingly. Furthermore it should be noted that chemical tankers are subject to restrictions w.r.t. sailing areas and places for anchoring and mooring.

5. REFERENCES

[1] A.W. Vredeveldt, M.J. Wolf, J. Broekhuijsen, E. Gret, Safe transport of hazardous cargo through crashworthy side structures, 2004, International Conference on Collision and Grounding of Ships, Izu Japan
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TNO report

Assessment of hazard identification study chemical tanker design Ecoliner

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Summary

Technical evidence, supporting a hazard identification study on the design of a natural gas fuelled chemical inland waterway tanker, has been assessed. The storage of the gas will be as liquid at cryogenic temperature (LNG). With exception of the location of the fuel tanks, the general conclusion is that in principle, LNG as bunker fuel is sufficiently safe. In addition, although these are not considered as show stoppers, some other safety issues are still to be resolved.

The most important issues are:
- protection of the LNG storage tank against ship collisions,
- how to handle LNG leakage from the cold box drip tray to the deck,
- how to prevent overfilling and uncontrolled pressure build up, during bunkering,
- prevention of accumulation of dangerous gas concentrations in the engine room.

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1 Introduction

There are currently three initiatives in progress on the use of natural gas as bunker fuel on inland waterway tankers. The ships will sail European waters, mostly the ARA (Amsterdam Rotterdam Antwerp) waterways and the river Rhine with adjacent rivers and canals. The natural gas will be stored in liquefied condition in insulated pressure vessels. There will be no liquefication facility on board, hence the tanks will be designed to cope with a pressure build up.

Safety studies have been carried out for all three initiatives. Documentation related to the studies has been submitted to the responsible authorities, CCNR (Central Commission for the Navigation of the Rhine) and UN ECE (United Nations Economic Council Europe).

DGLM (The Netherlands Directorate General Aeronautics and Maritime transport) has requested TNO to assess the technical evidence currently available and formulate a recommendation on how to progress.

There are significant differences between the three project initiatives, therefore it has been decided to formulate the recommendations for each initiative separately.

This report refers to the design of a motor tank ship Ecoliner.

According IMO standards [7] a formal safety assessment consists of five distinctive steps as shown in Table 1.1.

Table 1.1 FSA steps

step	***description***
1	HAZARD IDENTIFICATION
2	RISK ANALYSIS
3	RISK CONTROL OPTIONS
4	COST BENEFIT ASSESSMENT
5	RECOMMENDATIONS FOR DECISION MAKING

The documentation submitted to CCR/UN-ECE, is not restricted to a hazard identification study (step 1). Mitigation actions are also reported which formally are a part of the "*risk control options*" activity (step 3).
Many hazards as identified, are already covered IGC [3] code, IGF [2] code (IGF has a preliminary status only) and the design code for cryogenic vessels [5]. It is reasonable to state that when the LNG fuel system complies with these codes with respect to a hazard, sufficient safety is ensured related to this hazard. In such cases the associated risk needs not to be quantified as such and the FSA needs not be carried out to its full effect. From the available documentation is becomes evident that this approach has been chosen.
However some hazards are outside the scope of current safety codes. Obviously these need to be addressed in a FSA fashion.

2 Approach

The work allocated to TNO has been carried out through making seven distinct steps:

1. Study available information as submitted to authorities;
2. Identify additional information required;
3. Obtain additional information required;
4. Study additional information;
5. Discuss findings with relevant stakeholders;
6. Assess and verify available material;
7. Report the assessment.

Activities 1 and 2 of the study took place at the TNO offices. During this part a review of a number of HAZID documents was carried out. A requests for additional information were made.
Discussions were held with representatives from Bureau Veritas in Rotterdam in which the findings of this initial assessment were discussed. A visit was paid to MTS Argonon, which features a LNG installation, currently under construction at shipyard TRICO in Rotterdam. An important aim of the discussions was to acquire additional information identified by TNO to be missing in the HAZID study. Moreover clarifications were obtained on some unresolved issues.

Some reference material, available in the public domain, has also been considered while making the assessment.

When dealing with industrial activities where safety issues are relevant, such as building and operating chemical plants or building and operating (offshore) oil exploitation facilities, it is common to conduct an FSA (formal safety assessment, see introduction).
The philosophy related to FSA has been used by TNO as a guideline while assessing the available technical evidence.

The approach in [1] annex 6, is slightly different from a FSA. The document introduces the concept of the safety case, which may be regarded as a way of conducting an FSA. Table 2.1 lists the elements of this safety case.

Table 2.1 Safety case documentation (taken from [1])

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

As can be seen a HAZID is only one element of a safety case. In principle the other elements should be dealt with as well in order to complete the safety case. However it should be mentioned that a break down of a safety case into elements should be regarded as a guideline. Hence discarding some of the elements may be quite acceptable as long as the safety assessments yields convincing results.

In order to provide some additional structure, Table 2.2 was drafted, which is used as an (additional) guidance during the assessment.

Table 2.2 hardware systems and operational modes

		1	2	3	4	5	6
		sailing	manoeuvring	idle moored	(un)loading moored	bunkering moored	construction, repair, maintenance and demolition
1	LNG storage tank (*in operation mode*)	tank impact with bridge no issue protected by superstructure, ship impact, excessive pressure build up due to heating, sloshing damage, cargo tank slides/topples due to ship accelerations	ship impact, excessive pressure build up due to heating, sloshing damage, cargo tank slides/topples due to ship accelerations	ship impact, excessive pressure build up due to heating	ship impact, excessive pressure build up due to heating, dropped objects	ship impact, excessive pressure build up due to heating, cargo tank, dropped objects, pressure build up due to bunkering fault	<tank will not be gas free> dropped objects, leakage and hot work, LNG reactivity with other substances
2	Bunkering system (a*longside*)	n.a.	n.a.	n.a.	n.a.	Broken bunker hose (LNG spill on deck), gas release (explosion, fire), frozen couplings (quick release impossible), loss of control due to incorrect pressure reading or incorrect level reading or frozen valves or bad communication or software problems (tank pressure increases), liquid through venting system, damage to human skin, ship/shore, material failure, frostbite personnel	unnoticed damage to system
3	Pressure build up system (*pressure build up, underway*)	spill on deck, PCV 51 leaking in line, gas in ER, pressure build up above design	spill on deck, PCV 51 leaking in line, gas in ER, pressure build up above design	leakage of (liquid)gas in coolwater, leakage of coolwater into gas	spill on deck, PCV 51 leaking in line, gas in ER, pressure build up above design	spill on deck, PCV 51 leaking in line, gas in ER, pressure build up above design	mechanical damage (dropped objects, etc.), electric wire cut, sensor damage
4	Gas conditioning system (underway)	freezing heat exchanger, LNG spill on deck, uncontrolled flow,	freezing heat exchanger, LNG spill on deck, uncontrolled flow,	freezing heat exchanger, LNG spill on deck, uncontrolled flow,	freezing heat exchanger, LNG spill on deck, uncontrolled flow,	freezing heat exchanger, LNG spill on deck, uncontrolled flow,	
5	Gas turbine arrangement (underway)	gas/vent air mixture, gas escape, gas cannot be shut off,	gas/vent air mixture, gas escape, gas cannot be shut off,	gas/vent air mixture, gas escape, gas cannot be shut off,	gas/vent air mixture, gas escape, gas cannot be shut off,	gas/vent air mixture, gas escape, gas cannot be shut off,	
6	Machinery arrangement (underway)	inner pipe failure, fan failure, short-circuit main switch board,	inner pipe failure, fan failure, short-circuit main switch board,	inner pipe failure, fan failure, short-circuit main switch board,	inner pipe failure, fan failure, short-circuit main switch board,	inner pipe failure, fan failure, short-circuit main switch board,	
7	Otto engine, incl. gas supply (underway)	leakage, exhaust failure due to explosion, gas release, gas enters	leakage, exhaust failure due to explosion, gas release, gas enters	leakage, exhaust failure due to explosion, gas release, gas enters	leakage, exhaust failure due to explosion, gas release, gas enters	leakage, exhaust failure due to explosion, gas release, gas enters	

3 Technical evidence CCR and UN ECE, 13-08-2011

3.1 Description technical evidence

The following documents have been made available to TNO by the DGTL prior to the study:

Recommendation DRT 1145 ROSR
Recommendation DRT 1145 ROSR annex 1
Recommendation DRT 1145 ROSR annex 2
Recommendation DRT 1145 ROSR annex 3
Recommendation DRT 1145 ROSR annex 4
Recommendation DRT 1145 ROSR annex 5
Recommendation DRT 1145 ROSR annex 6
Att 1 000-000 General Arrangement
Att 2a 000-003 LNG irt accomodation
Att 2b 000-003a LNG irt accomodation
Att 2c 000-003B LNG irt accomodation
Att 3 675-000 Sprinkler LNG
Att 4 Monitoring of Gas Supply Systems
Att 5 321-000 LNG - NG diagram with gastight enclosures
Att 6 200-000 Layout Engine Room and Ventilation
Att 7 400-000 Power Management
Att 8 Safety sheet LNG

These documents were reviewed by TNO. The following criteria were considered:
- Was a structured, generally accepted, approach used for the HAZID?
- Were all Hazards addressed / identified?
- Were corrective measures proposed for these hazards?
- Do the corrective measures proposed provide a sufficient risk reduction?

3.2 Gaps

The review of the HAZID study resulted in the questions and requests as listed below.

The issues list was sent by e-mail to Lloyds Register on September 16th 2011.

1. . Has a risk ranking been made following the HAZID as reported ref. [1]?
A risk ranking will help to assess the necessity of safeguards.
2. . Has any assessment been done w.r.t. ship-ship collisions? Are there arguments why contact with the LNG tank can be ruled out? A safe distance between tank wall and ship side of 1000 mm seems too small.
3. . The documentation does not seem to address external safety issues, e.g. risks to terminals during loading and unloading. Are there reasons why this aspect may be irrelevant?

Moreover an update was requested on the current status of the pending issues as listed below.

4. Collision with bridge (no issue).
5. . In service inspection of LNG tanks needs further consideration, as mentioned in chapter 4 of ref. [1].
6. . Bunkering procedure identified as main hazard (chapter 4 of ref. [1]), automated bunkering procedure proposed for further consideration.
7. . Location of bunkering manifolds indicated as unresolved (chapter 4 of ref. [1]).
8. . Pressure regulating control valve identified as potential cause of pressure build up (chapter 4 of ref. [1]).
9. . Drip tray below cold box, may discharge LNG on deck (chapter 4 of ref. [1]).
10. CFD analyses proposed to demonstrate adequate ventilation in gas dangerous spaces (chapter 4 of ref. [1]).

It is noted that LNG spill from a fractured bunkering hose had not been considered. Additional data will be requested. This will be addressed under gap item no. 6, *bunkering procedure*.

Another issue to be considered is human error. Handling cryogenic liquids and flammable gas safely requires knowledge, skills and an attitude. In this document referred to as issue 11.

4 Additional evidence

4.1 Discussions

The issues mentioned in the previous paragraph were discussed. Also a visit was paid to MV Argonon, a type C tanker also featuring an LNG fuel installation.

Issues (reference to numbering in previous paragraph) :

1. No risk ranking was carried out. It was / is the intention to address all issues, i.e. to propose / install adequate safety barriers for *all* risks identified.
2. It was argued that ship-ship collisions, that might affect the LNG tanks on board, would also seriously damage the cargo area. As cargo volumes, and hence spilled quantities far exceed the volume of LNG that might be spilled, no significant additional risk would be the result. This issue is not yet resolved.
3. Loading/unloading was considered a main risk in the HAZID studies. There is a need to address a potential (L)NG spilled and the consequences. The latter should also include the effect of the cold LNG on the structural integrity of the ship.
4. Collision with a bridge is no issue for this ship, because the superstructure protects the tank.
5. The LNG tanks were built according to the specifications for the road tankers used for LNG transport [5]. Also the inspection regime for road tankers will be followed. This was considered (more than) adequate, because road tankers are likely to be exposed to larger shocks / vibrations during operation than ships.
6. The bunkering procedure was considered to pose the higher risk. Therefore this activity must be performed by skilled personnel only. Also automatic safety measures will be installed that would generate an automatic shut off (safety valves) to limit the volumes spilled during loading (see also nr 3 above). Also level indicators would be installed that would generate alarms and eventually shut down the loading operation. Further details w.r.t. the bunkering system including bunkering procedures should be described.
7. The location of the bunkering manifold must be chosen carefully because of vulnerability to mechanical damage and potential spill of LNG on deck. Further details to be specified.
8. The pressure regulating control valve in the pressure build up system has been identified as a potential hazard. Mitigating measures have been suggested, however it is not yet clear which will be used.
9. In issue has been identified related to the drip tray below the tanks, where condensed water vapour needs to be drained which may interfere with possible LNG drainage. It is not yet clear which solution has been chosen.
10. A point of on-going concern is the potential of gas built-up (i.e. an explosive gas-air mixture) in the engine rooms. It has not yet been demonstrated whether ventilation will be sufficient guarantee for an explosion free environment. The gas detection proposed might be unreliable because it might generate false alarms (leading to ignoring of alarms or by-passing the shut-off systems) or it could be in the wrong place (which means no detection). Odoration of the gas will help if the machine room is visited

regularly. TNO therefore remains of the opinion that the potential for a built up of an explosive atmosphere (in an area with numerous ignition sources) is still there. This issue needs to be further addressed.

4.2 Additional information

Issue 8. Pressure built up.
A calculation result is available on tank venting. It demonstrates that a tank, filled at 70%, exposed to an ambient temperature of 40 Celcius and a allowable pressure of 8 bar, will vent after 25 days.

4.3 Assessment of additional technical evidence and gaps

Issue 2. Ship-Ship collisions
This issue is dealt with by referring to IMO IGF code which implies that hull penetrations due to collisions, larger than 1000 mm, are unlikely. It is know that cryogenic storage tanks tend to have a large impact resistance and probably larger than the expected impact energy. It is suggested to give this scenario some consideration and secure documentation on impact resistance of cryogenic storage tanks.

Issue 3. External safety
This issue is dealt implicitly only. It is argued that effect distances associated with chemical tankers are substantially larger than those associated with LNG quantities currently envisaged as bunker fuel. It is noted that chemical tankers are subject to restrictions w.r.t. sailing areas and places for anchoring and mooring. Hence no further considerations are required at this stage.
However, when LNG fuel storage capacities increase substantially (>200 m3), this issue needs to be reconsidered.
When LNG fuel is considered for general cargo or container ships, the external safety issue needs to be addressed.

Issue 4. Calculation collision with a bridge
Since the superstructure protects the tanks, this scenario is no issue.

Issue 6 LNG spill on deck.
Information on how to prevent LNG storage tank overloading, e.g. through liquid level detection and high-high alarms, or, alternatively, technical evidence showing that overfilling will not have any adverse effects is still to be provided.

Issue 10. Gas/air mixture accumulation in engine room.
The geometry of the engine rooms seems to make them prone to gas accumulation. This issue needs to be addressed.

Issue 11. Human element.
There is general consensus on the required knowledge, skills and attitude of crew dealing with LNG bunker fuel. It is fortunate that chemical tankers are proposed as pioneers in using LNG as bunker fuel, because crews are qualified (ADN) to deal with hazardous substances, i.e. the cargo. However handling LNG requires additional knowledge and skill. It is still to be resolved who will teach the knowledge and skills and how many crew members trained on the LNG aspect must be onboard.
When LNG fuel is considered for general cargo or container ships, the external safety issue needs to be addressed because crews may not have any ADN qualification.

General remarks
Any safety assessment on a technology used in a new environment is a tremendous task. The main issue is overlooking the obvious. Also in the case of LNG as bunker fuel on inland waterway ships the making sure that all relevant

hazards have been addressed must remain on top of the priority list. Moreover accessibility of safety case documentation requires further attention.

5 Conclusions and recommendations

The general impression from the technical evidence studied so far, is that applying LNG as bunker fuel may cause a safety issue with regard to the location of the tanks on the aft deck. The ‘crashworthiness’ of the tanks is unknown and should be further investigated, because it cannot be ruled out that they are intrinsically safe.

Some technical evidence is not always readily available although it seems likely that it exists. Some issues, already identified in the HASID, still need to be resolved.

Tank damage due to collision with bridge is no issue for this ship.

Brittle fracture main deck due to LNG spill
LNG spill on deck due to rupture of the bunker hose is to be investigated.

Dangerous gas concentration in ER
The issue of dangerous gas concentrations in the ER needs further supporting evidence. Smoke tests are recommended.

References

[1] Recommendation to inspection bodies relating to the rhine vessel inspection regulations, on motor tank vessel “Damen River Tanker – 1145 Ecoliner”, type C tanker, official ID number 54314 and BV reg. no. 20629A. Versie 18-8-2011
[2] IGF, draft International code on safety for Gas-Fuelled ships, IMO
[3] IGC, International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk, 1993 Edition, IMO
[4] SANDIA REPORT, SAND2004-6258, Unlimited Release, Printed December 2004, Guidance on Risk Analysis and Safety, Implications of a Large Liquefied Natural, Gas (LNG) Spill Over Water
[5] EN13458-2 Cryogenic vessel – Static vacuum insulated vessels Part 2: Design, fabrication, inspection and testing
[6] NFPA 57, Liquefied Natural (LNG) Vehicular Fuel Systems Code 2002 Edition
[7] Guidelines for formal safety assessment (FSA) for use in the IMO rule making process, MSC/Circ.1023, MEPC/Circ.392, 5 April 2002

6 Signature

Delft, <datum>

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In addition to the initial Hazid study further research was done on what would happen with the LNG storage tanks onboard the Ecoliner of Damen after a collision.

Based upon a study made at the Helsinki University of technology and at the Schelde yard in Vlissingen it can be concluded that there is a low probability that a collision will take place at the location of the LNG tanks and that when such a collision takes place the majority of the available energy will be absorbed by a rotation of the struck ship (kinetic energy) and that a relative small amount (20%) has to be absorbed by the ship structure. The amount of energy that has to be absorbed by the ship structure is a factor 3 less compared to a location amidships which makes the location at least as collision resistant as a ship with a special energy absorbing structure in its cargo area.

The next study calculated the effect of LNG spill if a storage tank would rupture and all LNG would be spilled.

For the calculation the same accident scenarios will be taken into account as used for the effect analysis carried out for Type C tankers with enlarged cargo tanks.
The results are compared with the effect distances found for conventional Type C tanker cargo outflow in the event of a collision.

The most severe scenario that has been assessed concerns a hole size in the tank of $2m^2$ and the most severe location of the hole for the LNG tank would be a $2m^2$ hole located at the bottom of the tank. Further it is assumed that the LNG driven tanker sails at ballast draft with 100% filled LNG tanks. In this case the worst case scenario is considered.

Two hazards associated with LNG bunker fuel in the environment have been given consideration:

- Maximum pool radius on the water [m], assuming that direct contact with the cargo is lethal
- 10 kW/m^2. This is the quantity for heat radiation intensity. The calculated effects are the effects of a 'late pool fire' (pool fire of the maximum pool).

The procedure for the effect analysis of a LNG spill is taken from a report of Sandia.

In the following table the results of the LNG spill effect calculation are shown together with the results for the 380 m^3 Type C tanker cargo tank for the typical products as used in reference

		Max pool radius [m]	10 kW/m^2
$2\ m^2$ hole size	Benzene	234	263
	Acrylonitrite	249	575
	n-Hexane	235	264
	n-Nonane	236	283
	Acetic acid	234	261
	LNG	95	255

Comparing the effects it can be concluded that the calculated maximum pool radius and the distance related to the 10 kW/m^2 heat radiation intensity are the lowest for the LNG spill.
Therefore it can be concluded that for the Type C tanker DRT 1145 EL no additional effect distance can be associated with LNG.

As mentioned before the case considered is the worst case scenario. In reality it should be taken into account that the DRT 1145 EL has a stainless steel drip tray installed underneath the LNG tanks that can contain 100% of one tank volume.
This decreases the pool radius to the dimensions of the drip tray and the 10 kW/m^2 distance will be decreased accordingly.
Furthermore it should be noted that chemical tankers are subject to restrictions w.r.t. sailing areas and places for anchoring and mooring.

All mentioned studies and reports are available at the Bureau Veritas office.

Rotterdam, March 19th, 2012

	Reply TNO DRT 1145 Ecoliner

In addition to the initial Hazid study and the TNO report further research was done on what would happen with the LNG storage tanks onboard the Ecoliner of Damen after a collision.

Based upon a study made at the Helsinki University of technology and at the Schelde yard in Vlissingen it can be concluded that there is a low probability that a collision will take place at the location of the LNG tanks and that when such a collision takes place the majority of the available energy will be absorbed by a rotation of the struck ship (kinetic energy) and that a relative small amount (20%) has to be absorbed by the ship structure. The amount of energy that has to be absorbed by the ship structure is a factor 3 less compared to a location amidships which makes the location at least as collision resistant as a ship with a special energy absorbing structure in its cargo area.

Please find the report “considerations for collision scenario on LNG tanks Damen River liner” made by Mr Broekhuijsen of Damen Schelde attached.

The next study calculated the effect of LNG spill if a storage tank would rupture and all LNG would be spilled.

Attached you will find the calculation made by Mr Broekhuijsen of Damen Schelde, report “Effect analysis LNG spill DRT 1145 EL”.

DAMEN

DAMEN SCHELDE NAVAL SHIPBUILDING

MEMO

aan Willem Kroon
c.c. Rob Schuurmans, Liesbeth den Haan

datum 17 Januari 2012
referentie E10109

Afzender Joep Broekhuijsen

Onderwerp Considerations for collision scenario on LNG tanks

Considerations for collision scenario on LNG tanks Damen River Tanker – Eco liner

In this document a number of considerations are given for the review of the collision scenario “colliding with LNG tanks placed at the aft ship”.

For inland waterway tankers with enlarged cargo tanks the energy absorption capacity of the ship construction amidships has to be calculated and compared with a reference ship according to the guidance for enlarged cargo tanks within the ADNR [1]. Starting form a worst case approach the following assumptions are made:

1. For a collision scenario amidships the whole ship, including added water mass, has to undergo a sway motion, assuming an inelastic collision scenario. This implies that a large part of the available collision energy as to be absorbed by the ship’s s construction. This assumption has been verified by Tabri [2] with experimental research. Tabri shows that for a collision location amidships 60% of the available collision energy has to be absorbed by the ship structure. Where for a striking scenario at 75% of the ships length only 38% had to be absorbed by the ship structure.
   The LNG tanks for the Damen River Tanker are placed at a position at approximately 90% of the ships length where it can is estimated that the collision energy to be absorbed by the ship structure will be around 20%. The rest of the available energy will be transformed into kinetic rotation energy of the struck ship.
   The same trend can be absorbed for the penetration depth as a function of the collision location. Where collisions amidships result in a larger penetration compared with collisions near the front or the aft of the ship.

2. According to the guidance for enlarged cargo tanks within the ADNR different collision scenarios in longitudinal directions are determined based on the structural layout of the ship. A distinction is made between colliding on bulkhead, on web and between webs. The collision scenarios are weighted, where the ratio between the ‘calculated span length’ and the cargo tank length is determined. When we add the collision scenario ‘colliding on LNG tanks’ to the longitudinal collision scenario’s all the scenarios can be weighted by determining the ratio between the calculated span length and the total ship length. For the collision scenario ‘colliding at LNG tanks’ this implies that in only 6.6% of the collisions will take place at the location of the LNG tanks.

Conclusion

From 1 and 2 it can be concluded that there is a low probability that a collision will take place at the location of the LNG tanks and that when such a collision takes place the majority of the available energy will be absorbed by a rotation of the struck ship (kinetic energy) and that a relative small amount (20%) has to be absorbed by the ship structure. The amount of energy that has to be absorbed by the ship structure is a factor 3 less compared to a location amidships which makes the lacation at least as collision resistant as a ship with a special energy absorbing structure in its cargo area.

References:

1. ADNR 2009, 9.3.1 Constructievoorschriften voor tankschepen, 9.3.4 Alternatieve constructies,
2. Tabri, K, Broekhuijsen, J, Parametric study on ship collision based on experimental testing, 2007 International Conference on Collision and Grounding of Ships, Hamburg