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Assessment of the hazard identification study for the tank vessel Argonon carried out by TNO

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TNO report

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Assessment of hazard identification study MTS Argonon

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Summary

Technical evidence, supporting a hazard identification study on a natural gas fuelled chemical inland waterway tanker, has been assessed. The storage of the gas will be as liquid at cryogenic temperature (LNG). The general conclusion is that in principle, LNG as bunker fuel is sufficiently safe.
However, although they are considered as part of the normal engineering process, some safety issues are mentioned here which still need to be resolved:

- protection of the LNG storage tank against collision with a bridge,
- 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.

These issues are now being addressed and are subject to class approval.

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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 liquefaction 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.

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 motor tank ship **Argonon**.

2 Approach

Rules, regulations and legislation related to inland waterway ships do not allow fuels on board with a flashpoint lower than 55 ˚C. Hence natural gas in a gaseous state is not allowed. However when it can be demonstrated that adequate safety measures are in place, a derogation is possible. A derogation is granted when the requesting party can demonstrate ‘sufficient safety’. A trial certificate of approval on the basis of a recommendation from the administrative committee can be granted when the requesting party can demonstrate sufficient safety.

Natural gas is not uncommon as bunker fuel for sea going ships. Since the sixties of the last century, LNG carriers use the boil off as fuel. Since that time IMO has developed the International Gas Code (IGC) [3], with regulations which also deal with handling natural gas as fuel on board. Moreover IMO is currently developing the International code on safety for Gas-Fuelled ships, (IGF) [2].

The cryogenic fuel storage tank is of a type which is allowed to build up pressure, which is common in road transport. This type of tank is covered by a European code [5].

In all cases where the available codes are not applicable to inland waterway navigation, a ‘first principles’ approach is chosen, structured along the lines of a formal assessment.

According IMO standards [7] a formal safety assessment (FSA) consists of five distinctive steps as shown in Table 1.

Table 1 typical steps in an FSA

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 by 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 applicable 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 it becomes evident that this approach has been chosen.

Table 2 shows an overview of hazards on an aggregate level and how they are dealt with.

Table 2 hazards and applicable codes

Hazard	Effect	Argonon	IBC	IGF	EN13458	FSA
bridge collision	tank rupture, LNG on deck - brittle fracture, flamable gas mixture - fire	bunker boom protects tank			?	x
bunkering hose/pipe break, LNG spill on deck	brittle fracture - los of cargo, flamable gas mix. - fire	limited hose diameter and length!?				x
drip tray, drainage condensed water versus LNG spill drainage	brittle fracture - los of cargo, flamable gas mix. - fire	proposal to resolve in progress				x
external safety (effect distances)	injury to public	chemical tanker already use safety distances				x
gas/air mixture in ER	fire, explosion	CFD	x	x		
human error	frost bite, fire, explosion, brittle fracture ship deck	education and certification		x		x
mechanical failure components	various	covered by codes!?	x	x	x	
ship – ship collision	tank rupture, LNG on deck - brittle fracture, explosive gas mixture - explosion, flamable gas mix. - fire	1/5 B pro-tection	x	x	?	x

Some hazards are outside the scope of current safety codes. Obviously these need to be addressed in an FSA fashion.

The work done by TNO consists of 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 request for additional information was made and sent to class.
A meeting was held at shipyard Trico in Rotterdam on September 21st 2011, in which the findings of this initial assessment were discussed. Also a visit was paid to MTS Argonon, currently under construction at that yard.

An important aim of this meeting 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 ([4],[6]), 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], is slightly different from an FSA. The document introduces the concept of the safety case, which may be regarded as a way of conducting an FSA. Table 3 lists the elements of this safety case.

Table 3 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 activity in a safety case. In principle the other activities should be done as well in order to complete the safety case.
However it is mentioned that a break down of a safety case into activities should be regarded as a guideline. Moreover from the report on the HAZID, is can be seen that some of the other activities have been done as well. It appears that the safety case has been explored only to some extent, which is quite acceptable as long as the safety assessments yields convincing results.

In order to provide some additional structure, Table 4 was drafted, which is used as an (additional) guidance during the assessment.

Table 4 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, 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 frosen 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, uncuntrolled flow,	freezing heat exchanger, LNG spill on deck, uncuntrolled flow,	freezing heat exchanger, LNG spill on deck, uncuntrolled flow,	freezing heat exchanger, LNG spill on deck, uncuntrolled flow,	freezing heat exchanger, LNG spill on deck, uncuntrolled 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	Duel fuel 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, 23-05-2011

3.1 Description technical evidence

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

- Recommendation Argonon ADN version 17-8-2011.doc
- Recommendation Argonon CCR version 17-8-2011.doc
- Recommendation Argonon ADN Annex 1 Report ROT/11.M.0080 Issue 2.pdf [1]
- Recommendation Argonon ADN Annex 2 Drawing 30883-0000 H.pdf
- Recommendation Argonon ADN Annex 3 Drawing 30883-0200-D.pdf
- Recommendation Argonon ADN Annex 4 Drawing 1002-110-11 PID Sh.1.pdf
- Recommendation Argonon ADN Annex 5 Drawing 1002-110-11 PID Sh.2.pdf
- Recommendation Argonon ADN Annex 6 Drawing 1002-110-11 PID Sh.3.pdf
- Recommendation Argonon ADN Annex 7 Overview Deviations IGF code.doc
- Recommendation Argonon ADN Annex 8 General Overview LNG system.pdf
- Recommendation Argonon ADN Annex 9 General Information LNG system.doc
- Recommendation Argonon ADN Annex 10 Bunkering procedure.doc
- Recommendation Argonon ADN Annex 11 Maintenance Procesdure.doc
- Recommendation Argonon ADN Annex 12 Training procedure.doc

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?

It is unpractical and unreasonable to attach all design documentation as appendices to a UN ECE or CCR recommendation. As a consequence various “gaps” could be identified which are not covered in the documentation as listed. However in many cases the issues identified are considered and documented. Only a few issues remained. Section 3.2 lists the issues not covered in the documentation. Section 3.3 deals with the additional data available.

3.2 Gaps

The review of the HAZID study resulted in the questions and requests as listed below. It is noted that most of the issues raised are already listed in Chapter 4 of the HAZID report [1].

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? Ships colliding in the side are considered in ADN w.r.t. cargo tanks larger than 380 m^3. Are there arguments why contact with the LNG tank can be ruled out?
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. Tank colliding with bridge structure is identified as unresolved, as mentioned in chapter 4 of LR document [1].
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 was requested and supplied. This will be addressed section 3.3, issue 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.

3.3 Additional background data

Additional information was obtained during discussions with the ship owner, builder and the classification society, as listed below.

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 by far exceed the volume of LNG that might be spilled, no significant additional risk is the result. Furthermore it is noted that a study is mentioned in which it is shown that no combination of shipped cargo with LNG would yield extra risks. A reference to this study is known to TNO (e-mail from mdeheer@thijs-en-jet.nl to G.C.M. Deen Shipping, d.d. 28 juli 2011).
3. Loading/unloading was considered a main risk in the HAZID studies. A simple calculation has been done, which demonstrates that temperature drops of the steel plating are about 15 ˚C, which will which does not impair the structural integrity of the ship. The calculations are based one (1) bunker hose with a length of 10 m and a diameter of 2’’. (e-mail from hstuker@cryonormprojects.com to Gerard@Deenshipping.com, d.d. 27 Sept 2011).

4. The owner submitted calculations which demonstrate that the bunker crane construction at the front of the ship acts as a barrier to prevent the LNG tanks from being damaged in case of a collision with a bridge (e-mail from Gerard@Deenshipping.com to lex.vredeveldt@tno.nl, d.d. 24 september 2011). This manual calculation regarding a collision of the bunker crane with a bridge shows that the bunker crane pedestal can absorb 0.38 MJ up to rupture. It is argued that from this analysis it can be concluded that the bunker crane acts as a protection for the LNG storage tank against bridge collision. This implies that the ship sailing at a speed of 2.2 km/hr will be stopped. It is also stated that standing orders are that bridge passages with little height margin are to be negotiated with a maximum speed of 1.0 km/hr.
5. The LNG tank is 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 will be installed that will generate alarms and eventually shut down the loading operation. Further details w.r.t. the bunkering system including bunkering procedures should be described, and assessed by class. LNG spill on deck due to hose failure during bunkering has been addressed, as is shown in Appendix B. Hose diameter and length are restricted to 2” and 10 m respectively.
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 need 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. An issue has been identified related to the drip tray in the cold box, where condensed water vapour needs to be drained which will 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. a flammable gas-air mixture) in the engine room. An inspection of the Argonon showed numerous areas (in particular against the ceiling) where pockets of stagnant gas could accumulate. The CFD calculations will not be able to predict such pockets. Also the proposed ventilation may not be a sufficient guarantee for an non flammable environment. The gas detection proposed might be unreliable causing false alarms (leading to ignoring of alarms or by-passing the shut-off systems) or it could be in the wrong places (which means no detection). Odoration of the gas will help if the machine room is visited regularly. A power point presentation by BUNOVA Development BV, d.d. 25 February 2011, Reference S11-007 has been made available.

4 Assessment

Issues 1, 5, 7 and 9, need no consideration in this report, they can be dealt with through normal engineering practice.

4.1 Ship – ship collision, issue 2

This issue was dealt with by referring to IMO regulations on damage stability which states that hull penetrations due to collisions, larger than 1/5 B, where B the beam of the ship, are unlikely. The LNG storage tank is located at the CL of the ship and hence not in the 1/5 B region. The scenario where a striking ship with a raking bow, e.g. a push barge, striking above the main deck (tanker at full draught and striking ship in ballast), is not covered by the 1/5 B scenario, because the tanker will not suffer structural damage. However it is to be expected that, even when the LNG storage tank is hit, the available collision energy will be low. It is known 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.

4.2 External safety, issue 3

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 related to LNG.
However, when LNG fuel storage capacities increase substantially (>200 m^3), this issue needs to be reconsidered.
When LNG fuel is considered for general cargo or container ships, the external safety issue also needs to be addressed.

4.3 Collision with bridge, issue 4

This reasoning on this issue is recommended for a reconsideration because the hazard occurs when a mistake is made with respect to, air-drafts in which case ship speed reduction will not be applied. A simple crash analysis shows that the boom pedestal can absorb 0.38 MJ.
It is suggested that stowing the bunker boom at an angle where the aft part is higher than the top of the LNG storage tank, may provide a collision energy absorbing device with a capacity much higher than 0.38 MJ.

4.4 LNG spill on deck, issue 6

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 under preparation. This issue is not typical for inland water way shipping, hence when common practice for sea going ships is followed, no problems are expected.

The LNG spill on deck during bunkering has been addressed separately. Due to the limited dimensions of the bunker hose only limited amounts of LNG can be spilled. When all evaporation heat is provided by the deck plating, which is a conservative assumption, a temperature drop of the steel of only 15 ˚C is expected. The hose dimensions are now limited to an inner diameter of 2” and a length of 10 m.

4.5 Pressure regulating control valve in pressure build up system, issue 8

The HAZID [1] identifies the pressure regulating control valve in the pressure build up system as an element which may fail. Mitigating options are available. The final choice is for the designers and builders and will be approved by class.

4.6 Gas/air mixture accumulation in engine room, issue 10

During a visit to the ship it was observed that in the engine room a gap exists between the shell of the accommodation and the outer shell. This gap seems prone to gas accumulation. Both ship owner and TNO feel it is doubtful whether this can be properly modelled in the CFD calculations. Therefore smoke tests were carried out which demonstrated that also these are properly ventilated. Moreover weekly leak checks are envisaged using foam.

4.7 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 on board.
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.

4.8 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 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 will not cause any safety issues which cannot be resolved. However, technical evidence is not always readily available although it seems likely that it exists. Moreover some issues, already identified in the HAZID, are still open. They are currently in the process of being resolved. The classification society is well positioned to judge the proposed technical solutions.

Tank damage due to collision with bridge
The assumption that collision of the LNG storage tank with a bridge will not occur because the bunker boom will protect the LNG storage from a contact with a bridge is valid. The energy dissipating mechanism is currently being reconsidered and analysed.

Brittle fracture main deck due to LNG spill
LNG spill on deck due to rupture of the bunker hose is expected not to cause any unacceptable temperature reduction of the steel deck. This conclusion is based on the assumption that the bunker hose has an inner diameter of 2” and a length of 10 m. Larger diameters and/or larger hose lengths require a new assessment.

Dangerous gas concentration in ER
The conclusion from the CFD calculations that no dangerous gas concentrations will occur in the ER required further supporting evidence. Smoke tests have been done and witnessed by class. Only minor modifications to the ventilators were required to ensure adequacy.

The human element
Parties involved clearly realise that the attitude, knowledge and skills of the crew with respect handling LNG is crucial from a safety point of view. It is considered an advantage that Argonon is a chemical tanker which implies that the crew is already used to handling hazardous cargo. Moreover a company who also provides courses for handling ADN cargo will develop a LNG course for ship crews and teach all crew members in due course.

References

[1] MTS Argonon, HASARD IDENTIFICATION STUDY, Liquefied Natural Gas Powered inland waterway chemical tanker, Report No. ROT/11.M.0080, Issue: 2, 23 May 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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