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TNO assessment of hazard identification study for chemical tanker design I-tanker

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TNO report

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Assessment of hazard identification study chemical tanker design I-tanker

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Summary

Technical evidence, supporting a hazard identification study on the preliminary design of a natural gas fuelled chemical inland waterway tanker, referred to by the builder as ***I-tanker***, has been assessed.
The storage of the gas will be as liquid at cryogenic temperature (LNG). With the chosen design concept, LNG as bunker fuel is considered sufficiently safe. The safety issues which have been identified are adequately being dealt with in the engineering phase, which is currently in progress.
TNO supports the Recommendation I-Tanker 1401 CCNR version 17-8-2011.

Contents

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).

The Netherlands Directorate General for Civil Aviation and Maritime Affairs (DGLM) 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 design known as the ***I-tanker***.

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

Although dubbed Hazard Identification Study, 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 in the IGC [3] code, the IGF [1] 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 it 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 (at least to some extent) 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 request for additional information was made.
Discussions were held with representatives from Lloyds Register in Rotterdam in which the findings of this initial assessment were discussed. A meeting was held with the designers/ builders of the I-tanker. 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 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 an other 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 earlier said, 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.

3 Technical evidence CCR and UN ECE, 17-08-2011

3.1 Description technical evidence

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

Recommendation I-Tanker 1402 CCNR version 17-8-2011
Recommendation I-Tanker 1402 CCNR Annex 1 Report ROT11M0090_Issue 2
Recommendation I-Tanker 1402 CCNR Annex 2 Drawing 14-0104_1401 Rev.A1
Recommendation I-Tanker 1402 CCNR Annex 3 Drawing 02-215-4001 Rev.A1
Recommendation I-Tanker 1402 CCNR Annex 4 Overview deviations IGF Code
Recommendation I-Tanker 1402 CCNR Annex 5 General overview LNG system
Recommendation I-Tanker 1402 CCNR Annex 6 General information LNG system
Recommendation I-Tanker 1402 CCNR Annex 7 Bunkering procedure
Recommendation I-Tanker 1402 CCNR Annex 8 Maintenance procedure
Recommendation I-Tanker 1402 CCNR Annex 9 Training procedure

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 has been discussed with Lloyds Register and the shipbuilder.

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 with respect to ship-ship collisions? 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 can be discarded?

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

4. Collision with a bridge (section 4.1 ref. [1]).
5. . In service inspection of LNG tanks needs further consideration, as mentioned in section 4.1 of ref. [1].
6. . Bunkering procedure identified as main hazard (section 4.1 of ref. [1]), automated bunkering procedure proposed for further consideration.
7. . Pressure regulating control valve identified as potential cause of pressure build up (chapter 4.2 of ref. [1]).
8. . Drip tray below cold box, may discharge LNG on deck (section 4.2 of ref. [1]).
9. . CFD analyses proposed to demonstrate adequate ventilation in gas dangerous spaces (section 4.3 of ref. [1]).

It is noted that LNG spill from a fractured bunkering hose had not been considered. Additional data was requested. This is 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 10).

4 Additional evidence

4.1 Discussions

The issues mentioned in the previous paragraph were discussed through e-mails and telephone conversations. Also a meeting was held with Peters Shipyards (the designers and builders of the I-tanker).

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, hence a ranking is not required since all risks will be addressed.
2. It is argued that ship-ship collisions, which affect the LNG tanks on board, will have caused damage the cargo tanks first. Since the I-tanker design features cargo tanks larger than 380 m^3, this scenario has been explicitly analysed according chapter 9.3.4 (Alternative Constructions) of ADN 2009 ref. [1], which demonstrates adequate protection against collision with respect to cargo outflow.
3. External safety has not been considered. It is argued that complying with de ADN regulations [1], already implies acceptable effect distances and hence do not require an explicit external safety analysis.
4. Collision with a bridge is no issue for this ship, because the superstructure protects the tank. This statement is supported by manual crash calculations based on Minorsky [8].
5. The LNG tanks are 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 is considered (more than) adequate, because road tankers are likely to be exposed to larger shocks / vibrations during operation than ships.
6. 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. 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. Also level indicators would be installed that would generate alarms and eventually shut down the loading operation. Further details with respect to the bunkering system including bunkering procedures should be described.
7. 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 decided which will be used.
8. 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. The issue is solved by providing drainage at two, slightly different, levels.
9. A point of concern is the potential of gas built-up (i.e. a flammable/ 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 of the shut-off systems) or it could be in the wrong place (which means no detection). Odorazation 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. (Addressed in section 4.2).

4.2 Additional information

Issue 4. Collision with a bridge.
The yard has issued a calculation of collision of the superstructure with a bridge ref.[10]. It demonstrates that the superstructure provides ample protection for the tank.

Issue 9. Gas/air mixture accumulation in engine room.
The geometry of the engine rooms is very simple, i.e. basically rectangular. Ventilation flow patterns are still complicated because of the equipment in the engine rooms. However stagnant air, possibly with flammable air gas mixtures are unlikely because of the simple box shape. Ventilation flow calculations [9] support this statement. It is noted that the engine rooms are separate containers which are no part of the ship structure. This is considered safe because any gas leakage is clearly contained, while no gas is present below deck. Moreover smoke tests are planned to verify the engineering results.

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 also expected that cryogenic storage tanks tend to have a large impact resistance. Currently the safety of the I-tanker does not rely on this property.
Moreover since the I-tanker design features cargo tanks larger than 380 m^3, the procedure according chapter 9.3.4 (Alternative Constructions) of ADN 2009 ref. [1], has been followed, which demonstrates adequate protection against collision with respect to cargo outflow.
Finally it is noted that, since cargo volumes, and hence spilled quantities in case of a collision, by far exceed the volume of the LNG which can be spilled, no significant additional risk would be the result. This issue is therefore resolved.

Issue 3. External safety
This issue is dealt implicitly only. It is argued that effect distances associated with chemical carried in tanks exceeding 380 m^3, are substantially larger than those associated with LNG quantities currently envisaged as bunker fuel. It is noted that chemical tankers are subject to restrictions with respect to 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 m^3), this issue needs to be reconsidered.
When LNG fuel is considered for general cargo or container ships, the external safety issue needs to be re-addressed. Reference to the I-tanker would be inappropriate.

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

Issue 6 LNG spill on deck.
From discussions with the yard is has become clear that various means are available to prevent LNG storage tank overloading. Several options are under consideration; e.g. through liquid level detection and high-high alarms. The final arrangement will be chosen during the engineering process and subjected to approval by the classification society.
Fracture of the bunker hose is another mechanism which may cause LNG spill on deck. The amount of LNG in the hose is small, hence the heat required to evaporate the liquid is limited. Hence the deck temperature drop will be limited as well. A simple calculation, which is part of the engineering process, will demonstrate this.

Issue 9. Gas/air mixture accumulation in engine room.
The geometry of the engine rooms is very simple, i.e. basically rectangular, which seems to make them less prone to gas accumulation. This issue can be handled through sound engineering. Smoke tests are proposed to demonstrate the adequacy of the proposed ventilation systems.

Issue 10. 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 training of crew needs to be addressed because crews are not required to 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 making sure that all relevant hazards have been addressed must remain on top of the priority list.
Allowing a few ship with LNG bunker fuel offers a splendid opportunity to gain experience. Although the recommendation explicitly mentions reporting experience gained with the ships, it remain unclear how this will be done.
Accessibility of safety case documentation, e.g. crashworthiness of cryogenic LNG storage tanks, 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 within the engineering process. All issues identified in the HAZID are adequately addressed in the current engineering process. The classification society is well poised to judge the proposed technical solutions.

Brittle fracture main deck due to LNG spill
LNG spill on deck due to rupture of the bunker hose is not expected to cause any brittle fracture, due to limited volumetric capacity of the hose. It is recommended however to conduct a calculation on the temperature drop of the deck in case of LNG spillage.

Dangerous gas concentration in ER
The issue of dangerous gas concentrations in the ER is resolved through adequate ventilation. However smoke tests are recommended to provide final proof.

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 the I-tanker is a chemical tanker which implies that the crew is already used to handling hazardous cargo.

References

[1] Recommendation I-Tanker 1401 CCNR version 17-8-2011
[2] IGF, draft International code on safety for Gas-Fuelled ships, IMO
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[6] NFPA 57, Liquefied Natural (LNG) Vehicular Fuel Systems Code 2002 Edition
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