Guide for the Risk Assessment for Gas-fuelled Ships Projects

Effective from 1 January 2018

Emirates Classification Society (Tasneef)
Aldar HQ 19th Floor,
Al Raha Beach, Abu Dhabi, UAE
Abu Dhabi, United Arab Emirates

Phone (+971) 2 692 2333
Fax (+971) 2 445 433
P.O. Box. 111155
info@tasneef.ae

GENERAL CONDITIONS

Definitions:

"*Administration*" means the Government of the State whose flag the Ship is entitled to fly or under whose authority the Ship is authorised to operate in the specific case.

"IACS" means the International Association of Classification Societies.

"*Interested Party*" means the party, other than the Society, having an interest in or responsibility for the Ship, product, plant or system subject to classification or certification (such as the owner of the Ship and his representatives, the ship builder, the engine builder or the supplier of parts to be tested) who requests the Services or on whose behalf the Services are requested.

"*Owner*" means the registered owner, the ship owner, the manager or any other party with the responsibility, legally or contractually, to keep the ship seaworthy or in service, having particular regard to the provisions relating to the maintenance of class laid down in Part A, Chapter 2 of the Rules for the Classification of Ships or in the corresponding rules indicated in the specific Rules.

"Rules" in these General Conditions means the documents below issued by the Society:

- (i) Rules for the Classification of Ships or other special units;
- (ii) Complementary Rules containing the requirements for product, plant, system and other certification or containing the requirements for the assignment of additional class notations;
- (iii) Rules for the application of statutory rules, containing the rules to perform the duties delegated by Administrations;
- (iv) Guides to carry out particular activities connected with Services;
- (v) Any other technical document, as for example rule variations or interpretations.

"*Services*" means the activities described in Article 1 below, rendered by the Society upon request made by or on behalf of the Interested Party.

"Ship" means ships, boats, craft and other special units, as for example offshore structures, floating units and underwater craft.

"*Society*" or *"TASNEEF"* means Tasneef and/or all the companies in the Tasneef Group which provide the Services.

"*Surveyor*" means technical staff acting on behalf of the Society in performing the Services.

Article 1

1.1. The purpose of the Society is, among others, the classification and certification of ships and the certification of their parts and components. In particular, the Society:
- (i) sets forth and develops Rules;
- (ii) publishes the Register of Ships;
- (iii) issues certificates, statements and reports based on its survey activities.

1.2. The Society also takes part in the implementation of national and international rules and standards as delegated by various Governments.

1.3. The Society carries out technical assistance activities on request and provides special services outside the scope of classification, which are regulated by these general conditions, unless expressly excluded in the particular contract.

Article 2

2.1. The Rules developed by the Society reflect the level of its technical knowledge at the time they are published. Therefore, the Society, although committed also through its research and development services to continuous updating of the Rules, does not guarantee the Rules meet state-of-the-art science and technology at the time of publication or that they meet the Society's or others' subsequent technical developments.

2.2. The Interested Party is required to know the Rules on the basis of which the Services are provided. With particular reference to Classification Services, special attention is to be given to the Rules concerning class suspension, withdrawal and reinstatement. In case of doubt or inaccuracy, the Interested Party is to promptly contact the Society for clarification.
The Rules for Classification of Ships are published on the Society's website: www.tasneef.ae.

2.3. The Society exercises due care and skill:
- (i) in the selection of its Surveyors
- (ii) in the performance of its Services, taking into account the level of its technical knowledge at the time the Services are performed.

2.4. Surveys conducted by the Society include, but are not limited to, visual inspection and non-destructive testing. Unless otherwise required, surveys are conducted through sampling techniques and do not consist of comprehensive verification or monitoring of the Ship or of the items subject to certification. The surveys and checks made by the Society on board ship do not necessarily require the constant and continuous presence of the Surveyor. The Society may also commission laboratory testing, underwater inspection and other checks carried out by and under the responsibility of qualified service suppliers. Survey practices and procedures are selected by the Society based on its experience and knowledge and according to generally accepted technical standards in the sector.

Article 3

3.1. The class assigned to a Ship, like the reports, statements, certificates or any other document or information issued by the Society, reflects the opinion of the Society concerning compliance, at the time the Service is provided, of the Ship or product subject to certification, with the applicable Rules (given the intended use and within the relevant time frame).
The Society is under no obligation to make statements or provide information about elements or facts which are not part of the specific scope of the Service requested by the Interested Party or on its behalf.

3.2. No report, statement, notation on a plan, review, Certificate of Classification, document or information issued or given as part of the Services provided by the Society shall have any legal effect or implication other than a representation that, on the basis of the checks made by the Society, the Ship, structure, materials, equipment, machinery or any other item covered by such document or information meet the Rules. Any such document is issued solely for the use of the Society, its committees and clients or other duly authorised bodies and for no other purpose. Therefore, the Society cannot be held liable for any act made or document issued by other parties on the basis of the statements or information given by the Society. The validity, application, meaning and interpretation of a Certificate of Classification, or any other document or information issued by the Society in connection with its Services, is governed by the Rules of the Society, which is the sole subject entitled to make such interpretation. Any disagreement on technical matters between the Interested Party and the Surveyor in the carrying out of his functions shall be raised in writing as soon as possible with the Society, which will settle any divergence of opinion or dispute.

3.3. The classification of a Ship, or the issuance of a certificate or other document connected with classification or certification and in general with the performance of Services by the Society shall have the validity conferred upon it by the Rules of the Society at the time of the assignment of class or issuance of the certificate; in no case shall it amount to a statement or warranty of seaworthiness, structural integrity, quality or fitness for a particular purpose or service of any Ship, structure, material, equipment or machinery inspected or tested by the Society.

3.4. Any document issued by the Society in relation to its activities reflects the condition of the Ship or the subject of certification or other activity at the time of the check.

3.5. The Rules, surveys and activities performed by the Society, reports, certificates and other documents issued by the Society are in no way intended to replace the duties and responsibilities of other parties such as Governments, designers, ship builders, manufacturers, repairers, suppliers, contractors or sub-contractors, Owners, operators, charterers, underwriters, sellers or intended buyers of a Ship or other product or system surveyed.
These documents and activities do not relieve such parties from any fulfilment, warranty, responsibility, duty or obligation (also of a contractual nature) expressed or implied or in any case incumbent on them, nor do they confer on such parties any right, claim or cause of action against the Society. With particular regard to the duties of the ship Owner, the Services undertaken by the Society do not relieve the Owner of his duty to ensure proper maintenance of the Ship and ensure seaworthiness at all times. Likewise, the Rules, surveys performed, reports, certificates and other documents issued by the Society are intended neither to guarantee the buyers of the Ship, its components or any other surveyed or certified item, nor to relieve the seller of the duties arising out of the law or the contract, regarding the quality, commercial value or characteristics of the item which is the subject of transaction.
In no case, therefore, shall the Society assume the obligations incumbent upon the above-mentioned parties, even when it is consulted in connection with matters not covered by its Rules or other documents.
In consideration of the above, the Interested Party undertakes to relieve and hold harmless the Society from any third party claim, as well as from any liability in relation to the latter concerning the Services rendered.
Insofar as they are not expressly provided for in these General Conditions, the duties and responsibilities of the Owner and Interested Parties with respect to the services rendered by the Society are described in the Rules applicable to the specific Service rendered.

Article 4

4.1. Any request for the Society's Services shall be submitted in writing and signed by or on behalf of the Interested Party. Such a request will be considered irrevocable as soon as received by the Society and shall entail acceptance by the applicant of all relevant requirements of the Rules, including these General Conditions. Upon acceptance of the written request by the Society, a contract between the Society and the Interested Party is entered into, which is regulated by the present General Conditions.

4.2. In consideration of the Services rendered by the Society, the Interested Party and the person requesting the service shall be jointly liable for the payment of the relevant fees, even if the service is not concluded for any cause not pertaining to the Society. In the latter case, the Society shall not be held liable for non-fulfilment or partial fulfilment of the Services requested. In the event of late payment, interest at the legal current rate increased by 1.5% may be demanded.

4.3. The contract for the classification of a Ship or for other Services may be terminated and any certificates revoked at the request of one of the parties, subject to at least 30 days' notice to be given in writing. Failure to pay, even in part, the fees due for Services carried out by the Society will entitle the Society to immediately terminate the contract and suspend the Services.
For every termination of the contract, the fees for the activities performed until the time of the termination shall be owed to the Society as well as the expenses incurred in view of activities already programmed; this is without prejudice to the right to compensation due to the Society as a consequence of the termination.
With particular reference to Ship classification and certification, unless decided otherwise by the Society, termination of the contract implies that the assignment of class to a Ship is withheld or, if already assigned, that it is suspended or withdrawn; any statutory certificates issued by the Society will be withdrawn in those cases where provided for by agreements between the Society and the flag State.

Article 5

5.1. In providing the Services, as well as other correlated information or advice, the Society, its Surveyors, servants or agents operate with due diligence for the proper execution of the activity. However, considering the nature of the activities performed (see art. 2.4), it is not possible to guarantee absolute accuracy, correctness and completeness of any information or advice supplied. Express and implied warranties are specifically disclaimed.
Therefore, except as provided for in paragraph 5.2 below, and also in the case of activities carried out by delegation of Governments, neither the Society nor any of its Surveyors will be liable for any loss, damage or expense of whatever nature sustained by any person, in tort or in contract, derived from carrying out the Services.

5.2. Notwithstanding the provisions in paragraph 5.1 above, should any user of the Society's Services prove that he has suffered a loss or damage due to any negligent act or omission of the Society, its Surveyors, servants or agents, then the Society will pay compensation to such person for his proved loss, up to, but not exceeding, five times the amount of the fees charged for the specific services, information or opinions from which the loss or damage derives or, if no fee has been charged, a maximum of AED5,000 (Arab Emirates Dirhams Five Thousand only). Where the fees charged are related to a number of Services, the amount of the fees will be apportioned for the purpose of the calculation of the maximum compensation, by reference to the estimated time involved in the performance of the Service from which the damage or loss derives. Any liability for indirect or consequential loss, damage or expense is specifically excluded. In any case, irrespective of the amount of the fees charged, the maximum damages payable by the Society will not be more than AED5,000,000 (Arab Emirates Dirhams Five Millions only). Payment of compensation under this paragraph will not entail any admission of responsibility and/or liability by the Society and will be made without prejudice to the disclaimer clause contained in paragraph 5.1 above.

5.3. Any claim for loss or damage of whatever nature by virtue of the provisions set forth herein shall be made to the Society in writing, within the shorter of the following periods: (i) THREE (3) MONTHS from the date on which the Services were performed, or (ii) THREE (3) MONTHS from the date on which the damage was discovered. Failure to comply with the above deadline will constitute an absolute bar to the pursuit of such a claim against the Society.

Article 6

6.1. These General Conditions shall be governed by and construed in accordance with United Arab Emirates (UAE) law, and any dispute arising from or in connection with the Rules or with the Services of the Society, including any issues concerning responsibility, liability or limitations of liability of the Society, shall be determined in accordance with UAE law. The courts of the Dubai International Financial Centre (DIFC) shall have exclusive jurisdiction in relation to any claim or dispute which may arise out of or in connection with the Rules or with the Services of the Society.

6.2. However,

(i) In cases where neither the claim nor any counterclaim exceeds the sum of AED300,000 (Arab Emirates Dirhams Three Hundred Thousand) the dispute shall be referred to the jurisdiction of the DIFC Small Claims Tribunal; and

(ii) for disputes concerning non-payment of the fees and/or expenses due to the Society for services, the Society shall have the right to submit any claim to the jurisdiction of the Courts of the place where the registered or operating office of the Interested Party or of the applicant who requested the Service is located.

In the case of actions taken against the Society by a third party before a public Court, the Society shall also have the righ t to summon the Interested Party or the subject who requested the Service before that Court, in order to be relieved and held harmless according to art. 3.5 above.

Article 7

7.1. All plans, specifications, documents and information provided by, issued by, or made known to the Society, in connection with the performance of its Services, will be treated as confidential and will not be made available to any other party other than the Owner without authorisation of the Interested Party, except as provided for or required by any applicable international, European or domestic legislation, Charter or other IACS resolutions, or order from a competent authority. Information about the status and validity of class and statutory certificates, including transfers, changes, suspensions, withdrawals of class, recommendations/conditions of cl ass, operating conditions or restrictions issued against classed ships and other related information, as may be required, may be published on the website or released by other means, without the prior consent of the Interested Party.

Information about the status and validity of other certificates and statements may also be published on the website or released by other means, without the prior consent of the Interested Party.

7.2. Notwithstanding the general duty of confidentiality owed by the Society to its clients in clause 7.1 above, the Society's c lients hereby accept that the Society may participate in the IACS Early Warning System which requires each Classification Society to provide other involved Classification Societies with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific propert y of another party), to enable such useful information to be shared and used to facilitate the proper working of the IACS Early Warning System. The Society will provide its clients with written details of such information sent to the involved Classification Societies.

7.3. In the event of transfer of class, addition of a second class or withdrawal from a double/dual class, the Interested Party undertakes to provide or to permit the Society to provide the other Classification Society with all building plans and drawings, certificat es, documents and information relevant to the classed unit, including its history file, as the other Classification Society may require for the purpose of classification in compliance with the applicable legislation and relative IACS Procedure. It is the Owner's duty t o ensure that, whenever required, the consent of the builder is obtained with regard to the provision of plans and drawings to the new Society, either by way of appropriate stipulation in the building contract or by other agreement.

In the event that the ownership of the ship, product or system subject to certification is transferred to a new subject, the latter shall have the right to access all pertinent drawings, specifications, documents or information issued by the Society or which has come to the knowledge of the Society while carrying out its Services, even if related to a period prior to transfer of ownership.

Article 8

8.1. Should any part of these General Conditions be declared invalid, this will not affect the validity of the remaining provisions.

INDEX

1 INTRODUCTION

Purpose of this guide is to provide a framework for the risk assessment activities that can be required in marine designs using gas as fuel.

2 BACKGROUND

The IGF Code (Ref. 1) is 'goal based' and therefore, not all risks are necessarily covered by the prescriptive requirements within the Code. Hence, risk assessment activities have to be conducted to ensure that the risks not covered by the prescriptive requirements are addressed such that they are 'designed out' as far as possible, and if not, 'As Low As Reasonably Practicable' (ALARP concept).

The IGF Code requires that the risk assessment is undertaken using acceptable and recognised techniques, and the risks and their mitigation are documented to the satisfaction of the Administration.

It is well known that there are many acceptable and recognised techniques and means to document a risk assessment, as explained in Ref. 2. As such, it is not the intent of the requirements in this guide to limit a risk assessment to a particular technique or means of documentation, but to provide a framework for designers that will undertake this type of activity.

There is no requirement to measure the overall level of risk associated with the fuels covered by the IGF Code. That is, there is no requirement to quantify the overall level of risk to people, the environment or assets from the receipt, storage and use of fuel. The risk assessment is just required to provide information to help determine if further measures are needed to 'design out' risks or to ensure they are ALARP.

In particular, the IGF Code states that risk assessment "need only be conducted where explicitly required by paragraphs 5.10.5, 5.12.3, 6.4.1.1, 6.4.15.4.7.2, 8.3.1.1, 13.4.1, 13.7 and 15.8.1.10 as well as by paragraphs 4.4 and 6.8 of the annex". Hence, the IGF Code allows the scope of the risk assessment to be limited to these paragraphs. It is important to note that there are differences of opinion on the scope of risk assessment required by these paragraphs. Therefore, the views of stakeholders and approval by the Administration is necessary when finalising the scope of the risk assessment.

The risk assessment includes consideration of bunkering equipment installed on board but does not cover the bunkering operation of: ship arrival, approach and mooring; preparation, testing and connection; fuel transfer; and completion and disconnection. Bunkering of fuel is the subject of separate assessment and reference should be made to appropriate and specific guidance (e.g. ISO/TC18683 "Guidelines for systems and installations for supply of LNG as fuel to ships").

The IGF Code requires that consideration be given to physical layout, operation and maintenance. Typically, the risks associated with maintenance are controlled by job specific risk assessments before the activity is undertaken, as required by safety management of the Company. Therefore, consideration of maintenance can be assumed to mean high-level considerations of layout to facilitate a suitable working environment. This requires consideration of, for example, equipment isolation, ventilation of spaces, emergency evacuation, heating and lighting, and access to equipment. The purpose of this is to minimise the risk to operators during maintenance, and to reduce the likelihood of human errors introduced during maintenance, due to 'a poor working environment'.

Occupational risks can be excluded from the risk assessment, since they are expected to be covered by the safety management system of the ship.

The assessment should also highlight potential systems interface and integration issues, such as control systems, power supplies to essential equipment and the like. This is particularly important where a number of stakeholders are involved in separate elements of design, supply, construction and installation.

The scope should obviously cover the design and arrangement as installed onboard. Therefore, where the risk assessment is undertaken prior to finalising the design, it may require revision to ensure that the risks remain ALARP.

The IGF Code makes no reference to periodic update of the risk assessment. This should be undertaken in case of changes to the design/arrangement and/or its operation. This helps ensure the risks are maintained ALARP throughout the life of the fuel system.

The final scope of the risk assessment should be agreed with appropriate stakeholders (e.g. the Administration) and guided by applicable classification rules and the IGF Code.

3 GENERAL APPROACH

Within the scope of design and arrangement of gas fuel systems, all or some of the following stages of the risk assessment activity may be followed:

- Qualitative, where frequency and severity are estimated according to attributes expressing quality or kind (e.g. high, low, medium etc.);
- Semi-quantitative, where frequency and severity are estimated approximately within numerical ranges;
- Quantitative, where full quantification of frequencies and consequences is carried out.

The three approaches require an increasing order of detail, complexity, resources and background information/data to retrieve. In turn, the choice of the depth of the analysis depends on the design phase. In any case, a dedicated multi-disciplinary team has to be set up, with the involvement of Class and Administration early in the design process.

A broad, qualitative risk assessment should be carried out at the initial design stages, The usual qualitative methods like HAZID/FMECA/HAZOP are normally sufficient to broadly categorize the risks according to the risk matrix agreed among the stakeholders, and to suggest alternatives for risk reduction. As the design progresses, becomes more complex and shows multi-faceted aspects, the need of more in-depth and accurate assessments usually arises.

If, already at this preliminary stage, the ALARP is not proven, or special critical issues are highlighted, then the risk team must consider additional and/or alternative mitigation measures (safeguards) and re-evaluate the risk. A proposed fuel system cannot be 'accepted' until ALARP is achieved. In this regard, additional studies need to be undertaken to help decide if existing, additional or alternative measures could achieve the necessary risk reduction.

When considering mitigation measures the following hierarchy of mitigation must apply:

- firstly, measures to prevent the release of fuel;
- secondly, measures to protect against the consequences of a release of fuel.

In addition, when considering mitigation (i.e. safeguards) engineering solutions must take preference over procedural controls. This helps promote an inherently safer design. Furthermore, passive measures must take preference over active measures. For example, a passive measure is one where no manual or automated action is required for it to function on demand and as intended. By contrast, an active measure requires some means of activation for it to operate. Both passive and active measures may be required to demonstrate that the risk has been mitigated as necessary.

If qualitative methods are not sufficient to evaluate the risk, a quantitative approach is needed. The scope and depth of the quantitative analysis depends on the problems under study. In general, it is preferable to give precedence to the consequence analysis over the likelihood analysis, for various reasons:

- as explained above, IGF does not require to measure the absolute risk level;
- failure data of LNG components are scarce and uncertain, whilst the development of consequence models has reached a mature stage;
- however, the standard risk measure from QRA i.e. likelihood x severity may be useful when comparing two competitive solutions, taking proper account of the uncertainties.

4 SCENARIOS FROM IGF CODE

The scenarios for which IGF explicitly requires the risk assessment are in paragraphs 5.10.5, 5.12.3, 6.4.1.1, 6.4.15.4.7.2, 8.3.1.1, 13.4.1, 13.7 and 15.8.1.10. The relevant excerpts are listed below.

- 5.10.5: Each tray shall have a sufficient capacity to ensure that the maximum amount of spill according to the risk assessment can be handled.
- 5.12.3: The airlock shall be designed in a way that no gas can be released to safe spaces in case of the most critical event in the gas dangerous space separated by the airlock. The events shall be evaluated in the risk analysis.
- 6.4.1.1: The risk assessment required in 4.2 shall include evaluation of the vessel's liquefied gas fuel containment system, and may lead to additional safety measures for integration into the overall vessel design.
- 6.4.15.4.7.1: The containment system and the supporting hull structure shall be designed for the accidental loads specified in 6.4.9.5. These loads need not be combined with each other or with environmental loads.
- 6.4.15.4.7.2: Additional relevant accidental scenarios shall be determined based on a risk analysis. Particular attention shall be paid to securing devices inside of tanks.
- 8.3.1.1: The bunkering station shall be located on open deck so that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations shall be subject to special consideration within the risk assessment.
- 13.4.1: The tank connection space shall be provided with an effective mechanical forced ventilation system of extraction type. A ventilation capacity of at least 30 air changes per hour shall be provided. The rate of air changes may be reduced if other adequate means of explosion protection are installed. The equivalence of alternative installations shall be demonstrated by a risk assessment.
- 13.7: Bunkering stations that are not located on open deck shall be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed outside. If the natural ventilation is not sufficient, mechanical ventilation shall be provided in accordance with the risk assessment required by 8.3.1.1.
- 15.8.1.10: Permanently installed gas detectors shall be fitted at ventilation inlets to accommodation and machinery spaces if required based on the risk assessment required in [4.2].

However, the aforesaid points do not necessarily cover the risk assessment subject in full. Additional studies may be needed in the following cases:

- requests by the flag
- requests by the owner
- deviations from the IGF code.

5 TECHNICAL APPROACH

The scenarios described in Sec 4, and any other additional study that be requested, may be approached according to various techniques to be agreed with Class and Administration. A general guidance can be found in the following.

5.1 Failure Databases

In general, as mentioned above, the consequence analysis ought to have priority over the probabilistic analysis. However, probabilistic databases can be useful to select the scenarios to simulate. Those scenarios that entail a leak from pipes, connections and the like can resort to publicly available databases to obtain the most frequent equivalent area of the leak. If such data are not available or are too uncertain, the equivalent area should be agreed among the design team, and ought to be subject to a sensitivity analysis. It is to be noted, however, that usually such databases are not specific for LNG systems, but for generic hydrocarbon industries.

Some notable industrial databases where to obtain leak frequencies and areas are reported in item [3] to [5].

5.2 Consequence Models

Basically, the hazards associated with LNG are described below.

LNG is a cryogenic liquid that, if released from its storage or transfer equipment, presents unique hazards to nearby people and property when compared with traditional fuel oil. The primary hazards are health-related and process-related.

- Health Issues
  - Serious injuries to personnel in the immediate area if they come in contact with cryogenic liquids. Skin contact with LNG results in effects similar to thermal burns and with exposure to sensitive areas, such as eyes, tissue can be damaged on contact. Prolonged contact with skin can result in frostbite and prolonged breathing of very cold air can damage lung tissue.
  - Asphyxiation. If the concentration of methane is high enough in the air, there is a potential for asphyxiation hazard for personnel in the immediate area, particularly if the release occurs in confined spaces.
- Process Issues
  - Brittle fracture damage to steel structures exposed to cryogenic temperatures. If LNG comes into contact with normal shipbuilding steels, the extremely cold temperature makes the steel brittle, potentially resulting in cracking of deck surfaces or affecting other metal equipment.
  - Formation of a flammable vapor cloud. As a liquid, LNG will neither burn nor explode; however, if released from bunkering equipment, it will form a vapor cloud as the LNG boils at ambient temperatures. To result in a fire or explosion, the vapor cloud must be in the flammable range, which for methane is between 5.3% and 14% by volume in air, and there must be an ignition source present. There are a number of factors affecting the consequence potential of an LNG release, including: the surface it is released on, the amount released, air temperature, surface temperature, wind speed, wind direction, atmospheric stability, proximity to offsite populations, and location of ignition sources. Although LNG vapors can explode (i.e., create large overpressures) if ignited within a confined space, such as a building or ship, there is no evidence suggesting that LNG is explosive when ignited in unconfined open areas.
- Rapid Phase Transition (RPT). Rapid physical phase transition may occur when LNG liquid is rapidly converted to methane vapor after LNG liquid is spilled in water, e.g. during bunkering operations. Small pockets of LNG that evaporate instantaneously when superheated in water create pressure pulses, which will travel at the speed of sound and decay as any other pressure pulse. RPT is not characterized as a detonation since it does not involve any combustion. Rather, RPTs generate overpressures only capable of nearby window breakage. Pressure pulse is unlikely to damage large structural elements of a ship. Therefore, no specific modelling is recommended as it is not likely to increase the hazard range of a major spill that has already occurred.

The risk assessment of interest for IGF Code is related to process-related hazards, as the health-related hazards have to be dealt with in the framework of the safety management system of the Owner.

From what is said above, it appears quite obvious that, in general, the first and foremost risk to deal with is related to loss of containment, causing liquid spills and gas releases in various degrees according to the extent of the event. In the former case, the liquid LNG would then undergo a change of state to gas. The consequences of both phenomena within the surrounding environment (brittle failure and vapour cloud) have to be assessed. For this purpose, it is necessary to resort to software tools based on valid physical principles and officially validated.

Various commercial tools are available to model LNG releases; simplified tools can be sufficient for releases in open spaces without significant obstacles, but for complex physical phenomena and geometries, Computational Fluid Dynamics (CFD) tools are normally needed.

The following guidance is provided to deal with the IGF scenarios.

5.2.1 Drip tray capacity (5.10.5 of IGF Code)

This study requires the knowledge of the location of the drip trays, and assumptions on the possibility of leakage from the equipment fitted above each tray (typically, pipe joints). The material of the trays must obviously be suitable to accommodate cryogenic fluids, according to the applicable rules.

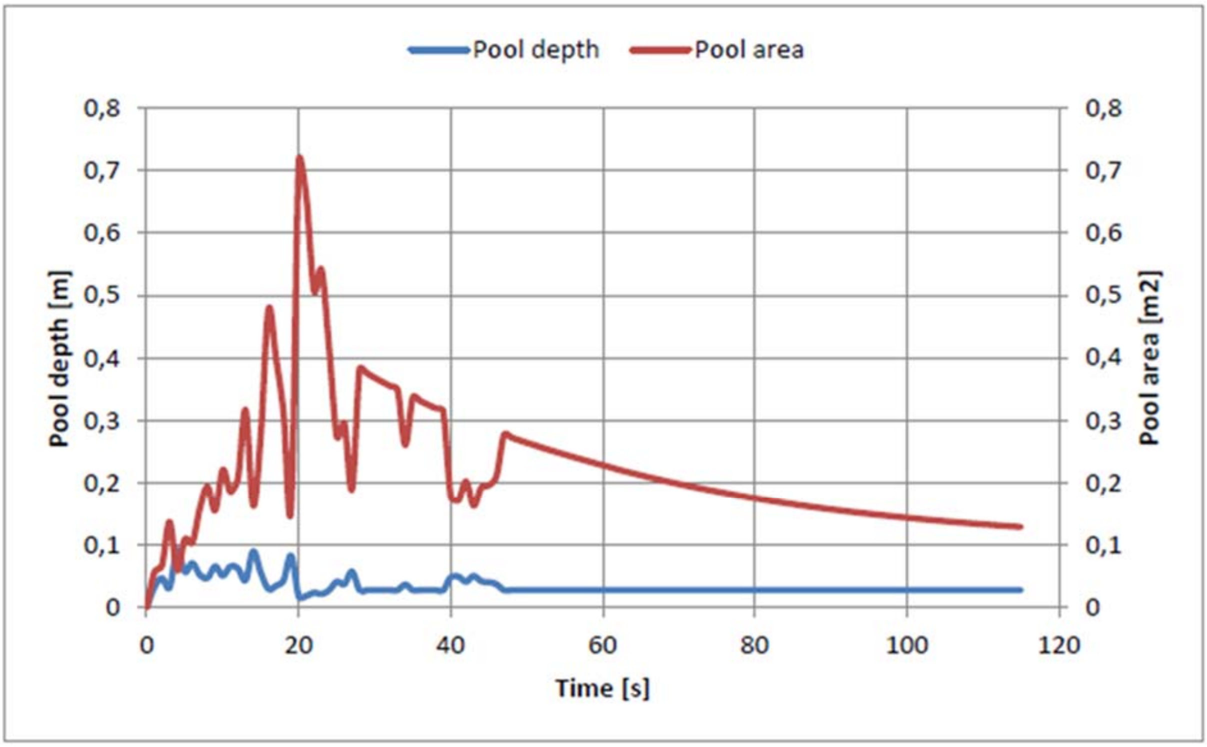
The simulation of this scenario entails the spill of liquid with subsequent evaporation, in the actual layout surrounding the trays. Two competitive phenomena take place: the spill, which is collected in the tray, and the evaporation. A CFD simulation is suggested, aimed at evaluating if the tray volume is adequate to collect the liquid spill minus the quantity evaporated. In turn, the spill depends on the flowrate

through the leak area, and on the time to shutoff the flow.
The simulation requires the following information:

- LNG pressure and temperature;
- Environmental parameters (temperature, pressure, humidity);
- Leakage area;
- LNG flowrate through the joint above the tray;
- Time required to isolate the leak, inferred from the characteristics of the envisaged safety systems : gas detectors, isolation valves, ESD and detection time for operator actions;
- Geometry of tray, pipe joint and surrounding environment;
- Capacity and activation of the ventilation
- Existence of ignition sources for the vapors.
- Sensitivity analyses ought to be carried out for the most uncertain parameters.

A typical output of the results is as shown in Figure 1.

Figure 1: LNG film depth and area on the drip tray



5.2.2 Airlocks (5.12.3 of IGF Code)

According to IGF code Para. 5.12.3, “The airlock shall be designed in a way that no gas can be released to safe spaces in case of the most critical event in the gas dangerous space separated by the airlock. The events shall be evaluated in the risk analysis according to 4.2”.
This analysis should be carried out for all the airlocks installed in confined or enclosed spaces.
In order to assess the structural integrity of the space and the suitability of the designed airlock, the maximum pressure within the space has to be evaluated. If the space is completely enclosed, in case of gas leak the pressure would tend to increase, but the effectiveness of the ventilation system would contrast this phenomenon. In order to check the maximum pressure in case of an accidental release of LNG, it is necessary to use a tool that is able to simulate the gas behavior in confined spaces; if the geometry is complex, CFD is recommended.

The simulation of this scenario entails the spill of liquid with subsequent evaporation, or the gas release, in the actual surrounding layout. The results should show if the overpressure due to the evaporation is acceptable for the surrounding enclosure, or mitigating measures like increase of the ventilation, faster activation of the safety systems etc. need to be implemented. Moreover, if the spill is LNG, the simulation should also verify the final temperature of the drip tray, and its volume to check if the spilt volume is fully collected.
The simulation requires the following information:

- LNG or gas pressure and temperature;
- Environmental parameters (temperature, pressure, humidity);
- Leakage area;
- LNG or gas flowrate through the equipment that can be affected by the leak;
- Time required to isolate the leak, inferred from the characteristics of the envisaged safety systems:

gas detectors, isolation valves, ESD and operator actions;

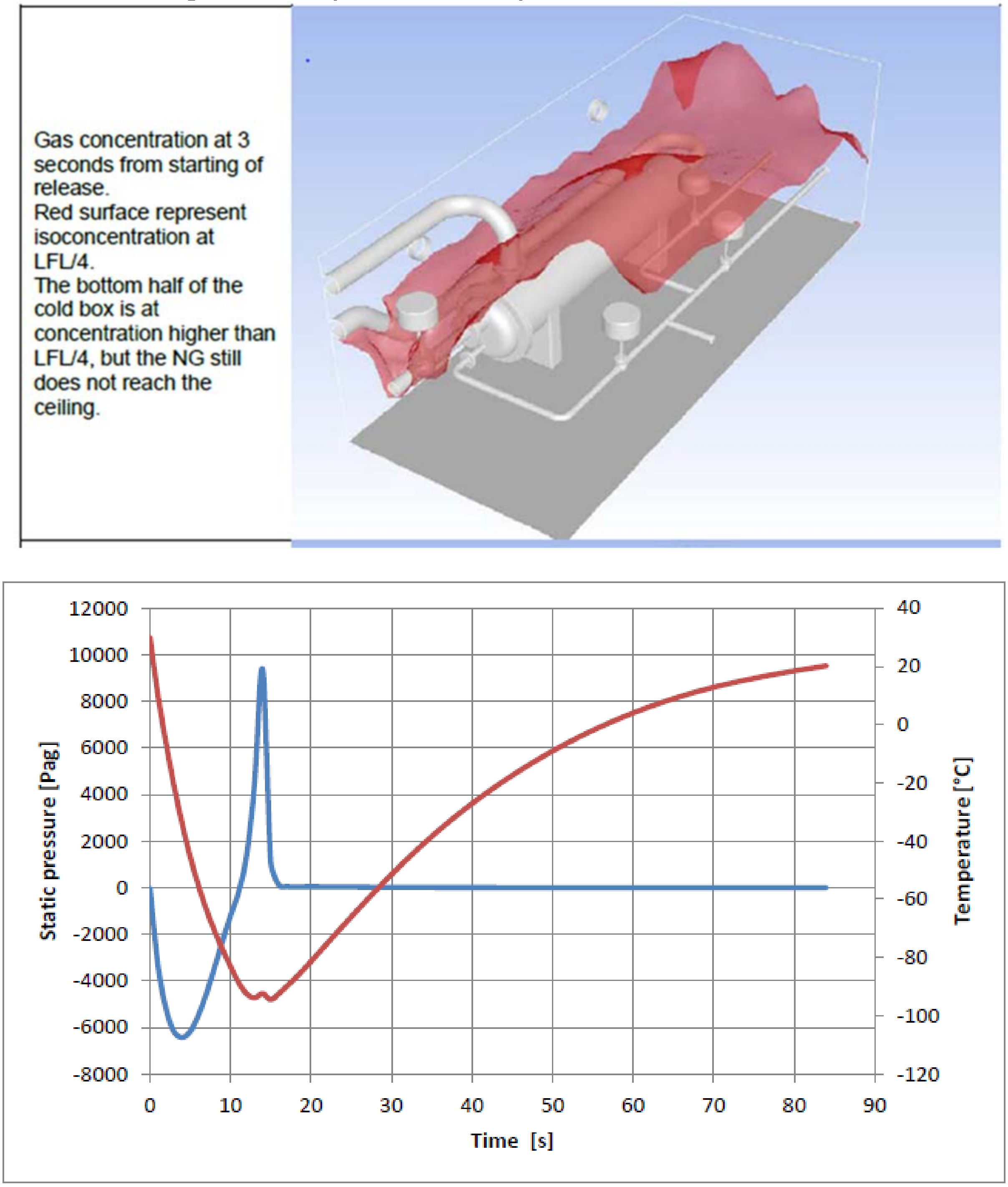
- Geometry and material of affected equipment and surrounding environment;
- Capacity and activation of the ventilation
- Existence of ignition sources for the vapors.

Sensitivity analyses ought to be carried out for the most uncertain parameters.

The simulation results should confirm that the overpressure transient is not hazardous for the enclosure.

A typical output of the results of this type of simulation for a leakage from a cold box is as shown in Figure 2.

Figure 2: Static pressure and temperature trends in the cold box



5.2.3 Gas Fuel containment (6.4.1.1 and 6.4.15.4.7.2 of IGF Code)

According to IGF code Para. 6.4.1.1, “The risk assessment required in 4.2 shall include evaluation of the vessel's liquefied gas fuel containment system, and may lead to additional safety measures for integration into the overall vessel design”.

Moreover, Para. 6.4.15.4.7.2 states “Additional relevant accidental scenarios shall be determined based on a risk analysis. Particular attention shall be paid to securing devices inside of tanks”.

Section 6.4 of the IGF Codes provides a methodology, inferred from IGC Code, for a safe design. On this basis, the failure of the tank itself for intrinsic causes may be generally excluded. It is therefore more useful to focus on its appendages: supports, pipe fittings, valves etc. to verify their compliance with Section 6.3 (e.g. § 6.3.9, <..If piping is connected below the liquid level of the tank it has to be protected by a secondary barrier up to the first valve..>). Considerations of potential loss of integrity of such items should be made.

Failure of control of pressure and temperature of liquefied gas fuel tanks should be investigated through the usual tools like HAZOP, FMECA and the like.

Additional risks should be checked, in relation to procedures of emptying and purging the tanks in normal and abnormal scenarios, connections with other tanks, venting and bunkering.

Special considerations should be made on the safety procedures in the events of fire within and outside the tank(s) space(s). In case of deviations from IGF, they may call for a dedicated fire risk analysis in addition to the compliance with the requirements set forth in Sec. 11 and 12.

A typical scenario that could be studied in this framework is the release from a pipe or flange in the tank connection space.

The general process is the same as described above. The simulation of this scenario entails the spill of liquid with subsequent evaporation, or the gas release, in the actual surrounding layout. The results should show if the overpressure due to the evaporation is acceptable for the surrounding enclosure, or mitigating measures like increase of the ventilation, faster activation of the safety systems etc. need to be implemented. In order to check the maximum pressure in case of an accidental release of LNG, it is necessary to use a tool that is able to simulate the gas behavior in confined spaces; if the geometry is complex, CFD is recommended.

The simulation requires the following information:

- LNG or gas pressure and temperature;
- Environmental parameters (temperature, pressure, humidity);
- Leakage area;
- LNG or gas flowrate through the equipment that can be affected by the leak;
- Time required to isolate the leak, inferred from the characteristics of the envisaged safety systems : gas detectors, isolation valves, ESD and operator actions;
- Geometry and material of affected equipment and surrounding environment;
- Capacity and activation of the ventilation
- Existence of ignition sources for the vapors.

Sensitivity analyses ought to be carried out for the most uncertain parameters.

Of particular interest is the scenario of failure of the liquid bunkering section between the tank and the Emergency Shutdown Valve; this case is particularly severe even if characterized by a small release area, since it cannot be mitigated by ESD, and would continue up to the complete depressurization of the tank. It has to be ascertained how the gas release in the tank is handled by the ventilation, and where it is conveyed.

A typical output of the results of pressure and temperature over time in the tank connection space after flange failure is as shown in Figure 3.

5.2.4 Bunkering station (8.3.1.1 and 13.7 of IGF Code)

According to IGF code Para. 8.3.1.1, “The bunkering station shall be located on open deck so that sufficient natural ventilation is provided. Closed or semi-enclosed bunkering stations shall be subject to special consideration within the risk assessment.”., which is linked to Para. 13.7, “Bunkering stations that are not located on open deck shall be suitably ventilated to ensure that any vapour being released during bunkering operations will be removed outside. If the natural ventilation is not sufficient, mechanical ventilation shall be provided in accordance with the risk assessment required by 8.3.1.1”.

Moreover, according to MSC-1/Circ.1558, the special consideration should as a minimum include, but not be restricted to, the following design features:

• segregation towards other areas on the ship
• hazardous area plans for the ship
• requirements for forced ventilation
• requirements for leakage detection (e.g. gas detection and low temperature detection)
• safety actions related to leakage detection (e.g. gas detection and low temperature detection)
• access to bunkering station from non-hazardous areas through airlocks
• monitoring of bunkering station by direct line of sight or by CCTV.

If the bunker station is enclosed or semi-enclosed as said above, the assessment of ventilation in case of gas release is required.

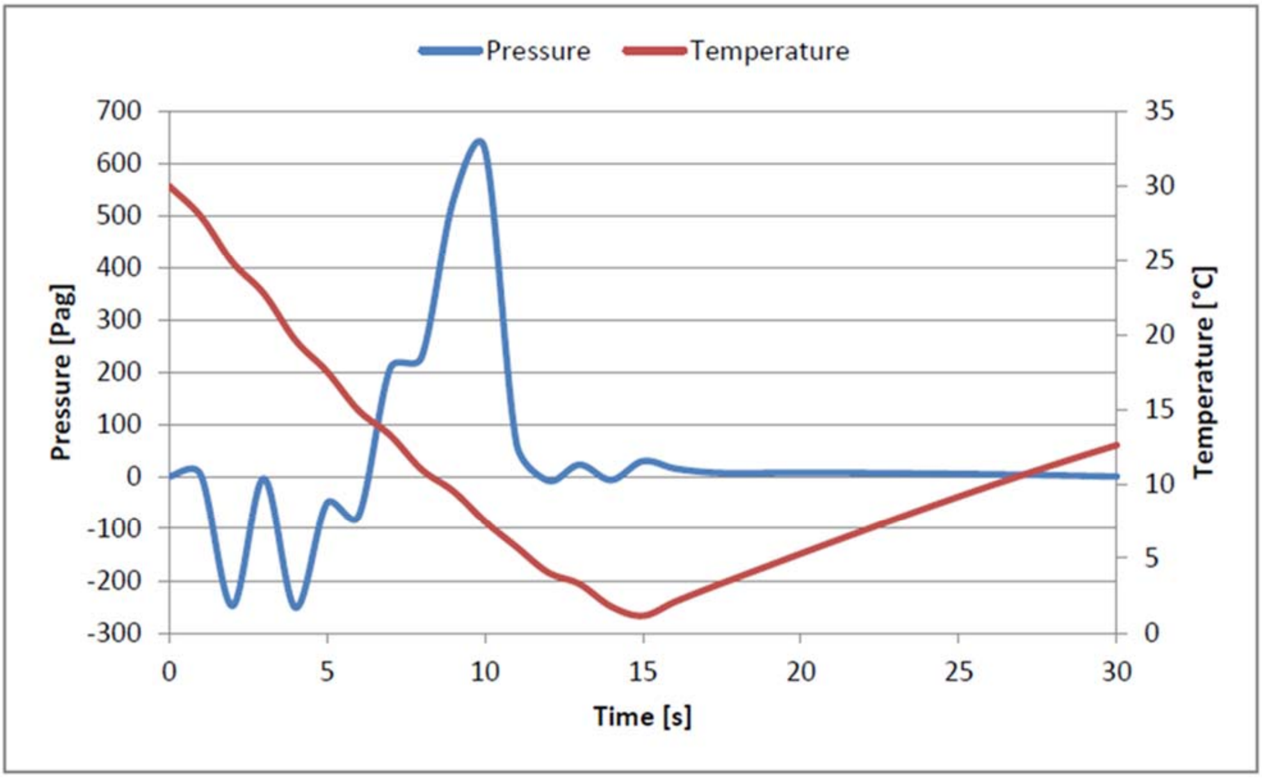
The simulation of this scenario entails the spill of liquid with subsequent evaporation, or the gas release, in the actual surrounding layout, during the bunkering. The results should show if the gas release is carried over by the ventilation, whether natural or forced, with and without ESD intervention that would stop the bunkering. Moreover, if the spill is LNG onto

drip trays, the simulation should also verify the final temperature of the drip tray, and its volume to check if the spilt volume is fully collected.
After the spill, two competitive phenomena take place: the spill, which is collected in the tray, and the evaporation, dispersed by natural and forced ventilation. A CFD simulation is suggested, aimed at evaluating first of all if the tray volume is adequate to collect the liquid spill minus the quantity evaporated. In turn, the spill depends on the flowrate through the leak area, and on the time to shutoff the flow. This simulation does not differ from that already presented in Sec. 5.2.1.
Then, the simulation has to describe the phenomena of evaporation and ventilation.
The simulation requires the following information:

- LNG temperature, pressure and flowrate during bunkering;
- Environmental parameters (temperature, pressure, humidity, wind);
- Leakage areas and position on the flange or joint affected;
- Time required to isolate the leak, inferred from the characteristics of the envisaged safety systems : gas detectors, isolation valves, ESD and detection time for operator actions;
- Geometry of tray, pipe joint and surrounding environment;
- Designed capacity of the tray ;
- Design and geometry of the LNG bunkering, inclusive of transfer system (hose or hard arm) and pumping system;
- Capacity and activation of the ventilation;
- Existence of ignition sources for the vapors.

Sensitivity analyses ought to be carried out for the most uncertain parameters like the Class of wind stability and velocity.
A typical output of the results of LFL envelope, superimposed on the ship profile, is as shown in the Figure 4.

Figure 3: Pressure and temperature profile in the Tank connection space



5.2.5 Gas detection (15.8.1.10 of IGF Code)

According to IGF Code Para. 15.8.1.10, "Permanently installed gas detectors shall be fitted at ventilation inlets to accommodation and machinery spaces if required based on the risk assessment required in 4.2". This analysis has to be carried out when any of the previous studies, or further ad-hoc studies, indicate the existence of scenarios with gas that reaches the ventilation of accommodations or machinery spaces. Such analyses may suggest that further detectors have to be envisaged in addition to Class Rules and IGF Code 15.8.
Such studies are based on the simulation of gas dispersion, and they should predict not only the flow, but the flammable concentrations in space and time detectable by the sensitivity of the instruments.
Also in this case, the tools to be used depend on the complexity of the layout under study: for simple geometries, simplified tools may suffice, otherwise the use of CFD is recommended.

6 CONCLUSIONS

This Guide provides a framework to undertake the risk assessment explicitly required by IGF Code, paragraphs 5.10.5, 5.12.3, 6.4.1.1, 6.4.15.4.7.2, 8.3.1.1, 13.4.1, 13.7 and 15.8.1.10. It includes recommendations for simulating the scenarios mentioned in each paragraph .

This guidance is non mandatory, and equivalent methods can be used. However, it is to be recalled that the final scope and criteria of the risk assessment should be agreed with appropriate stakeholders (e.g. Class, owner and yards) and approved by the Flag Administration.

7 REFERENCES

1. International Code for Ships using Gases and other Low Flashpoint Fuels (IGF Code), adopted with IMO Resolution MSC.391(95)
2. “Tasneef Guide for Risk Analysis”
3. “OGP Risk Assessment Data Directory”, by International Association of Oil & Gas Producers
4. OREDA, “Offshore Reliability Data”, SINTEF, Safety and Reliability Department
5. “Hydrocarbon Release System” online database https://www.hse.gov.uk/hcr3/.

Figure 4: Cloud envelope of LFL concentration