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Risk assessment as required by the IGF Code

1.1 General

To help eliminate or mitigate risks a risk assessment is required by the IGF Code[1]. In this regard it 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 recognised that there are many acceptable and recognised techniques and means to document a risk assessment. As such, it is not the intent of this document to limit a risk assessment to a particular technique or means of documentation. This document does, however, describe recommended practice and examples to help satisfy the IGF Code.

1.2 Risk assessment - Objective

The objective or goal of the risk assessment, as noted in the IGF Code, is to help *"eliminate or mitigate any adverse effect to the persons on board, the environment or the ship"*[2]. That is, to eliminate or mitigate unwanted events related to the use of low-flashpoint fuels that could harm individuals, the environment or the ship.

1.3 Risk assessment - Scope

The IGF Code requires the risk assessment to cover the use of low-flashpoint fuel[3]. This is taken to mean assessment of the supply of such fuel to consumers and covers:

- equipment installed on board to receive, store, condition as necessary and transfer fuel to one or more engines, boilers or other fuel consumers;
  Such equipment includes manifolds, valves, pipes/lines, tanks, pumps/compressors, heat exchangers and process instrumentation from the bunker manifold(s) to delivery of fuel to the consumers.

- equipment to control the operation;
  For example, pressure and temperature regulators and monitors, flow controllers, signal processors and control panels.

- equipment to detect, alarm and initiate safety actions;
  For example, detectors to identify fuel releases and subsequent fires, and to initiate shutdown of the fuel supply to consumers.

- equipment to vent, contain or handle operations outside of that intended (i.e. outside of process norms);
  For example, vent lines, masts and valves, overflow tanks, secondary containment, and ventilation arrangements.

- fire-fighting appliances and arrangements to protect surfaces from fire, fuel contact and escalation of fire;
  For example, water sprays, water curtains and fire dampers.

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1. International Code of Safety for Ships Using Gases or Other Low-Flashpoint Fuels (IGF Code) - as adopted at MSC 95 (June 2015).
2. IGF Code (ref 1 of this document), Part A, Chapter 4.1.
3. IGF Code (ref 1 of this document), Part A, Chapter 4.2, Paragraph 4.2.1.

- equipment to purge and inert fuel lines;
  For example, equipment to store and supply nitrogen for the purposes of purging/inerting bunker lines, and equipment used for the safe transfer/disposal of fuel.

- structures and constructions to house equipment;
  For example, fuel storage hold spaces, tank connection spaces and fuel preparation rooms.

In agreement with stakeholders (e.g. the Administration) the scope can exclude items that have been previously subjected to a risk assessment, provided there are no changes to 'context of use' and mitigation measures taken as a result of previous risk assessment are to be included. This can help reduce assessment time and effort.

The term 'context of use' (used above) refers to differences, such as differences in design or arrangement, installed location, mode of operation, use of surrounding spaces, and the number and type of persons exposed. For example, if an item is located on a cargo ship on-deck, it is a change to the 'context of use' if the same item is then installed below deck on a passenger ship. In addressing 'context of use' it is important to recognise that these 'differences' can significantly decrease or increase risk resulting in the need for fewer, more, changed or alternative means to eliminate or mitigate the risks.

With regards to liquefied natural gas (LNG), 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 should be sought 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 as per ISO/TC18683 and reference should be made to appropriate and specific guidance.

The IGF Code requires that consideration is 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. Therefore, consideration of maintenance is taken to mean high-level consideration of design and arrangements to facilitate a safe and appropriate 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 likelihood of unwanted events resulting in harm during maintenance. In addition, the purpose is to minimise the likelihood of unwanted events after maintenance, as a result of deficient work where a contributory cause was 'a poor working environment'.

The assessment should also appreciate potential systems integration issues such as equipment control and connection compatibility. This is particularly important where a number of stakeholders are involved in separate elements of design, supply, construction and installation.

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4. IGF Code (ref 1 of this document), Part A-1, Chapter 4.2, Paragraph 4.2.2.

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Occupational risks can be excluded from the risk assessment. They are an important safety consideration and are expected to be covered by the safety management system of the ship.

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

The IGF Code makes no reference to periodic update of the risk assessment. This should be undertaken where changes to the design/arrangement and/or its operation have been made, and in response to changes in performance of equipment and controls. This helps ensure the risks are 'mitigated as necessary' through-out 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.

1.4 Risk assessment - Approach

IMO has published guidance on formal safety assessment (FSA) and this provides useful information on risk assessment approaches and criteria[5]. The purpose of the guidance is to help evaluate new regulations on maritime safety and protection of the environment. In this regard, assessment is focused on risk quantification and cost benefit analysis to inform decision-making. As such, it is a useful reference to IMO's views on risk assessment and criteria. However, the IGF Code does not require a quantitative measure of risk to people, the environment or assets from the use of fuel. The risk assessment is simply required to provide information to help determine if further measures are needed to 'eliminate' risks or to ensure they are 'mitigated as necessary'. Therefore, a qualitative or semi-quantitative approach to the risk assessment is appropriate (i.e. Qualitative Risk Assessment, QualRA[6]). That is not to say that a fully quantitative approach is inappropriate or that circumstances might not favour its use (i.e. Quantitative Risk Assessment, QRA). What is important is that the risk assessment is of sufficient depth to help demonstrate that risks have been 'eliminated' or 'mitigated as necessary'.

As a minimum, the risk assessment should detail:

A. how the low-flashpoint fuel could potentially cause harm – Hazard identification;
That is, systematic identification of unwanted events that could result in, for example, major injuries or fatality, damage to the environment, and/or loss of structural strength or integrity of the ship.

B. the potential severity of harm – Consequence analysis;
That is, the potential severity of harm (i.e. consequences) expressed in terms of, for example, major injuries, single and multiple fatalities, adverse environmental impact, and structural/ship damage sufficient to compromise safe operations.

C. the likelihood of harm – Likelihood analysis;
That is, the probability or frequency with which harm might occur.

D. a measure of risk – Risk analysis;
That is, a combination of consequence (B) and likelihood (C).

5. Revised Guidelines for formal safety assessment for use in the IMO rule-making process. MSC-MEPC.2/Circ.12, 8th July 2013.
6. Where some form of quantification occurs, then the approach is semi-quantitative. However, such approaches are often referred to as qualitative and this term is used throughout this document.

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E. judgements on risk acceptance – Risk assessment.
The measure of risk (D) should be compared against criteria to judge if the risk has been 'mitigated as necessary'.

Acceptable and recognised techniques to address the requirements noted above (i.e. A-D) are described in, for example, ISO 31010[7], ISO 17776[8], ISO 16901[9], NORSOK Z-013[10], CPR 12E[11], and publications by CCPS[12] and HSE[13], etc.

The following sub-section, A1.4.1, outlines an approach to meeting the above requirements.

1.4.1 An approach to satisfying the IGF Code requirements - Qualitative Risk Assessment (QualRA)

A. Hazard identification

1. Divide the fuel system into discrete parts with respects to equipment function and location.
This promotes systematic consideration of each part of the system and helps identify specific causes of unwanted events related to a particular item, activity or section. A typical division of the system might be, for example: (a) the bunker station and fuel lines to the storage tank; (b) the fuel storage hold space; (c) the tank connection space; (d) the fuel preparation room; and (e) the fuel lines and valves 'regulating' fuel delivery to the engine.

2. Develop a set of guidewords/phrases and example causes that could result in unwanted events (e.g. a release of fuel or fuel system failure resulting in loss of power).
The guidewords/phrases and example causes are used as prompts. A typical, but not exhaustive list of prompts is given in Appendix 1.

3. By reference to design and arrangement information, location plans, process flow diagrams, mitigation measures and planned emergency actions use the prompts to identify potential causes of unwanted events (e.g. fuel releases and loss of power).
The prompts are used to stimulate discussion and ideas within a workshop led by a facilitator and attended by subject matter experts (SMEs).

4. Record the potential causes of unwanted events and mitigation measures
An example of a record sheet or worksheet is given in Appendix 2. This worksheet is also used to record steps B to E below, and forms part of the overall documentation of the risk assessment.

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7. Risk management: Risk assessment techniques. IEC/ISO 31010:2009.
8. Petroleum and natural gas industries - Offshore production installations - Guidelines on tools and techniques for hazard identification and risk assessment. EN ISO 17776:2002.
9. Guidance on performing risk assessment in the design of onshore LNG installations including the ship/shore interface. ISO/TS 16901:2015.
10. Risk and emergency preparedness assessment. NORSOK Standard Z-013, Edition 3, October 2010.
11. Methods for determining and processing probabilities. CPR 12E, 1997/2005.
12. e.g. Guidelines for chemical process quantitative risk analysis. Centre for Chemical Process Safety, American Institute of Chemical Engineers, Second Edition, 2000.
13. e.g. Marine risk assessment. Health & Safety Executive, 2001.

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B. Consequence analysis

5. For each identified cause, estimate the potential consequences in terms of, for example, major injuries, single and multiple fatalities, adverse environmental impact and damage sufficient to compromise safe operations.
The potential consequences can be estimated by the SMEs using judgement and reference to: (a) the fuel's properties/hazards; (b) the release location; (c) dispersion/leak pathways; (d) location and 'strength' of ignition sources; (e) proximity of vulnerable receptors; (f) generic or (if commissioned) specific fire and explosion modelling; and (f) expected effectiveness of existing/planned mitigation measures. The properties and hazards of liquefied natural gas (LNG) noted in (a) are summarised in Appendix 3.

6. Categorise the consequence estimates.
The consequences can be categorised by the SMEs to provide an indication of severity. For example, categories for harm to persons can distinguish between major injury, single fatality and multiple fatalities. Example consequence categories are given in Appendix 4.

C. Likelihood analysis

7. Estimate the annual likelihood of occurrence of 'cause and consequence'.
Likelihood can be estimated by the SMEs (or a suitably qualified individual) for each 'cause-consequence' pair or a grouping of causes with the same consequence. The estimation can be informed by reference to accident and near-miss reports, accident and equipment release data, analogy to accidents in similar or other industries and consideration of the reliability and effectiveness of mitigation measures. It is not always apparent if the likelihood of a 'cause-consequence' combination is credible (i.e. reasonably foreseeable). As a guide, an unwanted event may be considered credible if: (a) it has happened before and it could happen again; (b) it has not happened but is considered possible with an annual likelihood of 1 in a million or more; and (c) it is planned for, that is, emergency actions cover such a situation or maintenance is undertaken to prevent it. A guide to the likelihood of releases relevant to LNG equipment and operations is given in Appendix 5.

8. Categorise the likelihood estimates.
Likelihood can be categorised by the SMEs (or a suitably qualified individual) to provide an indication of accident/incident occurrence or other unwanted event occurrence. Example likelihood categories are given in Appendix 4.

D. Risk analysis

9. Estimate the risk.
Risk can be estimated by the SMEs (or a suitably qualified individual) by combining the consequence and likelihood categories to provide a risk rating. For example, if a 'cause-consequence' pair is categorised as, say 'A', and associated 'likelihood' as, say '1', then the risk rating is 'A1'. An example of a risk rating scheme is given in Appendix 4.

E. Risk assessment

10. Judge if the risk has been 'mitigated as necessary'.
The estimated risk can be compared against risk criteria embedded within a risk matrix. The matrix shows the risk rating (with respects to consequence and likelihood) and the criteria illustrate whether the risk has been 'mitigated as necessary'. An example of a risk rating scheme and its associated risk criteria are given in Appendix 4.

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With respects to D and E above, it is important to note that there are no universally agreed risk rating schemes or risk criteria: there are differences between governments, regulators and organisations. Therefore, prior to the commencement of the risk assessment, risk rating/criteria should be agreed with appropriate stakeholders (e.g. the Administration).

It should also be recognised that the risk rating of individual or grouped ‘cause-consequence’ pairs does not provide an indication of the collective (overall) risk from all potential ‘cause-consequence’ pairs. If the overall risk level is required then this can be determined using QRA.

Practically, the risk rating is an indication that additional or alternative mitigation measures:

- must be provided; or
- must be considered and implemented if practical and cost effective; or
- need not be considered further, beyond accepted good practice of reducing risk where practicable.

In each of the steps above many assumptions are made and there is uncertainty. Therefore, it is good practice for SMEs to list assumptions and ‘test’ the sensitivity of results to changes in any of these steps. For example, a change to an assigned consequence or likelihood category could alter the risk rating and the judgement on whether a risk is ‘mitigated as necessary’.

1.4.1.1 Mitigated as necessary

The phrase ‘mitigated as necessary’ is used in the IGF Code and is akin to the phrase ‘As Low As Reasonably Practicable’, commonly referred to as ALARP. Essentially, a risk is considered ALARP if all reasonably practicable mitigation measures have been implemented. This means that additional or alternative measures have been identified and implemented unless they are demonstrated as impractical or the cost of implementation is disproportionate to the reduction in risk. This concept of ALARP is established practice in many industries and recognised as best practice by IMO[14].

Where ‘mitigated as necessary’ is not proven then the SMEs should consider additional and/or alternative mitigation measures[15] and re-evaluate the risk. **The risk cannot be ‘accepted’ until ‘mitigated as necessary’ is achieved**. In this regard, additional study can be undertaken to help the SMEs decide if existing, additional or alternative measures can provide ‘mitigated as necessary’.

14. Revised Guidelines for formal safety assessment for use in the IMO rule-making process. MSC-MEPC.2/Circ.12, 8th July 2013.

15. Within the IGF Code, measures to reduce likelihood and measures to reduce consequences are both understood to be mitigation measures (i.e. they mitigate the risk). To align with the IGF Code this understanding is maintained within this document. It is recognised that in many other industries it is common to use the terms ‘prevention measures’ and ‘mitigation measures’, where the former reduces likelihood and the latter reduces consequences. Prevention and mitigation measures are often referred to as ‘safeguards’ or ‘barriers’.

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When considering mitigation measures the following **hierarchy of mitigation** is considered best practice:

- firstly, measures to prevent an unwanted event;
  That is, to ensure the unwanted event cannot occur or its likelihood of occurrence is greatly reduced;

- secondly, measures to protect against harm given an unwanted event.
  That is, to reduce the consequences after the unwanted event has occurred.

In addition, when considering mitigation measures it is good practice to consider **engineering solutions in preference to procedural controls**. This helps promote an inherently safer design. Furthermore, it is good practice to consider **passive measures in preference to 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. Whereas, 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. Examples of mitigation measures are listed in Appendix 6.

To help judge if mitigation measures are effective it can be useful to illustrate or map the pathway from 'cause' to 'consequence' and review the effectiveness of the mitigation measures. An example of such mapping and review is given in Appendix 7.

Whether a single mitigation measure or a collection of mitigation measures is practical and cost-effective is in some respects relative to the resources and skills available. If the SMEs cannot decide then the use of cost benefit analysis can be helpful. In any case, a documented justification for not implementing a mitigation measure should be made where SMEs judge the measure to be practical and cost-effective.

1.5 Risk assessment - Team

The team conducting the risk assessment should comprise of subject matter experts (SMEs) who are, collectively, suitably qualified and experienced. For the QualRA noted above, this means the workshop team includes individuals who are degree qualified and/or chartered/professional engineers, have operational ship experience and are experienced in risk assessment. Such qualifications and experience should be in relevant disciplines to cover engineering design and safe use of the fuel.

It is unlikely that one SME can satisfy the above team requirements. In any case, to ensure investigative discussion, generation of ideas, challenge and coverage of, for example, mechanical, process, electrical and operational aspects, a typical number of SMEs might be four to eight.

In addition to the SMEs, the team should be led by a facilitator (also referred to as the chair or chairman). The facilitator should be impartial with no vested interests in the fuel system, and experienced in leading such risk assessments. The facilitator may be supported by a scribe (also referred to as a secretary) to aid reporting.

The time expended by the team depends upon the agreed scope and the designs' 'complexity'. For example, a QualRA workshop for a new design might require two or three working days, whereas, a minor variation to a previously assessed and approved design might require only half a day.

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1.6 Risk assessment - Reporting

1.6.1 Main report

A written report documenting the risk assessment should be produced. This needs to be sufficiently detailed to support results, conclusions, recommendations and any actions taken. This is because the assessment will inform important design and operational decisions. Furthermore, the report is a record in helping to demonstrate 'mitigated as necessary'. A report only consisting of a completed worksheet is insufficient.

The specific contents of the report and its structure are dependent upon design and assessment specifics, and reporting preferences. However, for a QualRA, the report should provide:

- an overview of the design and arrangement;
  This is a simple explanation of the design and arrangement with respects to its intended operation and process conditions. Technical appendices should include process flow diagrams, general arrangement plans and all information used during the assessment. Where this is too cumbersome to include in the report in full, reference to this material is sufficient provided it remains accessible.

- an explanation of the risk assessment process;
  This is a description of the risk assessment method and includes how the design was divided into parts for assessment, how hazard identification was undertaken, and the selection of consequence and likelihood categories and risk criteria.

- information on the relevant qualifications and expertise of the team;
  This can be a table listing the names, job titles, relevant qualifications, expertise and experience of all team members (including the facilitator and scribe). It is not sufficient to simply list names and job titles.

- the time taken to complete the assessment and whether SMEs were present to provide their expert input;
  For a workshop, this can be a table listing the schedule/duration and attendance of each SME (i.e. full-time or part-time, and if part-time the 'parts' for which the person was absent). The purpose of this is to indicate if sufficient time was taken to assess the design/arrangement, and to highlight any SME absences that could be detrimental to results, conclusions and actions. For any SME absences, a note should be made by the facilitator as to whether this impacted adversely upon the assumptions and judgements made.

- risk results and conclusions;
  This is a listing or discussion of the results and a judgement on whether or not the risk has been 'mitigated as necessary'.

- recommendations and actions.
  This can include requests for modelling and analysis (e.g. gas dispersion or thermal radiation extent, etc.) and will most likely include additional and alternative mitigation measures to be investigated and/or implemented, who is responsible for these and, if known, an expected completion date. It is important that these recommendations and actions are suitably documented because they are likely to be used to plan a response and monitor progress until the recommendations/actions have been addressed.

An example report contents is given in Appendix 8.

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1.6.2 Terms of reference (ToR)

Prior to the workshop it is good practice for the facilitator to issue relevant information to the team. This is sometimes referred to as a terms of reference (ToR). This helps the team familiarise with the design and intended approach before the workshop. It also provides time for clarifications and agreement with the proposed consequence and likelihood categories and risk criteria. Importantly, it provides time to confirm the suitability of the proposed schedule and team. The ToR can form an appendix to the main report.

Typically, a ToR includes:

- objectives and scope of the assessment;
  This is to ensure all team members understand the objective and what equipment and operations are to be covered in the assessment.

- technical description of the proposed design and arrangements;
  This can include copies of process flow diagrams (PFDs) or schematics detailing process conditions of equipment and pipework, and a scaled layout drawing illustrating equipment and pipework arrangements, size and location.

- overview of the potential consequences of a fuel release;
  For LNG, this could refer to Appendix 3 of this document.

- technique to be used;
  This includes proposed consequence and likelihood categories and risk criteria.

- intended workshop schedule;
  This highlights the time to be given to the workshop and when SME input is required.

- team details.
  This includes the name and job title, relevant qualifications, expertise and experience of each SME and team member/workshop attendee.

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Appendix 1
Prompts - guidewords and phrases

Example prompts for use in QualRA

Failure of fuel containing equipment* – a hole/crack leading to release of fuel	
Wear and tear	*vibration, loading, cycling, prolonged use*
Erosion	*fuel contaminants, high stream velocity, prolonged use*
Stress and strain	*vibration, loading, cycling, ship movement, prolonged use*
Fatigue	*vibration, loading, cycling, ship movement, prolonged use*
Corrosion	*exposure to weather, exposure to sea water, humidity, loss of dry air supply, contact with corrosive materials*
Collision	*ship collides with another vessel, ship hits rocks, ship strikes the harbour wall or jetty*
Grounding	*ship runs aground*
Impact	*dropped object (e.g. during maintenance or cargo loading), collapse of supporting structure, maloperation during loading/maintenance*
Fire	*ignition of flammable materials, fire in adjacent spaces/areas*
** plus equipment containing gases or other substances that could release into spaces resulting in harm (e.g. asphyxiation, burns)*	
Failure of process control – operation outside of design conditions leading to subsequent release of fuel	
Temperature high	*loss of insulation, instrument failure, software failure, actuator failure, maloperation by operator, external fire, exposure to extreme weather, decomposition*
Temperature low	*loss of heating medium circulation, heating medium contamination, instrument failure, software failure, actuator failure, maloperation by operator, exposure to extreme weather*
Pressure high	*maloperation by operator (e.g. closed valve), loss of utilities (e.g. instrument air), external fire, loss of power supply, rollover, excess generation of boil-off gas, actuator failure*
Pressure low (vacuum)	*maloperation by operator, loss of utilities (e.g. instrument air), loss of power supply (electricity), actuator failure*
Flow high	*instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions*
Flow low	*instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions*
Flow reversed	*instrument failure, software failure, maloperation by operator (e.g. closed valve), exposure to extreme sea conditions*
No Flow	*instrument failure, software failure, maloperation by operator (e.g. closed valve), actuator failure*
Level high	*instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions*
Level low	*instrument failure, software failure, maloperation by operator, actuator failure, exposure to extreme sea conditions*
Fuel left in pipe/line	*maloperation by operator, closed valves, no inert/purge supply, limited inert/purge supply*
No fuel in pipe/line	*instrument failure, software failure, maloperation by operator, closed valves*
Loss of power	*loss of electrical signals, blackout, loss of instrument air, loss of hydraulic fluid*

Note: Poor manufacturing, installation and commissioning of equipment can increase the likelihood and/or consequences of fuel releases. If these aspects are not covered and controlled by, for example, class rules, then they should be included in the risk assessment. The assessment should cover intended operation, shutdown and start-up.

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Appendix 2
Record sheet / Worksheet

Worksheet Example

Worksheet for [project title]											
Part or Section [title]											
						Category & Rating					
Item / Activity	Guideword / Phrase	Causes (accident / incident)	Consequences	Mitigation (existing safeguards)	Additional / Alternative Mitigation (safeguards)	Consequence	Likelihood	Risk	Mitigated as necessary	Recommendations Comments / Actions	Action by / date

Note: The worksheet can be used to record risk ratings before and after consideration of additional/alternative safeguards by using one row for ‘existing safeguards’ and one row for ‘additional/alternative safeguards’. If preferred, the ‘Additional/Alternative Mitigation (safeguards)’ column can be moved after the ‘Category & Rating’ columns followed by additional ‘Category & Rating’ columns.

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Appendix 3
Properties & hazards of liquefied natural gas

3.1 LNG Properties

Liquefied natural gas (LNG) is a cryogenic liquid. It consists of methane with small amounts of ethane, propane and inert nitrogen. When used as a fuel, typically 94% or more is methane. Stored at ambient or near ambient pressure, its temperature approximates minus 162 deg.C and its specific gravity is about 0.42. Hence, if released onto the sea LNG floats (and can rapidly 'boil' – refer to 3.2.7). When stored at pressures of up to 10 bar the temperature typically remains below minus 130 deg.C with a specific gravity of approximately 0.4.

Released into atmospheric conditions, LNG rapidly boils forming a colourless, odourless and non-toxic gas. Although colourless, due to its very low temperature, water vapour in the air condenses forming a visible mist or cloud. The cold gas is initially heavier than air and it remains negatively buoyant until its temperature rises to about minus 100 deg.C. At this stage the gas becomes lighter than air, and in an open environment it is thought that this coincides with a gas concentration of less than 5%. At this temperature and concentration the gas is still within the visible cloud. As the gas continues to warm to ambient conditions its volume is approximately 600 times that of the liquid with a relative vapour density of about 0.55, and so the gas is much lighter than air (air = 1).

As the gas disperses, its concentration reduces. At a concentration in air of between 5% and 15% the mix is flammable and can ignite in the presence of ignition sources or in contact with hot sources at or above a temperature of approximately 595 deg.C (referred to as the auto-ignition temperature). Once below a concentration of 5% the mix is no longer flammable and cannot be ignited (and this is the case if the concentration remains above 15%). The 15% and 5% concentrations of LNG in air are commonly known as the upper and lower flammability limits, respectively. More recently, the limits are referred to as the upper and lower explosion limits, although ignition may not necessarily result in explosion.

3.2 LNG Hazards

3.2.1 Cryogenic burns

Owing to its very low liquid temperature, in contact with the skin LNG causes burns. In addition, breathing the cold gas as it 'boils' can damage the lungs. The severity of burns and lung damage is directly related to the surface area contacted by the liquid/gas and duration of exposure.

3.2.2 Low temperature embrittlement

In contact with low temperature LNG, many materials lose ductility and become brittle. This includes carbon and low alloy steels typically used in ship structures and decking. Such low temperature embrittlement can result in material fracture, such that existing stresses in the contacted material cause cracking and failure even without additional impact, pressure or use. For LNG duty, materials resistant to low temperature embrittlement are used. These materials include stainless steel, aluminium, and alloy steels with a high-nickel content.

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3.2.3 Asphyxiation

LNG is non-toxic and is not a known carcinogen. However, as it boils to gas it can cause asphyxiation as it displaces and then mixes with the surrounding air. The likelihood of asphyxiation is related to the concentration of gas in air and duration of exposure.

3.2.4 Expansion and pressure

Released into the atmosphere LNG will rapidly boil with the volume of gas produced being hundreds of times that of the liquid (approximately 600 times at ambient conditions). Hence, if confined and unrelieved, the pressure will increase and this can damage surrounding structures and equipment.

3.2.5 Fire

3.2.5.1 Pool fire

A ‘small’ release of LNG will rapidly boil and ‘flash’ to gas (i.e. evaporate). However, given a ‘large’ and sudden release, a cold pool of LNG will form with gas boiling from the pool and mixing and dispersing with the surrounding air. If this mix is within the flammable range (i.e. 5% to 15% with air) and contacts an ignition source or a heated surface above the auto-ignition temperature (595 deg.C) it will ignite and the resultant flame will ‘travel back’ to the pool resulting in a pool fire.

3.2.5.2 Jet fire

If stored under pressure then a release of LNG may discharge as a jet of liquid, entraining, vapourising and mixing with air. If the mix disperses and reaches an ignition source or a heated surface (above the auto-ignition temperature) whilst in the flammable range it will ignite. The resultant flame will ‘travel back’ and may result in a pressurised jet fire from the release source. Similarly, where contained LNG has been heated to form gas, a pressurised release of this gas could ignite and result in a jet fire.

3.2.5.3 Flash fire

Release of LNG to atmosphere and ignition within a few tens of seconds is likely to result in a pool fire or jet fire (as noted above) with no damaging overpressure. This is because the flammable part of the cloud is likely to be relatively small and close to the release point upon ignition. However, if ignition is delayed, the gas cloud will be larger and may have travelled further from the release point. Ignition will then result in a flash fire as the flammable part of the cloud is rapidly consumed within a few seconds. This ignition is likely to be violent and audible, and is often mistaken for an explosion, although there is little appreciable overpressure.

3.2.5.4 Thermal radiation from a pool fire, jet fire and flash fire

Harm to people and damage to structures and equipment from fire is dependent upon the size of the fire, distance from the fire, and exposure duration. Within a metre of the fire, thermal radiation may approximate 170 kW/m^2 but this rapidly falls with distance from the fire.

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As a rough guide:

- 6 kW/m^2 or more and escape routes are impaired and persons only have a few minutes or less to avoid injury or fatality[16];
- 35 kW/m^2 results in immediate fatality[16];
- 37.5 kW/m^2 has long been considered as the onset of damage to industrial equipment and structures exposed to a steady state fire[17];
- industrial equipment and structures within a flash fire are unlikely to be significantly damaged; and
- persons within a pool, jet or flash fire are likely to be fatally injured.

An LNG fire on a ship could result in fatalities and damage to equipment and structures (including the hull).

3.2.6 Explosion

Release of LNG to atmosphere and delayed ignition of the resultant flammable cloud beyond a few tens of seconds can result in an explosion. This is because the cloud may have dispersed in and around equipment and structures causing a degree of confinement and increased surface area over which to increase flame speed as it travels (i.e. burns) through the flammable mixture. The resultant overpressure may be sufficient to harm individuals, and damage structures and equipment. Such an explosion is most likely to be a deflagration (rather than a detonation), categorised by high-speed subsonic combustion (i.e. the rate at which the flame travels through the flammable cloud).

3.2.6.1 Overpressure from an explosion

Harm to people and damage to structures and equipment from an explosion is dependent upon the magnitude of overpressure generated and the rate at which the overpressure is delivered (known as impulse). In addition, harm is often a result of falling or being thrown against hard surfaces or being struck by objects and debris as a result of the blast. As a rough guide:

- the probability of fatality from exposure to an explosion of 0.25 bar and 1 bar is about 1% and 50%, respectively[18];
- less than 0.25 bar could throw an individual against a hard surface resulting in injury or fatality[18]; and
- 0.3 bar is typically the limit of damage to structures and industrial equipment[18].

---

16. There are many quoted values from many sources and with inconsistencies. Thermal dose might be alternatively used. The values quoted here are based on: Health & Safety Executive, Indicative human vulnerability to the hazardous agents present offshore for application in risk assessment of major accidents, SPC/Tech/OSD/30, 2011, and supporting document: Methods of approximation and determination of human vulnerability for offshore major accident hazard assessment, http://www.hse.gov.uk/foi/internalops/hid_circs/technical_osd/spc_tech_osd_30/spctecosd30.pdf
17. Risk Analysis of Six Potentially Hazardous Industrial Objects in the Rijnmond Area, A Pilot Study. (1982). D. Reidel Publishing Company, The Netherlands.
18. There are many quoted values from many sources and with inconsistencies. Impulse might be alternatively used. The values quoted here for fatality and damage are based on Ref 16 and Methods for the determination of possible damage to people and objects resulting from releases of hazardous materials, CPR 16E, Labour Inspectorate, The Netherlands.

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An explosion of vapourised LNG on a ship could result in fatalities and damage to equipment and structures (including the hull).

3.2.7 Rapid phase transition

Upon release, LNG rapidly boils due to heat from the surrounds, be this from the air, water/sea, steel or ground. However, this rapid and sometimes violent boiling is not rapid phase transition (RPT); RPT is an explosive vaporisation of the liquid, that is, a near instantaneous transition from liquid to gas. This is a more violent event than rapid boiling and it can result in liquid ejection and damaging overpressure[19]. The phenomenon is well known in the steel industry, where accidental contact between molten metal and water can result in RPT.

3.2.8 Rollover

Slowly, stored refrigerated LNG evaporates (i.e. 'boils-off') as heat from the surrounds gradually 'leaks' into the tank. Essentially, liquid in contact with the wall of the tank warms, becomes less dense and rises to the top. This top-layer then begins to evaporate (i.e. boil-off) increasing the liquid layer's density. Liquid further away from the walls also warms but at a slower rate and because of this a less dense layer below the top layer forms. Owing to the hydrostatic head, the saturation condition of this layer changes and although it heats-up, it does not evaporate but remains in the liquid state and becomes 'superheated'. As the heating continues, the trapped layer's density reduces; this is an unstable state and when the density of this layer is similar to the top layer the two layers rapidly mix and the superheated lower layer vaporises. This rapid mixing and vaporisation is known as rollover and can cause damaging over-pressure and release of gas if not appropriately controlled.

The heating mechanism described above can result in a number of differing layers and is referred to as stratification. It is a phenomenon that is well known and is safely managed through venting, mixing and temperature control.

The above phenomenon is hastened by, or can directly occur when differing densities of LNG are bunkered.

3.3 References

The information and facts given in this appendix are well known and have been recorded in numerous papers and reports on LNG. However, original sources are not always readily available (or known) and so the information given in this section was cross-checked by reference to:

1. Chamberlain, G. (2006). Management of Large LNG Hazards. 23rd World Gas Conference, Amsterdam.

2. International Maritime Organization, Marine Safety Committee. (2007). FSA - Liquefied Natural Gas (LNG) Carriers, Details of the Formal Safety Assessment. MSC 83/INF.3.

3. Bull, D. and Strachan, D. (1992). Liquefied natural gas safety research.

19. Chamberlain, G. (2006). Management of Large LNG Hazards. 23rd World Gas Conference, Amsterdam.

No. 146 (cont)

4. Sheats, D. & Capers, M. (1999). Density Stratification in LNG Storage. Cold Facts, 15/2.

5. Bashiri, A. & Fatehnejad, L. (2006). Modeling and Simulation of Rollover in LNG Storage Tanks. 23rd World Gas Conference, Amsterdam.

Reference can also be made to ISGOTT (International Safety Guide for Oil Tankers and Terminals) Publication (2009) - Report on the Effects of Fire on LNG Carrier Containment Systems.

No. 146 (cont)

Comparison of the Hazards of LNG and Fuel Oil

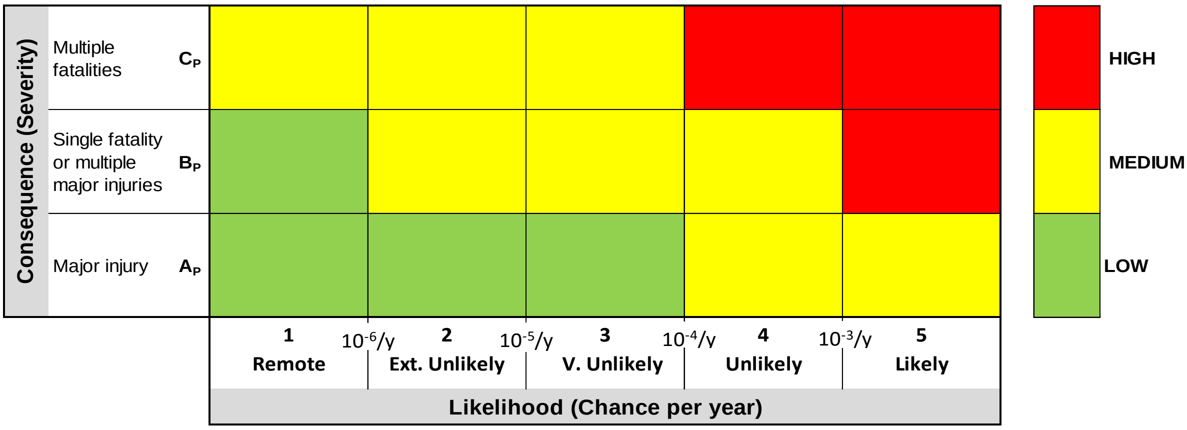
Hazards	LNG	Fuel Oil[1]
1. **Cryogenic Burns** Liquid contact with skin will cause burns and can result in fatality. Inhalation of gas can cause burns to the lungs and lead to fatal injury.	✓	X
2. **Low Temperature Embrittlement** Equipment/structures can fail on contact with liquid.	✓	X
3. **Rapid Phase Transition (RPT)** Released onto the sea a near instantaneous 'explosive' transition from liquid to gas can occur. This can result in structural damage to the hull.	✓	X
4. **Gas Expansion** A liquid pool rapidly boils, and as the gas warms and expands it requires a volume 600 times that of the liquid. This can result in equipment damage.	✓	X
5. **Asphyxiation** In a confined space, displacement and mixing of the gas in the air will reduce oxygen content and can cause asphyxiation.	✓	✓
6. **Pool Fire** Gas/vapour above the pool can ignite resulting in a pool fire. The intensity of the radiation can cause fatal injury and fail structure and critical equipment.	✓	✓
7. **Flash Fire** Gas/vapour can disperse away from the pool and ignite resulting in a flash fire. The short-duration and intense radiation can instigate secondary fires, and cause fatal injuries to those within the fire and to critical equipment. Most probably the fire will burn back to the pool and result in a pool fire.	✓	X[2]
8. **Explosion** Gas/vapour can disperse and collect in confined areas and ignite resulting in an explosion. The explosion can cause fatal injuries, instigate secondary fires, and fail structure and critical equipment. Most probably the explosion will burn back to the pool/gas source and result in a pool fire or jet fire.	✓	X[2]
9. **Rollover** Stored liquid can stratify, that is different layers can have different densities and temperatures. This can cause the layers to 'rollover' resulting in significant gas/vapour generation that must be contained. If released, this can result in flash fire or explosion.	✓	X
10. **Boil-off Gas (BoG)** LNG continually boils and must be re-liquefied or burnt-off. A release of BoG can ignite and result in a jet fire (given sufficient release pressure), flash fire or explosion.	✓	X

Note:
1. Fuel oil – heavy fuel oil (HFO) (ISO 8217).
2. If a fuel oil is 'sprayed' as an aerosol resulting in fine air-borne droplets, ignition can result in flash fire or explosion.

No. 146 (cont)

Appendix 4
Risk Matrix

Risk Matrix Example – persons on board



Consequence Category Examples

A_P Major injury - *long-term disability / health effect*
B_P Single fatality or multiple major injuries - *one death or multiple individuals suffering long-term disability / health effects*
C_P Multiple fatalities - *two or more deaths*

Likelihood Category Examples

1. Remote - *1 in a million or less per year*
2. Extremely Unlikely - *between 1 in a million and 1 in 100,000 per year*
3. Very Unlikely - *between 1 in 100,000 and 1 in 10,000 per year*
4. Unlikely - *between 1 in 10,000 and 1 in 1,000 per year*
5. Likely - *between 1 in 1,000 and 1 in 100 per year*

The likelihood categories can be related to a ship life. For example, assuming a ship lifetime is 25 years, then for a scenario with an annual likelihood of 1 in a million (i.e. rating 1 Remote) the probability of occurrence in the ship's lifetime is 1 in 40,000 (i.e. $1/(10^{-6} \times 25)$).

Risk Rating and Risk Criteria Examples

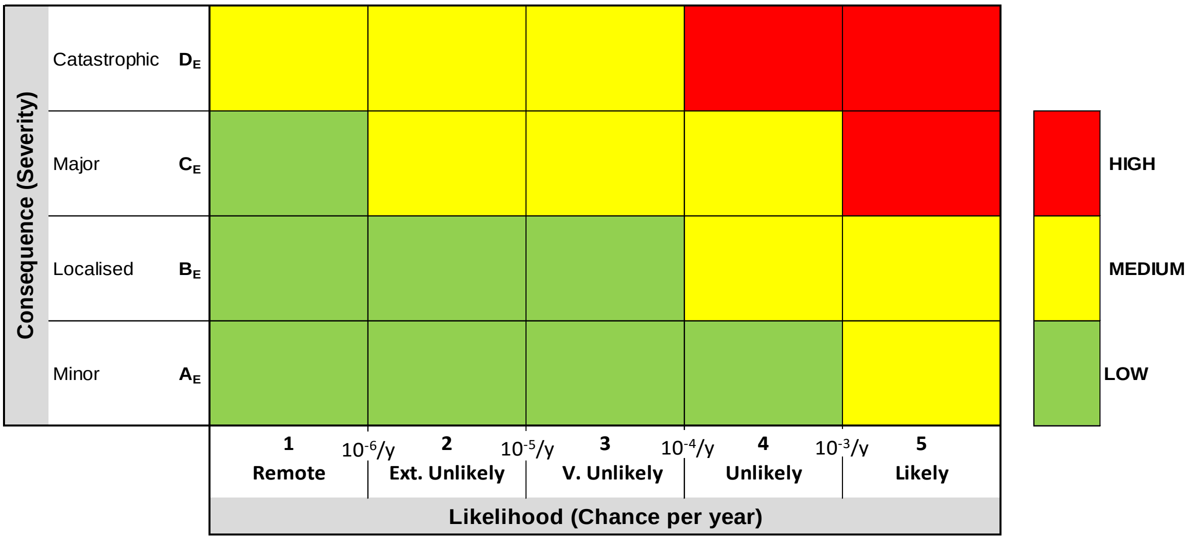
Low Risk – A_P1, A_P2, A_P3 & B_P1
The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective it is good practice to implement mitigation measures that would further reduce the risk.

Medium Risk – A_P4, A_P5, B_P2, B_P3, B_P4, C_P1, C_P2 & C_P3
The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.

High Risk – B_P5, C_P4 & C_P5
The risk is unacceptable and is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.

No. 146 (cont)

Risk Matrix Example – environment



Consequence Category Examples

A_E Minor - *limited and reversible damage to sensitive areas/species in the immediate vicinity*
B_E Localised - *significant but reversible damage to sensitive areas/species in the immediate vicinity*
C_E Major - *extensive or persistent damage to sensitive areas/species*
D_E Catastrophic - *irreversible or chronic damage to sensitive areas/species*

Likelihood Category Examples

1. Remote - *1 in a million or less per year*
2. Extremely Unlikely - *between 1 in a million and 1 in 100,000 per year*
3. Very Unlikely - *between 1 in 100,000 and 1 in 10,000 per year*
4. Unlikely - *between 1 in 10,000 and 1 in 1,000 per year*
5. Likely - *between 1 in 1,000 and 1 in 100 per year*

The likelihood categories can be related to a ship life. For example, assuming a ship lifetime is 25 years, then for a scenario with an annual likelihood of 1 in a million (i.e. rating 1 Remote) the probability of occurrence in the ship's lifetime is 1 in 40,000 (i.e. $1/(10^{-6} \times 25)$).

Risk Rating and Risk Criteria Examples

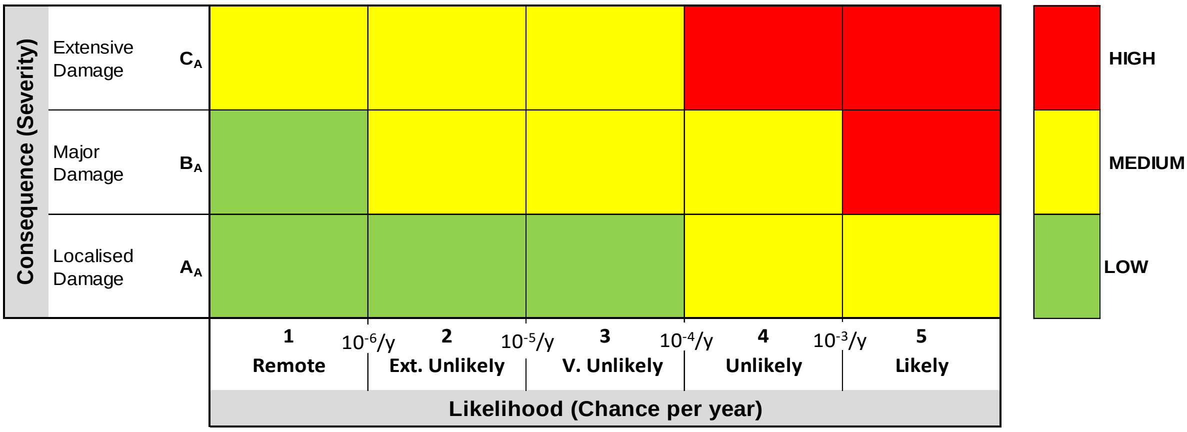
Low Risk – A_E1, A_E2, A_E3, A_E4, B_E1, B_E2, B_E3 & C_E1
The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective it is good practice to implement mitigation measures that would further reduce the risk.

Medium Risk – A_E5, B_E4, B_E5, C_E2, C_E3, C_E4, D_E1, D_E2 & D_E3
The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.

High Risk – C_E5, D_E4 & D_E5
The risk is unacceptable and is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.

No. 146 (cont)

Risk Matrix Example – ship assets (equipment, spaces and structure)



Consequence Category Examples

A_A Localised damage - *an event halting operations for more than x days*
B_A Major damage - *an event halting operations for more than y days*
C_A Extensive damage - *loss of ship, an event halting operations for more than z days*

Likelihood Category Examples

1. Remote - *1 in a million or less per year*
2. Extremely Unlikely - *between 1 in a million and 1 in 100,000 per year*
3. Very Unlikely - *between 1 in 100,000 and 1 in 10,000 per year*
4. Unlikely - *between 1 in 10,000 and 1 in 1,000 per year*
5. Likely - *between 1 in 1,000 and 1 in 100 per year*

The likelihood categories can be related to a ship life. For example, assuming a ship lifetime is 25 years, then for a scenario with an annual likelihood of 1 in a million (i.e. rating 1 Remote) the probability of occurrence in the ship's lifetime is 1 in 40,000 (i.e. $1/(10^{-6} \times 25)$).

Risk Rating and Risk Criteria Examples

Low Risk – A_A1, A_A2, A_A3 & B_A1
The risk can be accepted as 'mitigated as necessary'. Where practical and cost-effective it is good practice to implement mitigation measures that would further reduce the risk.

Medium Risk – A_A4, A_A5, B_A2, B_A3, B_A4, C_A1, C_A2 & C_A3
The risk is tolerable and considered 'mitigated as necessary'. This assumes that all reasonably practicable mitigation measures have been implemented. That is, additional or alternative mitigation measures have been identified and implemented unless judged impractical or the cost of implementation would be disproportionate to the reduction in risk.

High Risk – B_A5, C_A4 & C_A5
The risk is unacceptable and is not 'mitigated as necessary'. Additional or alternative mitigation measures must be identified and implemented before operation, and these must reduce the risk to medium or low.

Appendix 5
Likelihood of releases

Indicative likelihood categories

The following table provides indicative likelihood categories as follows: (a) named equipment item fails and releases fuel[20], and (b) collisions and groundings[21].

Likelihood values differ dependent upon source, assumptions made and the inclusion/ exclusion of causes, etc. Therefore, it is important to refer to the original data sources to ensure the indicative likelihood category remains valid for specific cases of interest.

Indicative Likelihood Values by Likelihood Category

1. Remote - 1 in a million or less per year (10^{-6}/y or less)			
Type C Fuel Tank	<1 x 10^{-6}		
2. Extremely Unlikely - *between 1 in a million and 1 in 100,000 per year (10^{-6}/y to 10^{-5}/y)*			
Leak ≥ 10 mm Ø	**50 mm or less Ø**	**51-150 mm Ø**	**151-300 mm Ø**
Pipework / per metre	7 x 10^{-6}	3 x 10^{-6}	3 x 10^{-6}
Flange	4 x 10^{-6}	5 x 10^{-6}	7 x 10^{-6}
Manual Valve	---	7 x 10^{-6}	9 x 10^{-6}
3. Very Unlikely - *between 1 in 100,000 and 1 in 10,000 per year (10^{-5}/y to 10^{-4}/y)*			
	50 mm or less Ø	**51-150 mm Ø**	**151-300 mm Ø**
Pipework / per metre	8 x 10^{-5}	4 x 10^{-5}	3 x 10^{-5}
Flange	4 x 10^{-5}	5 x 10^{-5}	8 x 10^{-5}
Manual Valve	3 x 10^{-5}	5 x 10^{-5}	7 x 10^{-5}
4. Unlikely - *between 1 in 10,000 and 1 in 1,000 per year (10^{-4}/y to 10^{-3}/y)*			
	50 mm or less Ø	**51-150 mm Ø**	**151-300 mm Ø**
Actuated Valve	3 x 10^{-4}	3 x 10^{-4}	3 x 10^{-4}
Instrument Connection	3 x 10^{-4} includes flange		
Process Vessel	7 x 10^{-4} pressurised vessel		
5. Likely - *between 1 in 1,000 and 1 in 100 per year (10^{-3}/y to 10^{-2}/y)*			
		50-150 mm Ø	**>151 mm Ø**
Heat Exchanger / Evaporator / Heater		2 x 10^{-3}	2 x 10^{-3}
Pumps (centrifugal or reciprocating)		5 x 10^{-3}	1 x 10^{-3}
Ro-Pax	1 x 10^{-2} collision / 1 x 10^{-2} grounding		
Cruise Ship	5 x 10^{-3} collision / 1 x 10^{-2} grounding		
Container Ship	2 x 10^{-2} collision / 7 x 10^{-3} grounding (data refers to wrecked/stranded)		
The likelihood values include all collisions and groundings. For collisions this means all collisions where the ship is 'struck' and where the ship is the 'striking ship'. The likelihood of interest might be less than the values above when consideration is given to ship, route and incident specifics. For example, assuming a release requires a Ro-Pax ship to be 'struck' and the collision to be 'serious' then the likelihood value approximates 5 x 10^{-4} (i.e. category 4 'Unlikely' where 'struck/striking' is assumed 50/50 and about 10% of collisions are 'serious'[21]).			

20. Indicative values are based on (a) and (b) and summarised in (c): (a) International Association of Oil & Gas Producers. (1 March 2010). Risk Assessment Data Directory – Process Release Frequencies, Report No. 434 – 1; (b) Health and Safety Executive. (1992-2006). Hydrocarbon Releases (HCR) System. https://www.hse.gov.uk/hcr3/; (c) LNG as a Marine Fuel - Likelihood of LNG Releases. Journal of Marine Engineering & Technology (JMET), Vol. 12, Issue 3, September 2013.
21. Formal Safety Assessment (FSA): FSA Container Vessels, MSC 83/21/2 (Table 3), 3 July 2007; FSA Cruise Ships, MSC 85/17/1 (Table 1), 21 July 2008; and FSA RoPax Ships, MSC 85/17/2 (Table 1), 21 July 2008.

No. 146 (cont)

Appendix 6
Mitigation measures

Example mitigation measures

Engineering Mitigation Measures
Protection from mechanical impact damage
Protection from vibration / vibration monitoring
Protection from wind, waves and weather
Pressure relief, venting
Increased separation or increased physical protection from collision / grounding
Secondary containment (e.g. double-walled pipework)
Welded connections in preference to flanged connections
Alarmed and self-closing doors
Bulkhead separation / cofferdam
Drip tray capacity, liquid detection
Spray shield coverage
Protection of structure from cryogenic temperatures and pressure from evolved vapour / gas
Independent bilge
Fire and gas detection, monitoring, audible / visual alarm and shutdown
Pressure and temperature detection, audible / visual monitoring, alarm and shutdown
Level detection
Forced / natural ventilation - airlock
Minimisation of ignition sources - Ex proof electrical equipment
Fire-fighting fire and cooling appliances - foam, water spray
Fire dampers
Separation of spaces
Access arrangements
Physical shielding
Mooring tension monitoring / alarm
Strain monitoring of supports
Buffer / overflow tank - Fuel recycling
Independent safety critical controls to IEC 61508
Radar monitoring
Service fluid - level / gas detection, alarm and shutdown
Flame arrestor
Procedural Mitigation Measures
Increased frequency of inspection (and maintenance)
Reduced parts replacement frequency
Specific training for low-flashpoint fuels
Restricted access
Monitoring

Note:

1. The mitigation measures above are largely generic and in no particular order. They are listed as a simple *aide memoir* when considering mitigation.
2. Within the IGF Code, measures to reduce likelihood and measures to reduce consequences are both understood to be mitigation measures (i.e. they mitigate the risk). To align with the IGF Code this understanding is maintained within this document. It is recognised that in many other industries it is common to use the terms ‘prevention measures’ and ‘mitigation measures’, where the former reduces likelihood and the latter reduces consequences. Prevention and mitigation measures are often referred to as ‘safeguards’ or ‘barriers’.

No. 146 (cont)

Appendix 7
Cause to Consequence Mapping

An established means to illustrate or map the pathway from 'cause' to 'consequence' is known as Bowtie. There are a number of variations on this theme and differing terminologies but essentially the Bowtie helps to visualise: threats or causes of an unwanted event; the barriers or mitigation measures to prevent the unwanted event; and the barriers to mitigate the consequences.

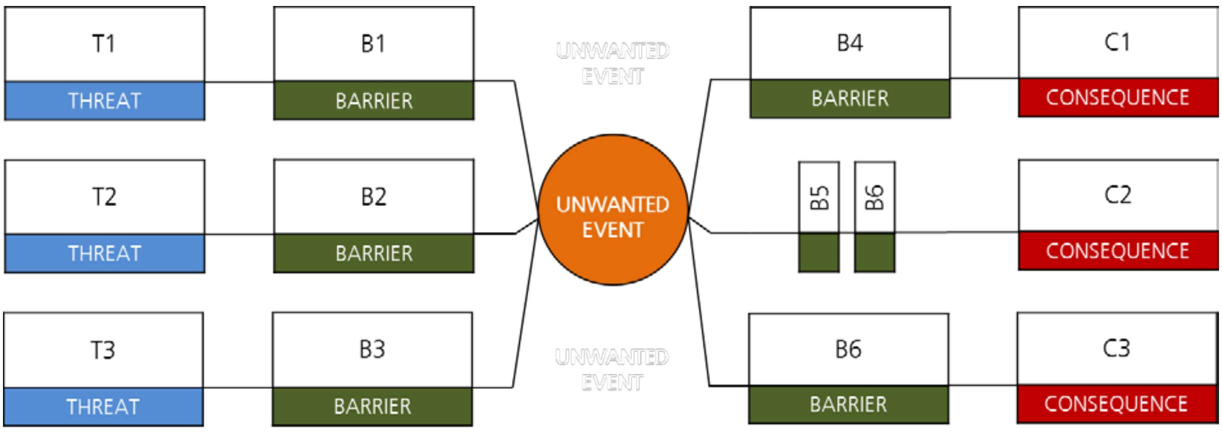
Bowtie examples

Threat – *A cause that can potentially lead to the unwanted event.*

Barrier – *A mitigation measure that can potentially prevent the unwanted event or its consequences.*

Unwanted Event – *A situation to be avoided e.g. a release of fuel or a loss of ship propulsion.*

Consequence – *An outcome of a threat and an unwanted event not being mitigated by the barriers.*



In respect of 'mitigation measures' (i.e. barriers) those prior to the unwanted event are often referred to as preventative barriers or prevention measures.

No. 146 (cont)

Appendix 8
Report Contents

Example report contents

Executive summary	
An overview of the assessment and main results and conclusions.	
1. Introduction	
A brief statement on the purpose of the assessment and the parties involved.	
2. Objective and Scope	
The principal objective is, for example, to demonstrate that the safety-risk is, or can be made acceptable/tolerable for Class approval. The scope is, for example, limited to the design/arrangement, the specific environment/location and the intended modes of operation.	
3. Description	
A simple explanation of the design and arrangement with respects to its intended operation and process conditions.	
4. Approach	
Overview of the risk assessment technique/method. This includes how the design was divided into sections for assessment, how hazard identification was undertaken, the selection of risk criteria, and the mechanism of risk rating and recording. In addition, a note on the actual workshop schedule illustrating the time expended on each section.	
5. Team	
The names, job titles, relevant qualifications, expertise and experience of the facilitator and SMEs. This can be recorded in a table, together with a record of workshop attendance. If this information is particularly large and would detract from the approach and results, the information can be included as an appendix.	
6. Results	
Discussion of the main findings and issues.	
7. Conclusions	
A summary judgement on whether the risks are 'mitigated as necessary'.	
8. Actions	
A listing of additional/alternative safeguards, including who is responsible and expected completion date.	
Appendices	
A.	Worksheets (as recorded in the workshop, including guidewords and phrases i.e. prompts).
B.	Drawings, Process Information and Reference Documents (including the Terms of Reference).

End of Document